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COMMITTEE PRINT

NATIONAL STRATEGY FOR TECHNOLOGICAL INNOVATION

PREPARED AT THE REQUEST OF

HON. HOWARD W. CANNON, *Chairman*

COMMITTEE ON COMMERCE,
SCIENCE, AND TRANSPORTATION
UNITED STATES SENATE

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LETTER OF TRANSMITTAL

U.S. SENATE,
COMMITTEE ON COMMERCE, SCIENCE,
AND TRANSPORTATION,
October 15, 1979.

DEAR COLLEAGUE: The Committee on Commerce, Science, and Transportation has conducted oversight hearings on the state of U.S. industrial technology and innovation, and has a continuing interest in national policy with respect to innovation. The Committee is concerned with the need to stimulate technological and industrial innovation to increase productivity, strengthen America's competitive position in world markets, and contribute to the overall vitality of the U.S. economy.

As part of the Committee's interest in examining various legislative proposals dealing with innovation, Senators Ernest F. Hollings, Adlai E. Stevenson, and I requested that a study conducted by Mr. Ellis R. Mottur, Guest Scholar at the Woodrow Wilson International Center for Scholars, be made available to the Committee. This document contains the report prepared by Mr. Mottur, including the outlines of an omnibus bill.

Although this report has not been considered or endorsed by the Committee or any of its members, I believe it will be of interest to many persons in Government, industry, labor, academia, and the general public. To insure its general availability, I have asked that this document be published as a Committee print.

Sincerely,

HOWARD W. CANNON,
Chairman.

LETTER OF SUBMITTAL

WOODROW WILSON INTERNATIONAL CENTER
FOR SCHOLARS
SMITHSONIAN INSTITUTION BUILDING
Washington, D.C.
AUGUST 21, 1979.

HON. HOWARD W. CANNON,
Chairman, Committee on Commerce, Science, and Transportation,
U.S. Senate, Washington, D.C.

DEAR MR. CHAIRMAN: In response to the request you, Senator Hollings, and Senator Stevenson made earlier this year, I am pleased to provide you with a report on my study of innovation and public policy at the Woodrow Wilson Center, entitled "National Strategy for Technological Innovation."

As you requested, the report "sets forth specific policy proposals for a national innovation strategy, along with whatever background analysis may be appropriate." I fully share your commitment to the urgent goal of strengthening innovation in our economy, and hope this report provides a useful input to your continuing deliberations on these important questions.

I shall, of course, be happy to respond to any further questions the committee may have regarding the specific content of the report or the broader issues it addresses.

For your information, I should mention that Senator Kennedy, as chairman of the Judiciary Committee and the Subcommittee on Health and Scientific Research of the Committee on Labor and Human Resources, has also requested the results of my innovation study, and I am providing him with a copy of the same report.

Thank you for affording me the opportunity to have been of service.

Sincerely,

ELLIS R. MOTTUR,
Guest Scholar.

PREFACE

As a guest scholar of the Woodrow Wilson International Center for Scholars over the past year, I have been conducting research for a book on innovation and public policy, from which this report is derived.[1] I should like to take this occasion to express my deep appreciation to the Director of the Center, Dr. James Billington, and his superlative staff for their encouragement, cooperation, and unfailing friendliness during my stay at the Center; and to my colleagues, the Wilson fellows, for the extraordinary degree of intellectual excitement and stimulation they engendered.

It is appropriate to note that the Center's grant to me was made possible by generous donations to the Center from nine corporations, for which I am extremely grateful. These are: Borg Warner, Dow Chemical, Exxon, Fairchild Camera & Instrument, General Electric, IBM, Northrop, Pfizer, and Texas Instruments. I should also like to express my deep personal appreciation to the executives of those corporations who recommended those grants. They are respectively: Donald Collier, J. M. Leathers, Edward David, Lester Hogan, Arthur Bueche, Lewis Branscomb, Thomas Paine, Barry Bloom, and Fred Bucy.

Of course, the statements, views, and recommendations expressed in this report are solely the responsibility of the author and do not necessarily reflect the views of other Wilson fellows, the Wilson Center management and staff, the corporations which made the grants for the project, or the corporation executives listed below.

It is my conviction that there is an urgent national need for improved public policy with respect to technological innovation. I hope this report contributes to enlightened public debate on this issue.

ELLIS R. MOTTUR.

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[1] My study at the Wilson Center was based in part on the extensive research on innovation which I had earlier conducted at George Washington University from 1967 to 1971. See reference No. 46 for the appropriate citation.

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SUMMARY AND CONCLUSION

Summary

Technology innovation is the key to conquering our present calamities and discovering future treasures. Without it, we are forever consigned to carving up the same old pie in smaller and smaller slivers. With it, we can expand the real wealth of the pie to provide larger portions for all. This report sets forth a national strategy for stimulating technological innovation.

It establishes the enormous importance of innovation to our economy and national well-being, and underscores the fact that U.S. innovation is lagging compared to foreign competitors and our inherent potential. It delineates the elements necessary to successful innovation and describes the reasons why it is currently lagging. The report then enunciates the policies needed to stimulate innovation, and sets forth specific legislative proposals to implement them. Each section of the report is summarized below.

SIGNIFICANCE OF INNOVATION

The importance of innovation is enormous. It is a key factor in assuring national security, economic vitality, and domestic problem solving. It is essential to increasing productivity; reducing inflation and achieving full employment; meeting international economic competition; developing alternative energy sources and improved methods of conservation; solving environmental problems; providing effective public services in cities and counties; generating the national wealth required to pay for necessary social services; and in general enhancing the quality of life in our country.

U.S. INNOVATION LAGGING

Despite America's impressive past record, innovation in the United States is currently lagging as compared with its challenges, competitors, and potential. Thus, in recent years U.S. capital investment in innovative activities has fallen short; for example, the capital obtained from public offerings by small firms dropped from $1.46 billion in 1969 to $16.2 million in 1975! Investment in R. & D. has stagnated: Federal funds for R. & D. in 1979 were 16 percent less than what they had been 12 years earlier; at the same time that Japan and West Germany recorded substantial growth in the proportion of their GNP going to R. & D. Similiarly, the proportion of scientists and engineers in the U.S. population has dropped since 1969, while it has shown an increase in most other advanced nations. America has shown a decline in its patent balance of 47 percent in recent years, and currently has a negative balance with Japan and West Germany. For the past 20 years U.S. productivity growth has been substantially below that of its

foreign competitors: between 1960 and 1976, Japanese productivity gained 5 times more rapidly than America's; and during the most recent quarter of 1979, U.S. productivity fell more precipitously than at any time since we began keeping records in 1947. It is not surprising, therefore, that—even in technology-intensive items—we now have a negative trade balance with Japan; and the traditional U.S. surplus in manufactured goods was transformed into a $3 billion deficit in the first quarter of last year. Along with these distressing economic indicators, stands our failure to produce the innovations necessary to meet our compelling national needs in fields such as energy, environment, and transportation.

NATURE OF THE INNOVATIVE PROCESS

To recognize the causes and devise remedies for our recent decline, we must first elucidate the nature of innovation and the elements required for its success. Innovation is more than an invention or technological development. It is the introduction, sale, or use of a new technology—whether product, process, or system—in the consumer or industrial marketplace or public arena. Thus, innovation encompasses the entire spectrum of research, development, invention, engineering, finance, marketing, production, management, and sales. For an innovation to succeed, it must embody the following elements:

(1) The imaginative matching of potential technologies with economic and social needs and opportunities;

(2) Strong leadership on the part of an individual who makes the sustained commitment to persist in pushing the innovation forward;

(3) The possibility of tapping or stimulating sufficient market demand so that the innovation can reach the scale or volume necessary for success;

(4) Individuals or firms, with access to sufficient capital, who are willing and able to take the risks and invest the time, money, and human energy to shape the potential technology to meet the particular market demand;

(5) A combination of potential rewards and risks, along with an expected probability of success, which is attractive enough to justify investment of the necessary capital, when compared with alternative uses to which it could be put;

(6) High caliber management skills to move the innovation successfully through engineering, production, marketing, distribution, and sale; and

(7) Sufficient time and continuing availability of resources to allow the innovation to prove itself out before the final reckoning of success or failure.

To assure that the innovative well does not run dry, the foregoing elements in the innovative process must be solidly grounded in:

(8) An ever-expanding reservoir of scientific knowledge, arising from the unfettered course of basic research and the directed currents of applied research aimed at the needs of the society at large, as well as the special requirements of particular industries;

(9) An abundant supply of highly qualified scientists, engi-

neers, and managers capable of moving the innovations ahead, with the intellectual flexibility and caliber to cope with constant advances in science and technology and a high degree of career mobility to redeploy their talents among academic, industry, and government organizations to meet shifting problems and priorities; and

(10) Sufficient high quality facilities, equipment, and instrumentation for conducting the necessary research, development, and engineering.

CAUSES OF RECENT DECLINE

The recent decline in U.S. innovation is caused by certain conditions prevalent in the overall economy and by a number of shortcomings within the innovative system itself. The principal external conditions which serve to impede innovation include: (a) the high rate of inflation which militates against the kind of long term, risky investments which are required for innovation; (b) the low rate of capital formation in our economy which limits the amount of capital available for investment in innovative ventures, (c) the burgeoning of Government regulations in recent years that slow the innovative process and focus management and technical talent on compliance rather than creation; and (d) the high rate of unemployment which reduces consumer purchasing power and thereby limits the potential consumer markets for innovation. The internal shortcomings in the innovative system include the following elements:

(1) Basic research—which can thrive only in an atmosphere of free inquiry and which requires long-term stability and continuity of support—is too much influenced by the inroads of inflation, the fluctuations of the annual appropriations process, and constantly shifting political currents and fads;

(2) Insufficient educational emphasis on pragmatic problem-solving for those engineers who will be working in industry; and inadequate continuing education and career planning, flexibility, and mobilty for scientists and engineers in general;

(3) Inadequate facilities, equipment, and instrumentation for university-based R. & D., along with difficulties of financing plant and equipment for small business technology firms;

(4) A deficient patent system which: (a) Offers inadequate incentives to induce the risks necessary to bring innovations into the marketplace; (b) provides insufficient stimulus to match potential technologies with economic and social needs and opportunities; (c) contains too many Government held patents which are rarely commercialized; (d) is too narrow in scope to reflect the latest advances in science and technology; (e) maintains an antiquated operation that does not provide timely or legally reliable patents; (f) results in excessive patent litigation that is time-consuming, costly, and riddled with inconsistencies and uncertainties; and (g) sometimes even serves to inhibit innovation;

(5) Not enough applied research on generic problems common to particular industries or industrial processes, such as the steel industry or computer-aided manufacturing;

(6) A lack of institutions to stimulate the design, development, and demonstration of major systems involving advanced technologies in priority national areas such as alternative energy sources, energy conservation, automated mass transit, pollution controls, and toxic waste disposal;

(7) The inability to generate strong, sustained large-scale market demand for public technology systems;

(8) Inadequate sources of venture capital and insufficient incentives and aids to small business technology firms in carrying out innovation and competing with larger established enterprises, despite the overwhelming evidence of small business' disproportionately large contribution to innovation in America;

(9) Lack of planning and provisions to aid communities and workers in averting or adjusting to major economic dislocations due to technological innovation;

(10) Insufficient technical and financial aid to small-scale, community technology projects, despite the spreading interest in this approach throughout the country and the relatively small Federal investment that would be entailed; and

(11) No central, high-level focal point for guiding and coordinating the innovation policies and programs of the Federal Government.

NATIONAL STRATEGY

Solutions to the external, macroeconomic impediments to innovation—such as inflation and inadequate capital formation—lie beyond the scope of this study. Similarly, the inhibiting effect of excessive regulation requires a major overhaul of the regulatory structure which encompasses a far wider range of considerations than that of the impact on innovation; accordingly, this issue deserves separate treatment and probably requires major legislation of its own.

The specific recommendations of this report are devoted entirely to removing the internal impediments to innovation or—stated more positively—to strengthening the innovative infrastructure and incentive system. They are designed primarily to impel the private sector to create the innovations of which it alone is capable; by shoring up market demand, and providing a panapoly of incentives to stimulate corporate and individual commitment to innovative action.

But although it is the private sector which ultimately must produce the innovations, it is government action—or inaction—which shapes the framework of institutions, laws, regulations, and incentives which, in the final analysis, serves to stifle or to spur innovation.

In designing a strategy whereby Government can stimulate innovation in the private sector, we must recognize at the outset that there are no quick fixes or simple prescriptions to follow. Since innovation encompasses the full spectrum of activities from basic research through development, invention, additional engineering, finance, production, marketing, distribution, and use in society—any strategy that will prove effective must impact on key elements throughout the entire process. Otherwise isolated improvements at particular points in the system may result in little or no overall effect on innovation.

Thus, increases in R. & D. funding alone will not generate innovations unless the resulting developments and inventions can be effectively coupled to market needs and opportunities. Similarly, such coupling itself will not produce the innovation, unless sufficient venture capital is available and the prospective return on investment makes the risks appear worth taking. And even all of these elements together will not insure innovation without effective incentives to attract and retain the high quality managerial skills necessary to guide the innovation through the marketplace to the ultimate users.

RECOMMENDATIONS

Therefore, the recommendations presented in this report address a whole array of strategic policy targets throughout the innovative process. Since they call for major new legislation, they are presented in the form of an omnibus bill, entitled "The Innovation for America Act." The proposed bill contains 13 titles, as follows: Title I—National Innovation Policy; Title II—Basic Research; Title III—Human Resources in Science and Engineering; Title IV—Scientific and Technical Equipment; Title V—Patent System; Title VI—Industry Generic Research; Title VII—Advanced Technology Systems; Title VIII—Market Demand; Title IX—Small Business Technology Innovation; Title X—Innovation Adjustment Assistance; Title XI—Community Technology; Title XII—Office of Innovation Policy; and Title XIII—General Provisions. Each of these titles is summarized below.

Title I—National innovation policy

This title sets forth Congress findings and establishes national goals and policies with respect to technological innovation. The findings include: (a) the significance of innovation to the economy and the society at large; (b) the lag in U.S. innovation; (c) the requirements for achieving successful innovation; (d) the causes of the U.S. lag; and (e) the need for a national strategy. The goals section includes: (a) the need for improved macroeconomic policy regarding inflation, jobs, and capital formation; (b) the need for regulatory reform; and (c) the need for strengthening the structure for public participation in decisionmaking on innovation policies and programs. The policy section sets forth 12 national policies for strengthening the infrastructure and incentives for stimulating technological innovation.

Title II—Basic Research

This title establishes a National Science Endowment which, by the year 2000, will provide sustained, stable funding for basic research on a self-supporting basis, with no further need for annual Federal appropriations. The NSE would operate as an autonomous public trust—somewhat analogous to the Federal Reserve Board.

Title III—Human resources in science and engineering

This title would strengthen the Nation's human resources in science and engineering and promote their optimum utilization, while enhancing their professional security. Specifically, this title would: (a) increase educational emphasis on pragmatic problem solving for en-

gineering students likely to enter industry or Government careers; (b) promote continuing education of scientists and engineers; (c) establish effective career planning programs, including a network of scientist and engineer talent banks; and (d) undertake a major study of careers in science and engineering to assure increased flexibility and mobility, while enhancing professional security.

Title IV—Scientific and technical equipment

This title would promote the wider availability of high quality facilities, equipment, and instrumentation for use in research, development, and engneering. Specifically, it would: (a) establish a National Technical Equipment Bank to channel equipment owned by the Government or surplus to the needs of various organizations to other organizations (universities and small business firms) which could make better use of it; (b) increase Federal funds for the purchase of new equipment to be used by universities; and (c) permit business firms accelerated depreciation for facilities and equipment used in innovation.

Title V—Patent system

This title reshapes the patent system to enable it to play the pivotal role in propelling innovations into the marketplace. Specifically, it: (a) expands the scope of patents to reflect the latest advances in science and technology; (b) modernizes the operation of the Patent Office to produce the more rapid issuance of legally reliable patents; (c) promotes the commercialization of the nearly 30,000 patents currently held by the Government by offering them for sale at public auction; (d) stimulates the imaginative matching of potential technologies with market needs and opportunities by creating a new category of prepatents; (e) increases the incentives associated with patents to encourage the risk taking necessary for innovation; (f) precludes the use of patents to stifle innovation; (g) promotes greater diffusion of innovations through mandatory licensing; and (h) ameliorates the process of patent litigation.

Title VI—Industry generic research

This title would authorize the establishment of Industry Generic Research Institutes to conduct applied generic research on problems of common concern to an entire industry (such as steel) or a group of industries (such as homebuilding) or a set of industrial processes (such as computer-aided manufacturing). The antitrust statutes and regulations would be amended or revised as necessary to facilitate firm's cooperating together to form such institutes, and Federal matching funds would be provided to aid their operation.

Title VII—Advanced technology systems

This title would establish an Advanced Technology Systems Administration (ATSA), as an independent agency, to serve as the civilian analog to the Defense Department's Advanced Research Projects Agency (ARPA). ATSA would plan, stimulate, and manage the design, development, and demonstration of major advanced technology systems in priority national problem areas, such as alternative energy sources, energy conservation, automated mass transmit, interurban high speed railroads, pollution controls, toxic waste disposal, and so forth.

Title VIII—Market demand

This title is aimed at stimulating markets for technological innovation in high priority areas of national need. Specifically, this title: (a) authorizes the establishment of Public Technology Market Consortia to aggregate State, local, and regional governmental market demand for public technology systems in fields such as automated mass transit, water purification, solid waste disposal and recycling systems; and (b) directs the concerted use of the Federal procurement power to generate large Government market demand for desirable innovations such as solar energy systems for Government housing or pollution controls for Government installations.

Title IX—Small business technology innovation

This title would aid small business technology firms in realizing their full potential in the innovative process. Specifically, it would: (1) assure them a greater share of Federal R. & D. funds; (2) afford them increased access to sources of venture capital; (3) provide them with a panoply of education and assistance programs in technical, managerial, and regulatory areas; (4) offer them "legal defender" aid in dealing with patent litigation; and (5) structure a host of special incentives to: (a) embolden the firms to make the R. & D. investments and take the risks necessary to innovation; (b) encourage them to utilize patents; (c) enable them to attract and retain high caliber executives; (d) stimulate them to diffuse the innovations they have developed; and (e) provide them with ample time to prove innovations out before the final reckoning of success or failure.

Title X—Innovation adjustment assistance

This title provides aid to communities and workers in averting or adjusting to major economic dislocations due to technological innovation. Specifically, it would provide for: (1) foresight and planning programs to afford early warning to communities and workers of impending economic dislocations due to innovation; (2) technical assistance to communities to aid them in their planning for and coping with the adverse effects of innovaton; (3) preference rights in Federal procurements for firms located in communities which have been adversely impacted by innovation; (4) worker information and retraining programs to aid them in adjusting to innovation; (5) relocation assistance for workers who are forced to move because of innovation; and (6) supplemental unemployment compensation for workers who lose their jobs because of innovation.

Title XI—Community technology

This title fosters community technology programs. Specifically, it provides technical assistance and Federal matching funds to community technology cooperatives for the acquisition, installation, and utilization of small-scale, community technology systems for the benefit of participating citizens. Examples of such systems include: water, wind, or solar energy generation; biomass energy conversion, and gasohol production.

Title XII—Office of Innovation Policy

This title establishes an Office of Innovation Policy in the Executive Office of the President to guide and coordinate the formation and implementation of the innovation policies and programs of the Federal Government.

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Title XIII—General provisions

This title contains definitions of terms, administrative provisions, and amendments to existing law. Total authorization for the programs contained in all titles of the bill is $397 million.

Conclusion

As stated at the outset, innovation is the key to conquering our present calamities and discovering future treasures. From Thomas Jefferson's inventions at Monticello to the astronauts' landing on the Moon, innovation has always been an integral aspect of the American scene, imparting a powerful impetus to our prosperity and way of life.

Only in the last decade have we begun to lag, as others have accelerated their competition and experimented with new institutional arrangements for fostering innovation. But our underlying innovative capabilities remain solid and strong. Our scientists and engineers represent a magnificent resource of creative ability. Our entrepreneurs and business managers are as enterprising and imaginative as ever. The problem lies not with our people, but with our policies and procedures. The innovative infrastructure has become too bureaucratical, and the economic system is not sending out the sort of signals calculated to encourage investment in the future.

Through the proposed legislation, we cannot expect to transform the economic climate overnight. But we can refashion the infrastructure so that it spurs rather than stifles innovation. Because of its many facets and interrelations, the proposed bill may seem extremely complicated. But its central message is clear and simple:

(1) Innovation can come only from the private sector; the Government's role is to stimulate not supplant private initiatives.

(2) Innovation principally responds to market demands. The Nation's pressing needs for improved public technology systems in such fields as energy, transportation, and waste recycling can be met only through the aggregation of sufficient market demand to elicit the requisite technology. The Government's role is to provide tehnical assistance and matching funds to augment local market demand and to aid in the development and demonstration of advanced technology systems which would not otherwise be launched. The Government must also use its extensive procurement power to stimulate private market demand for desirable innovations in such fields as solar home heating and cooling.

(3) Even more important, the Government should stimulate a vast new marketplace of innovative ideas by reshaping the patent system to expand its scope and force the public auction of innovative ideas when they are not being effectively pursued. Combined with the computerization of the Patent Office and a special innovation tax of only 10 percent on the sale of patents (in lieu of all other taxes), these measures will enable patents to achieve their full potential and become the principal propulsive force for innovation in our economy.

(4) Small business technology firms must also be empowered to realize their full potential in the innovative process through greater access to venture capital and Federal procurement contracts; technical, managerial, and regulatory assistance; and tax incentives to impel them to take the risks necessary to prove innovations out.

(5) Larger technology firms need to be stimulated to make the necessary investments through accelerated depreciation of the facilities and equipment used in innovation.

(6) Finally, the growing grassroots movement for the appropriate use of small-scale, community-based technology should be aided by matching Federal funds and technical assistance; and communities and workers who might be adversely affected by innovation should be aided by community and worker adjustment programs.

In short, innovation only happens when someone puts himself on the line to make it happen. This inevitably entails risks. Few will take such risks unless there is promise of ample market demand and sufficient incentives to make the risks appear worth taking. The policies and programs set forth in this report are aimed at stimulating individuals throughout the private sector to take such risks.

To accomplish this purpose, the model legislation includes a number of new institutions and policy mechanism. Admittedly it is not very popular at present to propose the establishment of new institutions. But it is only by imaginative innovation in the institutional infrastructure itself, that we can unleash the floodgates of innovation throughout our economy and society at large.

It is hoped that this report, the body of which is presented below, will contribute to informed public debate on these issues.

PART I—ANALYSIS

Significance of Technological Innovation

In the midst of the energy crisis, double digit inflation, the deepening recession, and the President's "crisis of confidence," it may be asked why should one worry about innovation? Aren't there enough more pressing problems to contend with at this time?

But it is the very presence of those other problems which underscores and lends urgency to the innovation issue. For if we had paid sufficient attention to innovation in the past, we wouldn't be in such difficult straits today. If, for example, after the Second World War we had accorded the same priority to solar energy research that we did to nuclear power—with the same level of financial investment and technical talent—who could doubt that we would be in a position to meet a signficant proportion of our energy needs today through solar power? Yet as late as 1969, the total solar research budget of the National Science Foundation was under $1 million, and efforts by the Congress to raise that amount were met with impoundments by the President.

Similarly, in the mid-1960's, a report commissioned by the President's science adviser forecast a major energy shortage in the future, but the Nation's attention was on Vietnam and the Great Society programs, and no one had time to plan for the problems of the future.

And even after the shock of the Arab oil embargo in 1973, when the handwriting on the wall was clear for all who had eyes to see, there was no mobilizing of the Nation's R. & D. resources to advance alternative energy sources, nor any marshalling of political machinery to promote massive conservation of energy.

Moreover, the overriding need for public transportation systems was apparent to those who forecast energy supply and demand as early as the mid-1960's, yet transit R. & D. has never received the all-out national commitment of resources which was required; and subsidies for roadbuilding continued in high gear, while matching funds for mass transit were always suffering from ignition problems and stalling.

So while steps to strengthen the Nation's innovation system may not lead to immediate solution of our current problems, they are essential to help avert similar problems in the future. It should be recognized that the initial thrusts toward innovation must oftentimes be taken before the economics are established as favorable for the new technology. Thus, in the past it had frequently been asserted that solar power and coal liquefication or gasification are not competitive with oil and, therefore, we shouldn't proceed with them. But it is only through continuing R. & D. and innovation that we can make these alternatives competitive in the future.

Ideally, R. & D. programs should be initiated long before their results are required. They should not have to be launched in reaction to present problems (as with the current synfuel proposal), but rather in anticipation of future problems. Thus, they should be started early enough so that the results are ready by the time the needs are upon us. Innovation is a time-consuming process which demands foresight and courage to commit resources before the final balance sheets can be drawn.

In effect, innovation is the cutting edge of our trajectory into the future. As planetary probes explore the reaches of outer space, so innovative technologies extend our reach into the future and create new options for shaping life in the world of tomorrow.

The impact of innovation—or the lack thereof—on our social-economic system is both profound and pervasive. Thus, "advances in knowledge have been the biggest single factor in economic growth and productivity gains in the United States over the past four decades." Moreover, "The rate of return on investments in R. & D. is generally high * * *. Private rates of return for innovations (are) generally in the 25-percent to 30-percent range * * * (and) public or social rates of return have been calculated to be * * * over 50 percent * * *. High-technology, R. & D. intensive industries have made an especially strong contribution to the economy * * *. These industries have on the average increased output, productivity, and employment several times as fast as low-technology industries, while raising their prices much less." [1]

In the words of the Comptroller General of the United States, the Honorable Elmer Staats: "technological innovation was responsible for 45 percent of the Nation's economic growth from 1929 to 1969. When high and low technology industries are compared, high technology firms have productivity rates twice as high, real growth rates three times as great, one-sixth of the annual price increases, and nine times the employment growth." [2]

Technological innovation, then, is clearly essential to increasing productivity and to the continuing creation of new products and industries. Its impact on inflation is equally great; indeed, there can be no lasting solution to the problem of inflation without a significant upsurge in innovation. For without innovation, productivity cannot be signficantly improved, and without such an improvement in productivity, inflation will continue to run rampant regardless of palliatives like the wage-price guidelines. Thus, while steps to enhance innovation may have little immediate impact on inflation, they are essential in any sustained, longrun solution to the problem.

On the whole, innovation also contributes to the generation of jobs. It is true, of course, that specific innovations sometimes eliminate the need for certain jobs and result in increased unemployment in particular localities. But the overall impact of innovation is to generate new products, industries, and jobs. Moreover, the effect of innovation on

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[1] American Association for the Advancement of Science, "Research and Development, AAAS Report III, R. & D. in the Federal Budget: Fiscal year 1979. R. & D., Industry, and the Economy." Prepared by Willis H. Shapley and Don I. Phillips. Washington, D.C., 1978, pp. 77–78.

[2] National Academy of Sciences, "Technological Innovation and the U.S. Economy." Washington, D.C., Nov. 14, 1978, p. 47.

productivity also helps generate jobs: According to Prof. Richard R. Nelson of Yale University, "More rapid technical advance and productivity growth, far from being a threat to employment, would facilitate a reduction in unemployment * * *. The proximate source of today's high unemployment is restrictive Government policies. If more rapid productivity growth can facilitate better control of inflationary pressures, governments will be able to relax their restraints. Far from being a threat to employment, more rapid productivity growth may be a prerequistite for a return to higher levels of employment." [3]

Furthermore, a study by the MIT Development Foundation showed that the average compounded annual growth in jobs for a sample of young high-technology companies, from 1969 to 1974, was 41 percent; whereas a sample of mature companies over the same period showed less than 1 percent growth in jobs. The study, which contrasted job growth for mature companies with innovative companies and with young high-technology companies, showed that:

> During the 5-year period the six mature companies with combined sales of $36 billion in 1974 experienced a net gain of only 25,000 jobs, whereas the five young, high-technology companies with combined sales of only $857 million had a net increase in employment of almost 35,000 jobs. The five innovative companies with combined sales of $21 billion during the same period created 106,000 net jobs.[4]

Innovation is also central to the United States' international economic competitive position.

> The U.S. trade balance for R. & D. intensive manufactured products has been positive and rising since 1960: the 1976 balance was five times that of 1960 and two and a half times the 1970 level.[5]

Thus,

> the trade balance for research and development-intensive manufactured products * * * is now over $28 billion. The trade balance for nonresearch and development-intensive products is down from a breakeven level in 1960 to a $16 billion deficit.[6]
>
> Clearly the technology-intensive product group has been responsible for yielding surpluses and largely covering deficits in trade from specific non-R. & D.-intensive product groups * * *. Its importance in maintaining an overall favorable trade balance is unquestionable.[7]

Thus it is innovation-engendered technology which has made for a favorable trade balance in recent decades, and which is essential to regaining a favorable balance in the future. The importance of foreign trade to the overall U.S. economy is seen from the fact that "the United States remains the world's largest exporter as well as its biggest importer." According to Hon. C. Fred Bergsten, Assistant Secretary of the Treasury for International Affairs:

> One out of every five jobs in this country now produces for exports to other countries. One out of three dollars of corporate profit in this country derives from international activities of American firms.[8]

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[3] Richard R. Nelson, "Technical Advance and Economic Growth: Present Problems and Policy Issues," in Proceeding of the International Conference on Science and Technology at New York University, March 1979. New York Academy of Sciences, New York.

[4] American Association for the Advancement of Science. "R. & D. in the Federal Budget, R. & D., Industry, and the Economy." AAAS Report No. 78–R–3, September 1978, Washington, D.C., pp. 132–33.

[5] National Science Board, National Science Foundation. "Science Indicators 1976". Washington, D.C. 1977, p. 3.

[6] NAS, "Technological Innovation and the U.S. Economy," p. 47.

[7] NSB, "Science Indicators" 1976, pp. 37–38.

[8] Helen Dewar, "The Impact of Exports and Imports," in the Washington Post, Washington, D.C., July 17, 1978, p. A22.

Essential as it is to maintaining a strong economy at home and competitive position abroad, innovation is equally important to meeting many of our pressing national needs. Thus technological innovation is required in order to develop: (1) Alternative energy sources such as solar, wind, geothermal, ocean thermal, coal liquification and gasification, and fusion power; (2) solutions to environmental problems such as air and water pollution and toxic waste disposal; (3) means for providing effective public services at reasonable costs in fields such as transportation, communications, fire fighting, public safety, and home utilities; and (4) effective defense and arms control technology to promote national security.

In a more fundamental sense, innovation may be seen as central to the generation of wealth in our society. First described by Fritz Machlup in "The Production and Distribution of Knowledge in the United States" [9] and by Daniel Bell in "The Coming of Post Industrial Society" [10], it is now generally recognized that we live in a knowledge society where the basic commodity is information. In such a society the most valuable information of all is the knowledge capacity to innovate. This capacity, rather than natural resources or industrial plant and equipment, becomes the key to generating new wealth. Therefore, if over the long haul we want to be able to afford to provide our citizens with necessary social services such as welfare, health care, and social security, we must foster sustained technological innovation throughout our economy.

In short, the significance of innovation is enormous. It is a key factor in insuring national security, the vitality of the economy, and fulfillment of our social needs. Specifically, it is essential to productivity; the creation of new products and industries; reducing inflation; achieving full employment; meeting international economic competition; developing alternative energy sources and improved methods of conservation; solving environmental problems; providing effective public services; generating the national wealth required to pay for neccessary social services; and in general enhancing the quality of life in our country.

U.S. Innovation Lagging

Despite America's impressive record of innovation over the past century, the consensus of informed judgment today is that U.S. innovation is lagging; as compared with its past, its potential, its current challenges, and its foreign competitors. The past year has witnessed a spate of articles on innovation, not only in the business and technical press, but in the popular media as well. The burden of these articles has been uniformly negative: That we are not innovating as rapidly and effectively as necessary to spur economic vitality and meet foreign competition. For example, the cover of a weekly newsmagazine was recently devoted entirely to innovation. The headline read: "Innovation—Has America Lost Its Edge?" The remainder of the cover consisted of a cartoon which attempted to convey the lack-

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[9] Fritz Machlup, "The Production and Distribution of Knowledge in the United States". Princeton : Princeton University Press, 1962.

[10] Daniel Bell, "The Coming of Post Industrial Society". New York : Basic Books, 1973.

adaisical pace of U.S. innovation.[11] Similar articles laced the business, technical, and popular press throughout the year.

At the same time a salvo of policy studies on innovation was launched by Government and business groups, along with a steady supporting fire of speeches on the topic by leaders of industry and the technical community. Thus, three of four congressional analytical arms have undertaken major studies of innovation: The General Accounting Office (GAO), the Congressional Research Service (CRS), and the Office of Technology Assessment (OTA). The prestigious business policy analysis organization, the Committee for Economic Development (CED) is carrying out a major study on innovation. But the most extensive effort is the administration's Domestic Policy Review of Innovation, chaired by the Secretary of Commerce and involving inputs from all affected Government departments and agencies, as well as from a large number of outside advisory panelists. The outside inputs were in the form of separate reports from special subcommittees on: Economic and Trade Policy; Regulation of Industry Structure and Competition; Patent Policy; Federal Procurement Policy; Environment, Health, and Safety Regulations; Direct Support of Research and Development; and statements from the Labor Advisory Subcommittee and the Public Interest Advisory Subcommittee. Throughout these reports

> there was general agreement * * * that American productivity is lagging, particularly in comparison with major competitors such as Japan and West Germany. The decline in the growth rate of productivity * * * is regarded as a major factor contributing to inflation and the decline of the dollar.[12]

And the reports underscored the link between innovation and productivity.

In short, there is a strong consensus of opinion that innovation in the United States is lagging. To the extent that relevant data are available, they all support this conclusion. Such data deal with the inputs or resources made available for the innovation process in the United States, the outputs from the process, the effects of innovation on the economy, and comparisons with foreign nations. Relevant data from these areas are summarized below.

A key input to the innovation process is capital investment. This is, of course, critical in all business activity, but it is especially significant in innovative undertakings, which frequently involve the development of ancillary instrumentation and techniques, as well as the introduction of new facilities and equipment. In his major study of the relationship between inventions and economic acticity, Jacob Schmookler showed that capital investment was a necessary precondition of inventive activity, or at least that capital investment and the market demands associated with such investment preceded the development of inventions.[13] However, the investment which precedes an invention is only the tip of the iceberg; for "90 percent of the investment necessary to bring innovation successfully to market comes after the inven-

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[11] "Innovation: Has America Lots Its Edge?" in Newsweek, June 4, 1979, cover page and pp. 58–68.

[12] John Walsh, "What Can Government Do For Innovation?" in "Science". Washington: American Association for the Advancement of Science. p. 380.

[13] Jacob Schmookler, "Invention and Economic Growth". Cambridge, Massachusetts: Harvard University Press, 1966.

tion process is complete."[14] In short, significant continuing capital investment is an essential prerequisite for healthy innovative activity.

But in recent years capital investment in innovative activities has fallen short of what is needed. This is partially due to the pervasive climate of uncertainty which has cloaked business decisionmaking in our society over the past decade. As long as the overall economic situation is uncertain, businessmen find it more difficult to make long-term commitments of capital. This is greatly exacerbated by the rampant inflation which has "meant that the cost of capital has reached all time highs, acting as a deterrent to capital spending," and which "has drastically altered the rates of return for new investments that businesses can accept. Faster recovery of capital costs has become a watchword in investment decisions by business, with an eye on the importance of profitability over the short term."[15] This is particularly important with respect to investment decisions on innovation, since innovations typically take long time periods to reach fruition. "It is rare that an important innovation can have a major impact short of 4 or 5 years, and, more frequently, the impact of a major innovation may not be felt for a decade or two."[16]

The problem is underscored by considering "the recycling time of risk capital for entrepreneurial types of investments," as noted by James Hillier the former Executive Vice President of RCA Corporation:

> If you invested in a standard innovation, say, in the mid-sixties, you could expect to get back your purchasing power so that you could recycle it into another innovation in about seven to nine years. For exactly the same innovation under today's conditions, it takes fourteen to fifteen years to recoup the original purchasing power. This means that we have to use twice as many constant dollars, twice as much purchasing power to achieve the same number of innovations today as it would have taken fifteen years ago.[17]

In any event, capital investment for innovation has fallen short over the past decade. "Capital expenditures by American businesses expanded by an average of 3.8 percent per year in real terms (from 1945 to 1970), but by only 0.9 per year since then.[18] Concurrently, "from 1969 to 1975, the total number of companies seeking equity funds for growth dropped 92 percent—from 1,800 to 150.[19] The capital acquired by firms with less than $5 million in net worth from public offerings since 1969 dropped from $1.46 billion in 1969 (with 548 offerings) to $16.2 million in 1975 (with 4 offerings)! The catastrophic decline in capital obtained by small businesses * * * extends to other sources of small business financing, including professional managed venture capital sources and high-risk investments by individuals."[20] "A recent survey by the American Electronics Association (AEA) documents

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[14] Final Report of the Subcommittee on Economic and Trade Policy of the Advisory Committee on Federal Policy on Industrial Innovation to the Secretary of Commerce. Washington, Feb. 15, 1979, p. 6.

[15] *Ibid.*, pp. 5–6.

[16] Final Report of the Subcommittee on Procurement and Direct Support of Research and Development of the Advisory Committee on Federal Policy on Industrial Innovation to the Secretary of Commerce, entitled "Federal Procurement Policy." Washington, January 26, 1979, p. 2.

[17] NAS, *Technological Innovation and the U.S. Economy*, p. 57.

[18] Report of Subcommittee on Economic and Trade Policy, p. 6.

[19] Report of Subcommittee on Procurement, p. 17.

[20] Final Report on Patent Policy of the Subcommittee on Patent and Information Policy of the Advisory Committee on Federal Policy on Industrial Innovation to the Secretary of Commerce. Washington, February 6, 1979, pp. 1–2.

the increasing difficulty that new, small companies are having in gaining access to capital markets. Of the firms they studied: Companies founded between 1971 and 1975 were able to raise only half as much equity capital, on the average, as firms founded between 1966 and 1970; and firms founded in the more recent period had an average debt to equity ratio of more than 2:1, compared to the more secure 1:1 ratio that had prevailed for the previous fifteen years. * * * For the small businessman, the availability of capital has become the greatest unaddressed problem." [21] The significant of this shortage of capital for small business is underscored by the finding that small firms produce proportionately more innovations than do larger firms.[22]

Another striking indication of the decline the capital investment in innovative activities is the fact that: "as recently as 1968, 300 to 400 high technology firms were founded. But in 1976 the number was zero." [23]

Along with capital investment, the key indicators for input to innovation derive from specific statistics on the allocation of financial and human resources to R. & D. activity; for R. & D. is the underpinning of innovation. R. & D. by itself will not automatically produce or guarantee innovation; but without the reservoir of knowledge which derives and is replenished from R. & D., sustained innovation is unlikely. "All available evidence indicates that R. & D. is an important contributor to economic growth and productivity * * * the contribution of R. & D. to economic growth/productivity is positive, significant, and high," [24]

But resources for R. & D. over the past decade have lagged considerably. Thus "total (Federal) funds budgeted for fiscal year 1979 for the conduct of R. & D. * * * in constant dollar terms (are) * * * actually 16 percent below fiscal year 1967." [25] "As a fraction of the Gross National Product (GNP), national R. & D. spending has dropped from the high of 2.97 percent reached in 1964, falling to an estimated 2.25 percent in 1976 * * *. (In constant dollars) Federally supported R. & D. expenditures * * * in 1976 (were 18 percent below the peak reached in 1967. * * * As a fraction of the total Federal budget, R. & D. funds have declined substantially, falling, to an estimated 6 percent in 1976 from a high or 13 percent in 1965. As a fraction of the "relatively controllable" portion of the Federal budget, R. & D. outlays amounted to 13.5 percent in 1976—the lowest level since 1967 when they were 16.3 percent.[26]

With respect to basic research (which comprises about 13 percent of all R. & D. spending), "national spending * * * in constant dollars * * * in 1976 * * * remained nearly 11 percent below the peak year of 1968 * * *. In constant dollars, estimated Federal and Industrial support for basic research in 1976 was 15 percent below the peak levels which each had reached in 1968 * * *. In 1976 basic research expenditures by universities and colleges (in constant dollars) * * * were

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[21] Report of the Subcommittee on Economic and Trade Policy, pp. 3–4.
[22] "Technological Innovation: Its Environment and Management." U.S. Department of Commerce. Washington, January 1967, pp. 16–18.
[23] NAS, "Technological Innovation and the U.S. Economy," p. 48.
[24] "A Review of the Relationship between Research and Development and Economic Growth/Productivity." Washington, National Science Foundation, February 1971, p. 3.
[25] AAAS Report III, p. 14.
[26] NSB, "Science Indicators 1976", p. 44.

roughly equal to the level reached in 1969 * * *. In constant dollars, Federal spending for academic basic research peaked in 1968, but real dollar expenditures for 1976 remained an estimated 10 percent below that peak year." [27]

With respect to industrial R. & D., "total funding for industrial R. & D. has barely kept up with inflation for the last 10 years. Increases in private industry funding of R. & D. have largely been offset by decreases in Federal funding of industrial R. & D. * * *. We see some signs of our decline in that the average constant dollar investment in R. & D. by industry has increased by less than two-tenths of a percent per year from 1967 to 1977." [28] Moreover, "there has been recent evidence * * * of a shrinking of time horizons and a growing conservatism regarding industrial R. & D." [29] "There has been an increased private-sector R. & D. emphasis in recent years on low-risk, short term projects directed at incremental product changes, and a decreased emphasis in the longer term research that could lead to radically improved products and processes." [30]

With respect to human resources, "in 1975, approximately 531,000 scientists and engineers (on a full-time equivalent basis) were engaged in R. & D. * * * almost 28,000 fewer than the peak employment level reached in 1969 * * *. The number of R. & D. scientists and engineers in industry * * * reached almost 360,000 * * * in 1975, (but) was still nearly 7 percent less than the peak employment reached in 1969." A particularly disquieting aspect of the human resources situation is the fact that there has been an aging of the academic workforce. Thus "of all the doctoral faculty involved in R. & D., the proportion of young science and engineering investigators decreased from 44 percent in 1968 to 30 percent in 1974." [31]

Another important indicator of inputs to innovation are Federal funds provided for the dissemination of scientific and technical information. For innovation cannot occur if the results of R. & D. are not incorporated in technology and used in the economy and the society at large. This process is facilitated through the dissemination of scientific and technical information. Thus it is disquieting to note that "Federal obligations for the dissemination of scientific and technical information, measured in real dollars, peaked in 1968 at $435 million but fell to an estimated $321 million in 1976." [32]

Thus far we have considered data reflecting inputs to the process of innovation, or resources made available to R. & D. and innovation activities. Now we shall turn to those data relating to outputs of the process, its effect on the economy, and comparisons with foreign nations.

Although the current scope of patents is such that they do not adequately reflect the full range of innovation occurring in our economy, they nevertheless provide one of the best indicators available for gaging the extent of inventive activity which is taking place. The

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[27] Ibid., p. 66.
[28] Industrial Innovation and Its Relation to the U.S. Domestic Economy and International Trade Competitiveness. Washington, Congressional Research Service Report No. 78–204 SPR. October 13, 1978, p. 7.
[29] Nelson, p. 9.
[30] CRS Report No. 78–204 SPR, p. 14.
[31] NSB, Science Indicators 1976, p. 130.
[32] Ibid., p. 45.

data on patents is not reassuring. Thus, "the total number of patents issued annually has declined since 1971." [33] At the same time, "although positive, the U.S. patent balance declined almost 47 percent between 1966 and 1975. This was due to the 91-percent increase of foreign-origin patenting, coupled with the leveling off and eventual decline in the number of foreign patents awarded to U.S. citizens. The United States has a favorable but declining patent balance with Canada, the United Kingdom, and five European Economic Community countries, but a negative balance with West Germany and Japan. The share of U.S. patents granted to foreign residents has more than doubled in the last 15 years, reaching a level of more than 35 percent in 1975 * * *. The percent of patents due to foreign inventors increased in nearly every product field from 1965 to 1975." [34] "In the 1950's, according to an analysis by the Stanford Research Institute, 82 percent of the major inventions brought to market were developed in the United States. By the late 1960's, the figure had declined to 55 percent." [35]

Perhaps the most important indicator of the extent and effectiveness of innovation consists of data relating to productivity gains. For although productivity gains are generated by other factors besides technical change (such as increased skills in the work force and improved organization of production); and although technological innovation not only enhances productivity, but also can lead to new goods and services—nevertheless, the date of productivity growth is as good an indicator of the extent and quality of innovation in our economy as we have available.

It is, therefore, distressing to note that "productivity gains * * * have averaged only 1.6 percent during the last decade, a discouragingly low figure compared to the 3.2 percent average for the first two decades in the postwar period (and) compared to the 5 and 6 percent figures of our major trading partners * * *. If productivity over the last 10 years had increased at the same 3.2-percent annual rate of growth of the two previous decades, then output per hour would have been 11-percent higher in 1977. The difference would have meant more than a $100 billion increase in terms of real gross national product at the 1977 employment level." [36] It is disturbing not only that productivity growth is substantially less than it had been in past decades, but that it is significantly lower than that of our trading partners. "Economists generally agree that the rate of productivity growth in the American economy has been substantially below that of America's major foreign competitors." [37]

Thus, while U.S. productivity grew 2.8 percent from 1960 to 1970, during the same period productivity grew 3.3 percent in the United Kingdom, 3.7 percent in Canada, 5.5 percent in West Germany, 5.9 percent in France, 7.4 percent in Italy, and 10.8 percent in Japan.

Productivity levels in the United States (currently) exceed those of France, West Germany, and the United Kingdom, but U.S. productivity gains between 1960 and 1976 were the smallest of the five countries. Japanese productivity gains

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[33] Report on Patent Policy, p. 2.
[34] NSB, "Science Indicators 1976," pp. 2, 3, 92.
[35] Newsweek, p. 58.
[36] NAS, "Technological Innovation", p. 45.
[37] Robert Gilpin, "Technology, Economic Growth, and International Competitiveness", a report to the Joint Economic Committee, U.S. Congress. Washington, July 9, 1975, p. 10.

were more than five times greater than U.S. increases.[38] Finally, productivity of U.S. businesses fell more rapidly in the second quarter of this year (1979) than at any time since the Government began keeping records in 1947.[39]

This disappointing record of U.S. productivity growth is a clear indication that U.S. innovation is not achieving all that one could reasonably expect of it.

Comparison with foreign nations along other dimensions serves to underscore the overall impression that U.S. innovation is lagging. For example, since 1964, the proportion of the gross national product devoted to R. & D. in the United States has substantially decreased; whereas "during the decade 1962–72, both Japan and West Germany recorded substantial growth in the proportion of their gross national product directed toward R. & D." [40] Although West Germany has recently leveled off and started to decline in its ratio of R. & D. expenditures of gross national product, Japan is still continuing to increase.

Another comparative measure of a country's R. & D. effort is the relationship between the number of scientists and engineers (S. & E.'s) and the population. The number of S. & E.'s per 10,000 population in the United States has remained constant since 1972. The 1975 level is 10 percent lower than that of 1969, when this ratio peaked in the United States . . . (but) data from the other countries studied showed a general increase in this ratio.[41]

While the U.S. trade balance for R. & D.-intensive manufactured products has been positive since 1960 and while surpluses from these product groups, until 1976, have been sufficient to cover the increasing deficits from non-R. & D. intensive products, nevertheless the situation is shifting to a less favorable stance for the United States. Thus, the United States now has a "negative trade balance in R. & D. intensive products with Japan * * * due mainly to U.S. imports of electrical machinery and to a lesser degree to imports of professional and scientific instruments and nonelectrical machinery." [42] In 1977, this amounted to "a $3.6 billion trade deficit with Japan in high-technology goods * * * about two-thirds of (which) was accounted for by imports of consumer electronic goods." [43] Even more foreboding is the fact that the newest bridge across the Mississippi River "is soon to be fabricated in Japan at a cost of $42 million, one-third less than the lowest American bid, and floated by barge in pieces the size of ship hulls to its destination at Luling, La." Moreover, in the first quarter of 1978, "the traditional U.S. surplus in trade of manufactured goods declined to the point of a $3 billion deficit," and "imports of machinery, transportation equipment and manufactured goods rose dramatically, suddenly overtaking oil as the biggest component of the country's trade deficit." [44]

In the words of Dr. Philip Handler, President of the National Academy of Sciences:

The topic of technological innovation is on the front page of the newspaper day after day. It is debated on talk shows, a concern of the Congress, and a central concern of the executive branch * * * if American streets did not abound in Datsuns, Toyotas, Mercedes, and Hondas, if most of our purchases of house-

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[38] NSB, "Science Indicators 1976", p. 3.
[39] John M. Berry, "Productivity Fell Sharply in 2d Quarter," in Washington Post, Washington, July 31, 1979, p. A1.
[40] NSB "Science Indicators 1976," p. 5.
[41] *Ibid.*, p. 2.
[42] *Ibid.*, p. 3.
[43] "Vanishing Innovation," in Business Week, July 3, 1978, p. 48.
[44] Dewar, pp. A1 and A22.

hold electronics were those made by General Electric, Westinghouse, and Zenith rather than by Sony and Panasonic, if those cameras and pocket calculators we carry were of domestic manufacturer * * * we would feel rather differently about this.[45]

The inroads of foreign manufacturers in consumer products are tangible indicators of the U.S. lag in innovation. But we can infer the lag just as well from the intangible, potential products, processes, and services which our society needs, but which technology has not yet created. These intangible indicators are just as valid for assessing the effectivness of innovation in our society as are the other indicators discussed above.

Thus, we all reognize the need for new technologies to aid in energy conservation and in the production of alternative energy sources; in pollution control technology; in automobile propulsion systems; in mass transit; waste recycling systems; rural telecommunications; health care delivery systems; public safety systems; and a host of other areas. In many instances, the basic science is adequate for substantial progress; yet innovation does not take off and move ahead as it should and could. Sometimes it may be due to the difficulty to aggregating sufficient market demand; sometimes to the inability to marshall sufficient incentives for entrepreneurs; sometimes to the presence of institutional or regulatory barriers; sometimes to the unavailability of sufficient capital; or the absence of managerial skills where they are needed.

A 19th century sage once remarked that if you built a better mousetrap, the world would beat a path to your door. But in the complex 20th century an improved solar collector, for example, may prove to be of no avail if it does not meet local building codes or FHA standards, if insufficient capital is available to exploit it, if an adequate market cannot be readily stimulated, or if the inventor or inventing organization does not have proper incentives or managerial skills to promote and produce the product. But whatever the reason or combination of reasons, the simple fact is that innovation is not occurring rapidly or effectively enough to meet many critical national and social needs.

Thus whether we consider past performance or present potential, current challenges or foreign competition—whether we examine patterns of capital investment or R. & D. funding, patents, productivity, international trade, or compelling national needs for new technology—we inescapably arrive at the same conclusion: That U.S. innovation is lagging.

Yet we know the enormous significance of innovation to national security, economic vitality, and social progress. And we know that the impediments to innovation are not intrinsic obstacles or insuperable barriers: They can be overcome. What then should we do about them? How should we proceed to ameliorate innovation?

Government Role and Responsibility

What is the appropriate role and responsibility of Government relative to innovation?

Recognizing that the private sector retains primary responsibility for producing innovations which will work and be widely used, many

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[45] NAS, Technological Innovation, pp. 4–5.

industrial leaders assert that the biggest obstacles to robust innovation are Government generated and consist of burdensome regulations and redtape on the one hand and restrictive tax policies on the other. Extremist proponents of those views believe that Government could best aid the innovative process by getting out of it altogether.

While this proposal has a lot of surface appeal—especially at the present time when the shortcomings of Government are widely apparent—most thoughtful observers would agree that, notwithstanding the private sector's preeminence in innovation, Government's role remains ubiquitous and cannot realistically be eliminated.

Thus, for example, irrespective of any deficiencies in organization and management of the national laboratories, there is no doubt that the Federal Government must maintain some national laboratories in fields such as defense, space, energy, health, environmental research, and the like; in-house Government R. & D. is a necessary part of the Nation's innovative system. Similarly, with respect to basic research—the ultimate underpinning of all innovation—there is no way at present that the Nation can be assurred an adequate level of basic research without a preponderant share of Federal funding.

With respect to applied research and development, Federal funding is obviously essential in the defense and space programs. While one can argue pro and con on the merits of such funding in other areas, a strong case can be made for Federal support whenever (a) the investments required exceed the capacity of private industry; or (b) the return on investment prospect is too long term or diffuse to elicit private funds; or (c) national priorities demand a pace or pattern of innovation unlikely to emerge in the private sector within a reasonable period of time.

Federal procurement overall inevitably impacts on the innovation process. Since the Federal Government is the largest single consumer in our society, the specifications it sets for its massive purchases generate major demand patterns which would inhibit or advance innovation in fields such as housing, automobile manufacturing, solar energy, computer systems, and so forth.

Standard setting is another area in which the Federal Government must play a major role. While State and local government and the private sector can contribute significantly to the establishment of reasonable standards, the ultimate responsibility in our continental, interdependent economy must reside with the Federal Government, especially in fields such as health, food and drugs, safety, and environmental quality.

Patent policy is a particular area in which the Federal Government clearly must bear a continuing responsibility that directly influences the innovative process. A host of other Federal policies ininvariably affect innovation through tax incentives and constraints, antitrust regulations, international trade policies, et cetera. Perhaps the most important Government impact on innovation, however, comes from general economic policy insofar as it influences the rate of inflation and the overall climate for investment.

In short, the Federal Government inevitably and extensively impacts on innovation in our society. In effect, Government action—

or inaction—serves to shape the framework of institutions, laws, regulations, and incentives within which innovation must occur. In addition, the Government directly intervenes in the innovative process through support of basic research, conduct of in-house research, funding for R. & D. in priority areas, and procurement of goods and services.

These are responsibilities which the Federal Government must fulfill. There can be no question of whether the Government should attempt to influence innovation. The only legitimate question is how to carry out its variegated role so as to advance rather than inhibit useful innovation. This is the principal issue to which this report is addressed.

The Process of Innovation

Before we can delineate a national strategy for stimulating innovation, we must examine the innovative process, establish overall policy guidelines, and identify target areas for Federal action, along with the goals to be pursued in each area.

First, we must be clear on what we mean by technological innovation. We do not mean merely the conception of a new scientific idea or research discovery. Nor do we mean merely an invention, or completion of a technological development, or even its incorporation in an engineering system capable of producing it.

At the heart of every innovation is a unique coupling or matching of some technological capability with a market need or opportunity. When this conceptual coupling has been turned into a tangible product, process, or system—which has been disturbed and used successfully within the market—then, and only then, can we say that an innovation has occurred.

So the notion of innovation is extremely broad and encompassing and involves elements of basic scientific research, invention, engineering know-how, marketing, finance, production, and management; but in all cases depends on the imaginative matching of technological capabilities with economic and social needs or opportunities.

Now how does this process occur? At one time innovation was naively viewed as a simple, linear progression whereby basic research led to applied research which in turn led to development or invention, which engendered further engineering, and then production and use. This is now recognized as a simplistic, misleading characterization.

> Technological innovation is not a simple, straightforward sequence of events that proceeds with deterministic regularity toward predictable ends. The singular term "process" ascribes too much simplicity and uniformity to what is in reality an exceedingly involved set of processes that follow a complex course of events that is often highly creative and unpredictable.[46]

There is nothing linear about the process of innovation. It can start from many points; it involves many dead ends, new starts, and innumerable feedback loops; and it is riddled through and through with risk. At its most crucial points, it entails creative leaps of imagination which can't be predicted or planned. When this author 10 years ago constructed a comprehensive systems model of the processes of technologi-

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[46] Ellis R. Mottur, "Technological Innovation for Civilian, Social Purposes". Washington: George Washington University. July 1971, p. 162.

cal innovation, the result was a model which depicted the interrelationships among 93 separate functions and hundreds of subfunctions.[47]

To understand the variations possible in patterns of innovation, one need only consider the starting point of particular innovations. Some for example, do not start from new research knowledge, but draw on knowledge which has been available for long periods. Thus, the reflection of radio waves by metallic objects was first demonstrated by Hertz in 1887, but the development of radar did not commence in earnest until 1934.[48] In other situations, however, new research findings can lead rapidly to innovation. Thus, Shockley theoretically predicted the possibility of the transistor in 1949; by 1951, Bell Telephone Laboratories announced the actual invention of the junction transistor; and by the mid-1950's, transistors were being mass-produced throughout the Nation.[49] However, in most instances the vast majority of necessary scientific advances have been made long before the innovation gets underway; a study by Illinois Institute of Technology, for example, showed that 90 percent of the essential scientific base had been established 10 years or more before the innovations occurred.[50]

Another variable which affects the rate and focus of innovative activity is the stage of development of the firms involved. Thus, "following the birth of a new product, the product design changes rapidly and radically; it is fluid, the manufacturing process is loosely organized and unsettled, and the organization is adaptive. Conditions at this point constitute the initial or "Fluid" stage of development and at this "Fluid" stage, major product innovations are rather frequent. * * * A turning point occurs with the emergence of a "dominant design" * * * that offers superior performance. * * * As the product and the manufacturing process develop over time, costs decrease, product designs become more standardized and suitable for broad market segments and change becomes less fluid. At the same time production processes, designed increasingly for efficiency, offer higher levels of productivity. * * * The nature and sources of technological innovation shift with these structural changes in product and process. Innovation becomes more incremental and technological progress takes the form of steady evolutionary development. Major innovations with potential to reshape the product or greatly improve productivity originate more frequently outside the firm and industry."[51]

Sometimes new technological developments virtually generate their own markets as in the case of computers and lasers.[52] Sometimes national needs serve to stimulate innovation as in the case of synthetic rubber during World War II or pollution controls at the present time. But in all cases, someone has to match the market need with the technological capability.

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[47] Ibid., "Part II—Systems Model of the Processes of Technological Innovation," pp. 161–348.

[48] Robert M. Page, "The Origin of Radar." New York: Doubleday, 1962, pp. 13–40.

[49] Richard R. Nelson, "The Link Between Science and Invention: The Case of the Transistor," in National Bureau of Economic Research, "The Rate and Direction of Inventive Activity." Princeton: Princeton University Press, 1962, pp. 549–583.

[50] Illinois Institute of Technology, "Technology in Retrospect and Cultural Events in Science (TRACES)," Report for the National Science Foundation. Washington: NSF C535, Dec. 5, 1968.

[51] William J. Abernathy, "The Productivity Dilemma: Roadblock to Innovation in the Automobile Industry," report of the Harvard University Graduate School of Business Administration, 1977. Executive summary, pp. 7–8.

[52] Nathan Rosenberg, "Science, Invention, and Economic Growth," Economic Journal, vol. 84, March, 1973. March 1974, pp. 90–108.

Generally, innovations don't happen by themselves. Moreover, in most cases a single individual has to take the lead in pushing the innovation forward against the innumerable obstacles that invariably arise. This entrepreneur or "innovation champion" (as Donald Schon has dubbed him) must serve as the change agent who makes the innovation happen in practice.[53] For in the final analysis, the success of most innovations depends on the initiative, imagination, judgment, commitment, and courage of particular individuals who are willing to place their time, talent, reputations, and careers on the line in situations of considerable uncertainty and risk. Providing such individuals with effective incentives must be a paramount imperative of public policy for innovation.

A point which cannot be overemphasized is that "uncertainty is inherent in technical innovation." [54] Along with this uncertainty factor goes an extremely high failure rate for innovations. Thus, a study by Edwin Mansfied showed that for every 100 projects which were initiated, only 57 were completed technically; 31 of these were commercialized, and only 12 of the original 100 eventuated in market success.[55]

In any case, in order for a particular innovation to succeed, it must embody the following elements:

First, there must be the creative coupling within someone's mind: Involving the perception of a new way in which a possible technological capability can be shaped to meet some economic, social, or human need; or to take advantage of some opportunity. This imaginative coupling or matching within the human mind is at the heart of the innovative process, but it must be accompanied by all of the following elements if it is to produce success.

Thus, second, there must be an effective change agent or "champion"— who may not be identical with the inventor or originator of the innovative concept, but who could be an individual enterpreneur, investor, or corporate or Government official—who persists in the commitment to make the innovation happen.

Third, it must be possible to tap or stimulate a sufficient market, in which the innovation can reach the scale or volume necessary for success, and in which the innovation can withstand the buffeting of competition.

Fourth, there must be access to sufficient capital to obtain the resources necessary to enable the innovation to succeed.

Fifth, the combination of potential rewards and risks, along with the perceived probablity of success for the innovation, must be sufficiently attractive to justify investment of the necessary capital when compared with alternative uses to which it could be put.

Sixth, adequate managerial skills must be brought to bear on the shaping of the innovation from research, invention, or initial development through any additional engineering that may be required, and through production, marketing, distribution, and sale within the market.

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[53] Donald A. Schon, "Champions for Radical New Inventions," Harvard Business Review, vol. 41, No. 2 (March–April 1963), pp. 77–86.

[54] Donald A. Schon, "Technology and Change". New York: Delacorte Press, 1967, pp. 24–32.

[55] Edwin Mansfield, "Research and Innovation in the Modern Corporation." New York: W. W. Norton & Co., 1971.

Seventh, there must be sufficient time and continuing availability of resources to allow the innovation to prove itself out before the final reckoning of success or failure.

National Strategy

With this understanding of the process, we are now in a position to consider the policy guidelines which should be followed in developing a national strategy for stimulating innovation.

First, we must emphasize at all times the primacy of the private sector in undertaking and consummating innovation in our economy; for only in the competitive arena—through the actions of private firms and individuals—can we expect the creativity and risktaking required for innovation to flourish.

Second, Government's role in innovation must be circumscribed and directed toward performing the following basic functions: (1) helping shape a macroeconomic environment conducive to innovation (i.e., with an adequate level of capital formation, a low rate of inflation, and high enough levels of employment to create the purchasing power needed to generate demand for innovation); (2) designing and administering specific incentives and appropriate constraints in patent, tax, antitrust, regulatory, international trade, and R. & D. policy so as to enhance rather than inhibit innovation; (3) providing support for basic research; (4) providing support for applied research when it is essential to the missions of Government departments and agencies; (5) engaging in specific innovation activities designed to meet government's special needs in fields like defense and space; (6) stimulating private sector innovation to meet national goals such as health, safety, and environment standards; and (7) directly intervening to help stimulate or shape industrial innovation only when the private sector is unable to succeed in a particular area and there is a compelling national need for action in that area.

Third, in keeping with the evidence of Schmookler and others that market demand is a principal prerequisite for successful innovation,[56] we must do everythng possible to: (1) maintain the strength and freedom of potential markets for innovation; (2) help strengthen those markets which are too weak or disaggregated to provide effective demand for innovation (e.g., housing markets or State and local government markets for public technology systems such as mass transit and solid waste disposal); and (3) in situations where markets are lacking, take any appropriate steps that may be possible to stimulate their emergence.

Fourth, considering the critical importance in innovation of coupling or matching technological capabilities with market needs and opportunities, we should design and introduce incentives and mechanisms to foster and facilitate that central function within the innovative process.

Fifth, in light of the traditional values attached to small business enterprises in America, as well as the unique and significant contributions they have made to technological innovation over the years, high

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[56] Schmookler, *op. cit.*

priority should be placed on programs to provide appropriate aid to technology-oriented small business firms in their innovative activities.

Sixth, in light of the enormous burden borne by the private sector in meeting the regulatory requirements imposed by government and the resultant inhibiting effect on innovation, high priority should be placed on rationalizing the regulatory system in order to: (1) eliminate unnecessary regulations; (2) remove inconsistencies among conflicting regulations; (3) establish effective mechanisms for assessing the relative benefits and burdens of proposed new regulations; and (4) institute procedures for promulgating and implementing regulations in such a way as to minimize their onerous burden on private organizations and individuals.

Seventh, in order to assure innovation which is sensitve and responsive to social and human needs and values, decisionmaking on national innovation policies and programs should provide for appropriate inputs and participation by any interested parties, including citizen groups and members of the public at large. However, this participation should be structured in such a way that it does not unduly add to the regulatory burden or excessively delay the introduction of timely innovations in the national interest.

Eighth, since innovation sometimes entails economic dislocations with adverse effects on particular communities and groups of workers, programs should be developed to avert such consequences whenever possible; and failing that, to provide appropriate adjustment assistance to communities and individual workers who are adversely affected by innovation.

With these overall policy guidelines, we are now in a position to fashion a national strategy for stimulating innovation. At the outset, however, we must recognize that there are no quick fixes or simple prescriptions for facilitating innovation. As discussed in an earlier section, the process is far too complex and far-reaching for such superficial measures.

Since innovation encompasses the full spectrum of activities from basic research through development, invention, additional engineering, finance, production, marketing distribution and use in the socioeconomic system, any strategy that will prove effective must impact on key elements throughout the entire process. Otherwise isolated improvements at particular points in the system may result in little or no overall effect on innovation.

For example, increases in R. & D. funding alone will not generate innovations unless the resulting developments and inventions can be effectively coupled to market needs and opportunities. Similarly such coupling itself will not produce the innovation, unless sufficient venture capital is available and the prospective return on investment makes the risks appear worth taking. And even all of these elements together will not insure innovation without effective incentives to attract and retain the high quality managerial skills necessary to guide the innovation through the marketplace to the ultimate users.

In short, for any innovation strategy to prove effective, it must simultaneously address a whole array of strategic policy targets throughout the innovative process.

Policy Targets and Goals

What are the strategic target areas toward which Federal policy should be directed in order to stimulate innovation in our society? And what are the goals to be pursued in each area?

The following areas have been selected as targets for Federal policy on innovation: (1) macroeconomic policy; (2) regulatory policy; (3) basic research; (4) human resources in science and engineering; (5) scientific and technical facilities and equipment; (6) the patent system; (7) industry generic research; (8) advanced technology systems; (9) market demand; (10) small business technology firms; (11) innovation adjustment assistance; (12) community technology; (13) public participation; and (14) policy implementation. The policy goals in each of these areas are discussed below.

Macroeconomic policy

Macroeconomic policies and patterns set the framework with which innovation must take place and, therefore, in a sense exert a greater influencce on the extent and rate of innovation than do specific policies in any particular area, such as applied research funding for example. However, the impact on innovation is only one of the factors that must be taken into account in determining national economic policy. Consequently, it is far beyond the scope of this report to attempt to deal with the full range of considerations necessary to discuss macroeconomic policy in detail. For our purposes, it is necessary only to note that it would be helpful if decisionmakers on macroeconomic policy would attempt to take the impact on innovation into account in their deliberations; and that innovation in our economy would be enhanced to the extent that capital formation was fostered, inflation was abated, and employment and consumer purchasing power were maintained at high levels. Happily for this author, the means of achieving those goals may be left to others to determine.

Regulatory policy

As stated in the preceding section on national strategy, the regulatory system should be rationalized in order to (1) eliminate unnecessary regulations; (2) remove inconsistencies among conflicting regulations; (3) establish effective mechanisms for assessing the relative benefits and burdens of proposed new regulations; and (4) institute procedures for promulgating and implementing regulations in such a way as to minimize their onerous burden on private organizations and individuals.

In furthering these policies, existing and proposed regulations should be divided into three categories: (a) Those which are absolutely required to prevent a clear-cut danger to human health and safety or the quality of life in our society; (b) those which appear desirable, but which are not clearly essential; and (c) those on which there are wide divergences of opinion as to their desirability. In the case of those which are absolutely required, mandatory regulations should be retained or issued as necessary. In the case of those which are merely desirable rather than essential, mandatory regulations should be replaced by a system of incentives and disincentives aimed at inducing the desired actions. In the case of those under serious contention, two

avenues toward resolution should be followed: First, if feasible, comprehensive cost-benefit analysis should be undertaken to determine whether the results lead to definitive positions on the points at issue. Second, when cost-benefit analysis is not feasible or when the results do not lead to definitive positions, then a system of negotiation should be employed wherein representatives of the parties in contention can argue their views and negotiate their differences, within a format similar to that of collective bargaining between companies and unions.[57] With respect to the interpretation and implementation of such regulations as are issued, special aid should be provided to small business firms to aid in their compliance without undue hardship.

Basic research

Basic research is the underpinning of innovation. The enormous importance of basic research to innovation has been substantiated in studies by the Battelle Memorial Institute [58] and the Illinois Institute of Technology.[59] Even though many years or even decades may elapse before research results find their way into practical applications, the history of science and technology abundantly demonstrates the ultimate pragmatic value of basic scientific knowledge. Thus basic research is an essential investment in America's future which must be sustained over the years; any time we skimp on it, we are shortchanging generations to come.

But the essence of basic research is that it be free and unfettered. Priorities are for applied research and development; basic research must follow where the opportunities and creative insights lead. Thus, it should be guided by the scientific community itself. This has been the case with respect to individual project support through the peer review system, and should continue to be the case in the future.

But basic research also requires continuity and long-term stability of funding if it is to achieve its maximum potential. The annual appropriations process, with its attendant political pressures, is inimical to these needs. The Nation would be better served by a system of autonomous, continuing funding for basic research, with decision-making resting in the hands of the scientific community through its peer review process.

To facilitate the more effective utilization of basic research results in the innovative process, the Nation's scientific and technical education and information programs should be strengthened, with high priority assigned to mechanisms to enhance the flow of basic research information across the boundaries into the technological community.

Human resources in science and engineering

Scientists and engineers represent one of the Nation's greatest resources. An enormous investment of Government, university, and private funds has gone into their education and training. It's important that the Nation receive the maximum return on this investment in human potential.

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[57] See "Federal Regulation: Roads to Reform," report of the Commission on Law, and the Economy, American Bar Association, Exposure Draft, Aug. 5, 1978, for a discussion of the use of incentives and bargaining in lieu of traditional methods of regulation.

[58] Battelle Institute, "Interactions of Science and Technology in the Innovative Process: Some Case Studies." National Science Foundation, March 1973.

[59] Illinois Institute of Technology, op cit.

Many scientists and engineers, especially younger ones, have been educated for an academic career when opportunities for such careers are declining and will continue to decline for the foreseeable future. It is important that current engineering education programs be designed to emphasize pragmatic applications and problems of the sort likely to be encountered by the graduates in careers in industry and Government where most of them will be employed. This would also enhance the value of this human resource for the innovative process.

At the same time, there is a need for continuing education or retraining programs for working scientists and engineers to (a) enable those with an overly academic orientation to be better equipped to deal with pragmatic problems in industry or Government; (b) bring them up-to-date on new developments in their fields; (c) equip them to participate more effectively in interdisciplinary activity; and (d) enable them to shift into different fields.

Virtually no career has a greater need for intellectual flexibility and career mobility than that of scientist or engineer. Mechanisms should be devised to facilitate such flexibility and mobility so that scientists and engineers can move freely back and forth from the academic world to industry, to Federal, State, and local government, and to other forms of public service—without jeopardizing job security or retirement benefits.

To facilitate the foregoing goals and to help avert major misallocations of scientific and technical talent in the future (as occurred in the late 1960's and early 1970's), mechanisms should be developed to provide continuing foresight, planning, and career guidance information for scientists and engineers.

Scientific and technical facilities and equipment

Specialized facilities, equipment, and instrumentation are essential to effective innovation. They represent an enormous capital investment, but one which returns its costs to society many times over. Indeed, in order to realize the maximum return on the investment in human resources in science and engineering, it is necessary to provide them with the highest quality plant and equipment possible. However, there has been a significant decline in Federal expenditures for R. & D. plant since the mid-1960's. Thus, total Federal expenditures for R. & D. plant dropped from a peak in 1965 of $1.45 billion to $652 million in 1975, both figures expressed in 1972 constant dollars.[60]

The situation with respect to universities, which have been increasingly hard pressed financially, is even worse. Federal funding for R. & D. plant in universities dropped from a peak of $212 million in 1966 to only $28 million in 1975, both figures expressed in 1972 constant dollars.[61] This is highly detrimental to the Nation's basic research programs, a majority of which are carried out in the universities—55 percent in 1976.[62] Obtaining high quality R. & D. plant also poses major problems for small business technology firms, which frequently don't have adequate capital resources to obtain the necessary equipment.

Because of the rapid pace of scientific advance, R. & D. equipment becomes outmoded more rapidly than is the case in other fields. There-

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[60] NSB, "Science Indicators 1976", p. 216.
[61] *Ibid.*, p. 217.
[62] *Ibid.*, p. 75.

fore, depreciating such equipment over its "useful" life period frequently may not allow for the purchase of more effective equipment which has become available during that period, and whose utilization would facilitate innovation.

In view of the foregoing, mechanisms and programs should be devised to aid universities and small business technology firms in obtaining high quality facilities, equipment, and instrumentation. Furthermore, depreciation of such items should be established on a basis consonant with the rapid pace of scientific advance.

Patent System

Over the past 2 centuries the patent system has served as an effective spur to innovation in the United States. But in recent decades its role has significantly diminished because: (1) The pace and pattern on innovation have outstripped the limited scope of traditional patents; (2) the increasing number of Government-held patents—currently 25,000 to 30,000 unexpired patents [63]—has obstructed potential innovations from reaching the marketplace; and (3) the antiquated patent search and award process does not yield reliable patents which will stand up in court:

> About 50 percent of all litigated patents are held invalid (and) 65 to 70 percent of appealed patent cases result in holdings of patent invalidity.[64]

But these shortcomings can be rectified; the patent system can be restored to a pivotal role in the innovative process, as envisioned in the Constitution which provided Congress with the power "to promote the progress of science and useful arts, by securing for limited times to authors and inventors the exclusive rights to their respective writings and discoveries." [65] The Founding Fathers rightfully recognized that progress is promoted by granting exclusive rights to inventors; for without such incentives, individuals and organizations will not undertake the extensive commitments necessary to transform inventions into useful innovations.

To restore the patent systems to its potential pivotal role, a number of "institutional innovations" and improvements must be introduced. First, the operation of the system must be modernized: With computerization of the search process and with a patent re-examination procedure to assure greater reliability for existing patents. Second, patents currently held by the Government and those arising in the future from federally funded innovations should not be retained by the Government, but should be channeled into the commercial sector through a system of public acutions whereby such patents would be sold to the highest bidder. (The Government, of course, would retain a nonexclusive license to use the invention for its own needs, and would not auction off those patents relating to national security.) Third, the scope of patent applicability must be expanded and periodically updated to insure that patents can be awarded for the latest advances in science and technology. Fourth, a new category of prepatents should be established to stimulate the coupling or matching of technological capabilities with market needs and opportunities. Prepatents would be awarded for conceptual matching of needs and capabilities, before a device had

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[63] Report on Patent Policy, Proposal V, p. 3.
[64] *Ibid.*, pp. 3–4.
[65] U.S. Constitution, Article I, Section 8, paragraph 8.

been developed in practice. Fifth, the duration of prepatents and patents should be set to reflect the realities of innovation in our social and economic system. However, sixth, mandatory public auctions should be employed to force the sale of prepatents and patents when their owners were not utilizing them in innovative activity. Seventh, mandatory licensing of patents should be employed, when necessary, to insure diffusion of innovations into other industries and markets. Eighth, to provide incentives that will significantly increase the rate of innovation in our society, special tax treatment should be accorded to the sale of prepatents and patents. Ninth, steps should be taken to improve and expedite the legal procedures for patent litigation. Tenth, fees for filing prepatents and patents and the proceeds from public auctions of Government-funded patents should be set aside in a special fund for the operation of the patent system.

The synergistic effect of these measures would be to create strong market demand for the creative coupling of technological capabilities with social and economic needs and opportunities and for their subsequent development into patentable inventions. At the same time, strong incentives would be provided to impel imaginative individuals and enterprising organizations to meet those demands.

Industry generic research

Useful applied research that would facilitate innovation in a particular industry is frequently not undertaken by any of the firms in that industry because it is not believed that the results would yield short-run competitive advantages. Yet such research could be of benefit to the entire industry, with respect to its overall cost structure; its use of resources, the quality of its products, or its ability to compete abroad; or of benefit to the overall economy in the generation of jobs or the meeting of particular social goals such as those in safety and the environment.

But for a variety of factors, particular firms in the industry may not perceive such research as likely to enhance their short-run profitability, and, therefore, will not pursue it; or none of the firms in the industry may possess the resources to carry out such research effectively.

In any case, "Highly effective stimulation of industrial innovation can be accomplished (through) research and development of appropriate, new, generic technology—technology which enables industry to move in new directions in processes and products, but is not, a priori, directed at development of specific, proprietary-type new processes or products. This is so because such new technology, generic to industrial activities, and in the public domain, can then be drawn on by industry as a whole to innovate new, specific proprietary processes and products." [66]

Accordingly, mechanisms should be developed to foster applied research of generic value to particular industries or groups of industries, but which is unlikely to be undertaken by individual firms within those industries. The results of such research should be made available to all firms in the industries concerned.

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[66] Final Report on Direct Federal Support of Research and Development of the Subcommittee on Procurement and Direct Support of Research and Development of the Advisory Committee on Federal Policy on Industrial Innovation to the Secretary of Commerce." Washington, Feb. 15, 1979, p. 10.

Advanced technology system

Innovation over the past quarter of a century has frequently involved advanced technology systems that were extremely complex and far reaching. These systems have been particularly characteristic of defense, space, and nuclear energy programs, but also can be extremely important in other fields as well (e.g., automated mass transit or waste recycling). Advanced technology systems are generally very expensive to design and develop, entailing considerable scientific and technical expertise, and have usually proved successful only when they were responding to large-scale market needs.

Since such systems require considerable investment and extensive development over long leadtimes, industry is frequently unable or unwilling to embark on such systems, without strong market guarantees and Government assistance in the funding of necessary R. & D. Moreover, the potential markets for such systems are frequently fragmented or otherwise incapable of generating the necessary demand. Furthermore, the Government agencies with an interest in such systems often don't have wide enough jurisdiction to encompass all aspects of the system, or are lacking in the skills, budget authority, and appropriations to fund the necessary R. & D. on a large enough scale to be effective.

Nevertheless, such systems can contribute an enormous amount—indeed are essential—to providing innovative responses to many of our national social needs. Accordingly, we need a Federal agency—a civilian analog of the Defense Department's Advanced Research Projects Agency (ARPA)—to plan and manage Federal programs for the design, development, and demonstration of advanced technology systems which are responsive to priority national needs and specific market demands; and which are too advanced or experimental for the R. & D. programs of particular Government agencies, or which transcend the jurisdiction of individual agencies.[67]

Market demand

Vigorous market demand is essential to sustained technological innovation. We have already discussed means of stimulating market demand for the buying and selling of prepatents and patents. But market demand is equally important to the success of the advanced technology systems treated in the preceding section.

All the well-meaning Government assistance for R. & D. will be to no avail, if it does not mesh with sufficient market needs for the resulting systems. Most such systems fall in the category of public technology, for which the markets are notably fragmented and ineffective. The Nation's needs in urban centers, as well as in suburban and rural areas, cannot be met unless we can generate strong enough market pull to elicit the requisite technology from the R. & D. enterprise. This holds for mass transit, waste recycling, energy conservation, rural telecommunications, and many other areas of public technology.

Accordingly, we must develop mechanisms for the aggregation of markets for public technology, through which communities would pool

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[67] See "The Role of Demonstrations in Federal R. & D. Policy," a report of the Office of Technology Assessment, U.S. Congress, July 1978, for an account of the factors which should be taken into account in planning and managing demonstration programs.

their needs and generate sufficiently large-scale markets to elicit the requisite technological innovations.

In addition to facilitating the emergence of strong markets for public technology, the Federal Government has another crucial role to play in stimulating markets for innovation. This is through deliberate exercise of the Federal procurement function: To generate large Government markets for desirable innovations such as solar energy for Government housing, better pollution controls for Government installations, and more energy-efficient vehicles for the Government fleets of cars and trucks. In carrying out this function, the Government should make use of performance specifications and adjust its competitive bidding regulations to permit cases where innovative performance considerations can outweigh lowest cost as a determining factor in the procurement.

Small business technology firms

The small business contribution to technological innovation has been enormous, and the future potential is even greater. Thus, "small firms have compiled a striking record of innovation in the private sector. Firms with less than 1,000 employees accounted for almost one-half of major U.S. innovations during the period 1953–73." [68] "On the basis of a sample of major innovations introduced to the market between 1953 and 1973, small firms (up to 1,000 employees) were found to produce about four times as many innovations per R. & D. dollar as medium-sized firms (1,000 to 10,000 employees) and about 24 times as many as large firms (over 10,000 employees). The total number of innovations produced by small firms was greater than for large firms." [69]

The landmark Charpie Report on Innovation stated:

> We analyzed several studies on the sources of invention and innovation. These studies were unusually consistent in indicating that independent inventors (including inventor-entrepreneurs) and small technologically-based companies are responsible for a remarkable percentage of the important inventions and innovations of this century—a much larger percentage than their relative investment in these activities would suggest. Professor Jewkes * * * showed that out of 61 important inventions and innovations of the Twentieth Century * * * over half of them stemmed from independent inventors or small firms. Professor Hamberg * * * studied major inventions made during the decade 1946–55 and found that over two-thirds of them resulted from the work of independent inventors and small companies. Professor Peck * * * studied 149 inventions in aluminum welding, fabricating techniques and aluminum finishing. Major producers accounted for only one of seven important inventions. Professor Hamberg also studied 13 major innovations in the American steel industry * * * seven (came) from independent inventors. Professor Enos * * * studied * * * seven major inventions in the refining and cracking of petroleum—all seven were made by independent inventors.
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> The important point to be made is that independent inventors and small firms are responsible for an important part of our inventive progress, a larger percentage than their relatively small investment in R&D would suggest. Some important inventive contributions of independent inventors and small organizations in the Twentieth Century (include): xerography, DDT, insulin, vacuum tube, rockets, streptomycin, penicillin, titanium, shell molding, cyclotron, cotton picker, shrinkproof knitted wear, Dacron polyester fiber "Terylene," catalytic cracking of petroleum, zipper, automatic transmissions, gyrocompass, jet engine, FM radio, self-winding wrist watch, continuous hot-strip rolling of steel, helicopter, mercury dry cell, power steering, kodachrome, air conditioning, polaroid camera, hetero-

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[68] "Small Firms and Federal R. & D.," report of the Office of Federal Procurement Policy, Office of Management and Budget, Executive Office of the President, 1977.
[69] NSB, "Science Indicators 1976", p. 92.

dyne radio, ball-point pen, cellophane, tungsten carbide, bakelite, and oxygen steel-making process. * * * We are persuaded that a unique cost-benefit opportunity exists in the provision of incentives aimed at encouraging independent inventors, inventor-entrepreneurs, and small technologically based businesses. The cost of special incentives is likely to be low. The benefits are likely to be high.[70]

In an earlier section of this report, we have indicated the difficulties of small business technology firms in obtaining adequate venture capital and affording high-quality facilities and equipment. In addition, such firms have severe problems in: (a) Competing with larger firms for Federal R. & D. procurements; (b) acquiring ancillary technical and management knowhow; (c) attracting and retaining skilled executives; (d) effectively engaging in patent litigation; and (e) exhibiting sufficient staying power to weather the inevitable losses of the early years of an innovation before it generates significant profits.

Therefore, to aid small business technology firms in their innovation activities, a wide array of policies and programs is needed, including: (1) Small business set-asides for Federal R. & D. procurements; (2) university-based technical, management, and regulatory training and assistance programs; (3) legal aid in patent litigation; (4) special stock option incentives for their executives; (5) other special incentives for the firms and their investors; and (6) aid in obtaining venture capital through creation of a special class of convertible securities whereby investors in small business technology firms could purchase Government-backed bonds in the firms, which could subsequently be converted into common stock.

Innovation adjustment assistance

Although the overall economic effect of innovation is to enhance the economy and generate more jobs, specific instances of innovation do occasionally engender economic dislocations with adverse effects on particular communities and groups of workers. To the extent possible, these effects should be averted or mitigated; and when that is not feasible, innovation adjustment assistance should be provided to the affected communities and workers. Thus, there should be foresight and planning programs to help avert or at least to afford early warning of such dislocations, and to provide plans for coping with them. The assistance programs should include relocation, retraining, and supplemental unemployment compensation programs for affected workers; and preference rights in Federal procurements for affected communities.

Community technology

Stemming from E. F. Schumacher's work with technology for developing countries as recounted in his book, "Small is Beautiful",[71] there is an emerging, grassroots movement in America which is variously termed "appropriate technology" or "community technology" or "small-scale technology." In response to this movement, a number of Federal agencies—at the direction and urging of Congress—have established "appropriate technology" programs, including the Agency for International Development (AID), Department of Energy (DOE), and National Science Foundation (NSF). And with the

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[70] "Technological Innovation: Its Environment and Management", *op. cit.*
[71] E. F. Schumacher, "Small is Beautiful". New York: Harper & Row, 1973.

sponsorship of former Senate Majority Leader Mike Mansfield, a National Center for Appropriate Technology has been established in Montana with Federal funding. The Congressional Office of Technology Assessment (OTA) is currently conducting a survey of case studies of appropriate technology throughout the United States.

A major attribute of many of the appropriate technology projects is their communal or cooperative character, whereby a group of people in an urban or rural community come together to construct and operate some "appropriate" or "community technology," (such as an ecologically-closed solar energy-greenhouse system, including a small pond with fish and a vegetable garden, as well as a waste recycling system generating biomass energy).

While this movement is not about to supplant the existing technological infrastructure of our society—as some of its more extreme proponents sometimes may imply--it nevertheless responds to a real and widespread urge in America for a more manageable scale to society and a do-it-yourself form of control over our technological artifacts. In fields such as energy conservation and solar, wind, biomass, and small-scale water power systems, this movement could make important contributions to our social well-being. Thus, for example, New England contains many abandoned small-scale waterworks which could be restored as small-scale hydroelectric systems to aid local communities in coping with their energy needs. In any case, this burgeoning urge throughout our land toward small-scale, community technology embodies innovative potential and should be fostered and facilitated through a Federal program to provide community technology cooperatives with Federal matching funds and technical assistance.

Public participation

In recent years, there has been a spate of statutory provisions and administrative regulations providing for increased public participation in governmental decisionmaking. Over the past decade, a grassroots movement of environmental, consumer, and minority groups has had considerable impact on public policy issues at the Federal, State, and local levels. This movement has strongly advocated wider public participation, and under prodding from the Congress, executive agencies have begun to be responsive to those demands.

Public participation may be seen as merely the current manifestation of the original impulse in the American colonies which led to such institutions as the New England town meeting; as such it is in keeping with the spirit of democracy and as American as apple pie. However, there are some observers who see the current movement as essentially obstructionist—who view citizen opposition to nuclear power, strip mining of coal, or timber production in national forests—as misguided efforts to turn the clock back to an earlier, simpler society.

Because of the exponentially growing complexity of our technological age, traditional avenues of public participation often proved inadequate and citizen groups turned to the courts to achieve the goals they could not secure through the normal governmental or political process. This has led to an enormous upsurge in litigation on such issues as powerplant siting, offshore drilling for oil and gas, building of pipelines, and construction of roads passing through local communities.

This litigation—which often appears interminable—has exacerbated the animosities between the advocates of public participation and those abhorring its inhibiting effects on industrial development.

The genius of the American people over the past two centuries has been their capacity to deflect sharp ideological disputes and meld conflicting concerns in the crucible of compromise and consensus. It is no exaggeration to note that the future survival of our democracy requires the reassertion of that genius to shape new institutions and mechanisms to meet the challenge of our technological age.

Specifically, we must devise mechanisms which assure constructive public participation in decisionmaking on national innovation policies and programs—by any interested party—and which afford access to the technical information and assistance necessary to make such participation meaningful.[72] At the same time, however, we must channel this participation in such a way that it is timely and consonant with the overall decision process and does not—as is now frequently the case—lead to endless litigation and stalemates on public policy.

In short, we must fashion a new social compact through which the advocates and opponents of public participation strike a compromise whereby access and ample resources for meaningful public participation are assured—in return for a binding commitment to abide by the open, democratically derived decisions which ensue. In keeping with our Anglo-Saxon heritage, citizens, of course, may have final recourse to litigation. But if we really seek an innovative society, litigation should be invoked only as a last resort—not as a routine replacement for a reasonable process of public policy formation.

Policy implementation.

To implement the goals in the preceding policy target areas and significantly strengthen the nation's innovative system will require new, wide-ranging legislation and extensive administrative action, cutting across many departments, agencies, and programs. To oversee the followup actions required to make such a program effective in practice will demand continuing leadership and coordination of the highest caliber and at the highest level, if it is to exert sufficient leverage to achieve the desired goals. Accordingly, an Office of Innovation Policy should be established within the Executive Office of the President to oversee implementation of these policies.

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[72] See Ellis R. Mottur, "Technology Assessment and Citizen Action," Chapter 11 (pp. 259–286) in "Technology Assessment," ed. Raphael G. Kasper. New York: Praeger Publishers, 1972, for a discussion of citizen involvement in technology assessment decisions.

PART II—RECOMMENDATIONS

Scope

The targets for Federal innovation policy, which were delineated in the preceding section, can be subsumed under four general headings: (1) macroeconomic policy; (2) regulatory reform; (3) public participation; and (4) innovation infrastructure.

As discussed earlier, macroeconomic policy is beyond the scope of this report. With respect to the other areas, major legislation is required in each case to achieve the goals set forth for regulatory reform, public participation, and innovation infrastructure.

Reform of the regulatory system is a massive undertaking which has been initiated through a number of actions in the Congress and the executive branch. Thus, the Congress has recently enacted airline deregulation and is currently considering trucking deregulation, as well as a host of other bills pertaining to regulatory reform. In the administration, a Regulatory Council has been established, a Regulatory Calendar is being prepared periodically, and efforts are underway to widen the applicability of cost-benefit analysis to proposed regulations.

Similarly, legislative activity and administrative action are underway with regard to public participation. In recent years Congress has opened up committee deliberations to the public, and the House has even permitted the TV cameras to intrude in its Chambers. Congress passed the Advisory Committee Act and various forms of "sunshine" legislation, as well as many amendments; and is currently considering other bills and provisions dealing with public participation, such as legislation to defray the expenses of nuclear intervenors. In the executive branch, regulatory agencies such as the Federal Trade Commission (FTC) have attempted to facilitate public participation in their proceedings; and other agencies like the National Science Foundation (NSF) and the Environmental Protection Administration (EPA) have instituted concrete measures to foster public participation in their activities.

In the case of both regulatory reform and public participation, the legislation which is required to achieve the goals set forth in the preceding section is massive and far reaching. In both these cases, however, innovation is only one of a number of considerations which must be taken into account in developing the legislation. The impact of regulation and the role of public participation are extremely important to innovation; but innovation in turn is only one of many factors which must be weighed in developing legislation in those areas. Consequently, legislation directed at those issues must be much more broadly based than what would emerge from an analysis of innovation.

Accordingly, it is not advisable to provide in depth recommendations for action in these areas, beyond the policy goals which have been set

forth in the preceding section. It is hoped that they will be taken fully into account by the decisionmakers dealing directly with those issues.

The detailed recommendations which constitute the remainder of this report shall be devoted entirely to the fourth set of policy targets, which collectively comprise the innovation infrastructure.

Since these recommendations call for major new legislation, it appeared useful to present them in the form of a draft, omnibus bill which encompasses the critical targets of leverage in the innovation infrastructure. Insofar as is possible, the provisions of the proposed bill are summarized in layman's language.

The bill is put forward not as a set of definitive answers to the problems of innovation, ready for final legislative editing and enactment into law. Instead it is intended to serve as a basis for Congressional hearings and a concrete target for critical evaluation by others: in the belief that public policy options often can be best appraised after they have been reduced from the level of generality to the specific provisions of legislative proposals.

These recommendations are offered in this spirit, and it is hoped that they will stimulate further informed debate to help shape a strong national strategy for innovation.

Presented below, therefore, is a narrative summary of the provisions of the proposed bill, which is entitled: "The Innovation for America Act."

Proposed Innovation for America Act

A BILL To strengthen the infrastructure and provide the incentives necessary to advance technological innovation in the United States.

CONTENTS

Title I—National Innovation Policy.
Title II—Basic Research.
Title III—Human Resources in Science and Engineering.
Title IV—Scientific and Technical Equipment.
Title V—Patent System.
Title VI—Industry Generic Research.
Title VII—Advanced Technology Systems.
Title VIII—Market Demand.
Title IX—Small Business Technology Innovation.
Title X—Innovation Adjustment Assistance.
Title XI—Community Technology.
Title XII—Office of Innovation Policy.
Title XIII—General Provisions.

Title I—National Innovation Policy

This title sets forth Congress' findings, goals, and policies with respect to technological innovation. The findings include: (a) the significance of innovation to the economy and the society at large; (b) the lag in U.S. innovation; (c) the requireemnts for achieving successful innovation; (d) the causes of the U.S. lag; and (e) the need for a national strategy. The goals include: (a) the need for improved macro-economic policy regarding inflation, jobs, and capital formation; (b) the need for regulatory reform; and (c) the need for strengthening the structure for public participation in decisionmaking on innovation policies and programs. The policy section sets forth 12 national policies for strengthening the infrastructure and incentives for stimulating technological innovation.

FINDINGS

Significance of technological innovation

The Congress finds that technological innovation is of enormous importance to the U.S. economy and national well-being because technological innovation is essential to: Assuring national security; increasing productivity; reducing and controlling inflation; achieving full employment; meeting international economic competition; developing alternative energy sources and improved methods of conservation; solving environmental problems; providing effective public services in cities and counties; generating the national wealth required to pay for necessary social services, including but not limited to social security, welfare, health care, and education; and enhancing the overall quality of life in America.

U.S. innovation lagging

The Congress finds that, despite America's impressive past record, technological innovation in the United States is currently lagging compared with its challenges, competitors, and potential, as is evidenced by the facts that—

(a) Capital investment in innovative activities in the United States has substantially declined in recent years;

(b) The U.S. investment in research and development has stagnated at a lower level than a decade earlier, while Japan and West Germany have recorded substantial growth in the proportion of their gross national product going to research and development;

(c) The proportion of the U.S. population comprised by scientists and engineers has dropped since 1969, while it has increased in many other advanced industrial nations;

(d) The United States has shown a decline in its patent balance of 47 percent in recent years, and currently has a negative balance with Japan and West Germany;

(e) For the past two decades, U.S. productivity growth has been substantially below that of its foreign competitors;

(f) Although technology-intensive products have consistently made a positive contribution to the U.S. balance of trade, which has been second only to that of agriculture, we now have a negative trade balance with Japan, even in technology-intensive items; and

(g) The United States has not generated the technological innovations necessary to meet compelling national needs in such fields as energy, environment, and transportation.

Requirements for achieving innovation

The Congress finds that technological innovation, which—as the introduction, sale, and use of a new technology in the consumer or industrial marketplace or public arena—encompasses the entire spectrum of research, development, invention, engineering, finance, marketing, production, management, and sales, must include the following elements if it is to succeed:

(1) The imaginative matching of potential technologies with economic and social needs and opportunities;

(2) Strong leadership on the part of an individual who makes the sustained commitment to persist in pushing the innovation forward;

(3) The possibility of tapping or stimulating sufficient market demand so that the innovation can reach the scale or volume necessary for success;

(4) Individuals or firms with access to sufficient capital, who are willing and able to take the risks and invest the time, money, and human energy to shape the potential technology to meet the particular market demand;

(5) A combination of potential rewards and risks, along with an expected probability of success, which is attractive enough to justify investment of the necessary capital, when compared with alternative uses to which it could be put;

(6) High caliber management skills to move the innovation successfully through engineering, production, marketing, distribution, and sale;

(7) Sufficient time and continuing availability of resources to allow the innovation to prove itself out before the final reckoning of success or failure;

(8) An ever-expanding reservoir of scientific knowledge on which innovation can be based;

(9) Sufficient high quality facilities, equipment, and instrumentation to conduct the research, development, and engineering necessary to innovation; and

(10) An abundant supply of highly qualified scientists, engineers, and managers capable of moving the innovations ahead.

Causes of U.S. lag

The Congress finds that the recent decline in innovation in the United States is caused by:

(A) Certain conditions in the economic and regulatory environment within which innovation must occur, including:

(1) The high rate of inflation which militates against the kind of long-term, risky investments which are required for innovation;

(2) The low rate of capital formation in the U.S. economy which limits the amount of capital available for investment in innovative ventures;

(3) The burgeoning of Government regulations in recent years that slow the innovative process and focus management and technical talent on compliance rather than creation; and

(4) The high rate of unemployment which reduces consumer purchasing power and thereby limits the potential consumer markets for innovation; and

(B) Shortcomings within the innovation infrastructure, including the following factors:

(1) Basic research—which can thrive only in an atmosphere of free inquiry and which requires long-term stability and continuity of support—is too much influenced by the inroads of inflation, the fluctuations of the annual appropriations process, and constantly shifting political currents and fads;

(2) Insufficient educational emphasis on pragmatic problem-solving for those engineers who will be working in industry; and inadequate continuing education and career planning, flexibility, and mobility for scientists and engineers in general;

(3) Inadequate facilities, equipment, and instrumentation for university-based research and development and difficulty in financing research and development plant and equipment for small business technology firms;

(4) A deficient patent system which (a) offers inadequate incentives to induce the risks necessary to bring innovations into the marketplace; (b) provides insufficient stimulus to match potential technologies with market needs and opportunities; (c) contains too many Government-held patents which are rarely commercialized; (d) is too narrow in scope to reflect the latest advances in science and technology; (e) maintains an antiquated operation that does not provide timely or legally reliable patents; (f) results in excessive patent litigation that is time-consuming, costly, and riddled with inconsistencies and uncertainties; and (g) sometimes even serves to inhibit innovation;

(5) Not enough applied research on generic problems common to particular industries or industrial processes, such as the steel industry or computer-aided manufacturing;

(6) A lack of institutions to stimulate the design, development, and demonstration of major systems involving advanced technologies in priority national areas;

(7) The inability to generate strong, sustained large-scale market demand for public technology systems;

(8) Inadequate sources of venture capital and insufficient incentives and aids to small business technology firms in carrying out innovation and competing with larger established enterprises, despite the overwhelming evidence of small business' disproportionately large contribution to innovation in America;

(9) Lack of planning and provisions to aid communities and workers in averting or adjusting to major economic dislocations due to technological innovation;

(10) Insufficient technical and financial aid to small-scale community technology projects; and

(11) No central, high-level focal point for guiding and coordinating the innovation policies and programs of the Federal Government.

Need for national strategy

The Congress finds that there are no "quick fixes" for improving innovation, but that the innovative process—with its extensive scope and complexity—can be significantly improved only through a comprehensive strategy that addresses key leverage points throughout the entire innovative process.

NATIONAL GOALS

In view of the foregoing, the Congress declares that it shall be a high priority goal of the United States to foster useful technological innovation which is responsive to economic, social, and human values, needs, and opportunities; and that to facilitate the achivement of this goal, the United States shall pursue the following related goals:

(a) To shape a macroeconomic environment which is conducive to innovation by promoting adequate capital formation, controlling inflation, and maintaining high levels of employment;

(b) To rationalize the regulatory system in order to (1) eliminate unnecessary regulations; (2) establish effective mechanisms for assessing the relative benefits and burdens of proposed new regulations; and (3) implement regulations in such a way as to to minimize their onerous burden on private organizations and individuals; and

(c) To provide for appropriate inputs and participation by any interested parties, including citizen groups and members of the public at large, in decisionmaking on national innovation policies and programs, but to structure said participation in such a way that it does not unduly add to the regulatory burden or excessively delay the introduction of timely innovations in the national interest.

NATIONAL POLICIES

In order to further the goal of fostering useful technological innovation by strengthening the innovation infrastructure, the Congress declares that it shall be the policy of the United States to—

(1) Establish a National Science Endowment which, by the year 2000, will provide sustained, stable funding for basic research on a self-supporting, self-regulating basis;

(2) Promote optimum utilization of the Nation's scientific and engineering talent through more effective career planning, more relevant engineering education, programs of continuing education, and programs to enhance career mobility and flexibility;

(3) Aid universities and small business technology firms in obtaining high quality facilities, equipment, and instrumentation to use in research, development, and engineering;

(4) Strengthen and expand the patent system to: (a) reflect the latest advances in science and engineering; (b) modernize its operations; (c) reduce the number of patents held by the Government; (d) stimulate the imaginative matching of potential technologies with market needs and opportunities; (e) provide sufficient incentives to encourage the risk taking necessary for innovation; and (g) ameliorate the process of patent litigation;

(5) Encourage firms to cooperate together, and assist them with matching funds, in the conduct of applied research on generic problems common to particular industries or industrial processes;

(6) Establish an Advanced Technology Systems Administration to plan and manage Federal programs for the design, development, and demonstration of advanced technology systems which are responsive to priority national needs and specific market demands, and which are too advanced or experimental for the research and development programs of particular Government agencies, or which transcend the jurisdictions of individual agencies;

(7) Aid communities throughout the Nation in the establishment of Public Technology Market Consortia in order to generate sufficiently large-scale market demand to stimulate needed innovations in public technologies;

(8) Make deliberate use of Federal procurement to generate large Government markets for desirable innovations such as solar

energy for Government housing or improved pollution controls for Government installations;

(9) Aid small business technology firms in their innovative activities through a variety of policies and programs which offer special incentives, technical, legal, and management assistance, increased access to venture capital, and a larger share of Federal research and development procurement;

(10) Aid communities and workers in averting or adjusting to major economic dislocations due to technological innovation;

(11) Provide matching funds and technical assistance to community cooperatives engaged in appropriate technology programs; and

(12) Establish an Office of Innovation Policy to guide and coordinate the innovation policies and programs of the Federal Government.

Title II—Basic Research

This title establishes a National Science Endowment which, by the year 2000, will provide sustained, stable funding for basic research on a self-supporting basis, with no further need for annual Federal appropriations.

This would be accomplished through a gradual transition to be completed by the year 2000. Each year from 1984 to 1999, there would be a Federal contribution to the endowment. Concurrently, a system of user fees would be initiated whereby industry, nonprofit R. & D. organizations, Government R. & D. agencies, universities, and other educational institutions would be assessed user charges according to their usage of basic research information in various fields of science. These fees would gradually increase during the transition period to be fully in effect by the year 2000, so that particular users would have ample time to adjust to these requirements. In addition, universities and other educational users would have preferential rates relative to the other categories of users. The NSE would also be authorized to issue government backed bonds.

By the year 2000, the combination of user fees, bond issues, and earnings on the endowment would enable the National Science Endowment (NSE) to fund the Nation's basic research programs without the need for annual Federal appropriations.

The NSE would be chartered by Congress as a nonprofit public corporation. The Endowment would be governed by a 21-member Board of Governors, 10 of whom would be appointed by the President with the advice and consent of the Senate, and 11 of whom would be elected by the membership of the Nation's scientific and engineering societies. Governors would serve for 7-year terms, which would be staggered to assure both continuity on the Board and the continual infusion of new blood. The President would appoint a Chairman and Vice Chairman from among the Board members, who could come from either the appointed or elected members. The Chairman, with the consent of the Board, would appoint an Administrator and Deputy Administrator, who in turn would appoint such staff as were necessary to administer the activities of the Endowment.

Through this institutional innovation, basic research would be recognized as a continuing investment in the Nation's future. The

NSE would operate as an autonomous public trust—somewhat analogous to the Federal Reserve Board—and basic research would be free to follow scientific opportunities and creative insights, guided only by the scientific community itself through the peer review system.

The NSE would replace the basic research programs of NSF. Other NSF programs would be unaffected by this transition.

The far-reaching nature of this transformation requires careful deliberation and detailed planning before it can be implemented. This statute, therefore, establishes a Presidential Commission to plan the transition. The Commission on the National Science Endowment would be expected to start work by the spring of 1981 and issue its recommendations in the spring of 1983. The Commission would then aid the President and Congress in following up on the recommendations and go out of existence by September 30, 1984, when the transition to the new system would formally begin. Thus the NSE would commence operations at the start of the fiscal year beginning October 1, 1984.

This bill authorizes $10 million for operation of the Presidential Commission through September 30, 1984. A new authorization bill would be required by October 1, 1984, to authorize funds for building up the Endowment over the 15-year period from 1984 to 1999. Thus, the Nation would not have to make a long-term financial commitment to building the Endowment until there was ample opportunity to consider the detailed report of the Presidential Commission.

Title III—Human Resources in Science and Engineering

This title would strengthen the Nation's human resources in science and engineering and promote their optimum utilization, while enhancing their professional security. Specifically, this title would: (a) increase educational emphasis on pragmatic problem solving for engineering students likely to enter industry or Government careers; (b) promote continuing education of scientists and engineers; (c) establish effective career planning programs including a network of scientist and engineer talent banks; (d) undertake a major study of careers in science and engineering to assure increased flexibility and mobility, while enhancing professional security.

Engineering education

The National Science Foundation (NSF) would be required to sponsor the development of more pragmatically oriented engineering curricula; and to sponsor industry internships for graduate and undergraduate engineering students, so that they could acquire greater understanding of the real problems of technological innovation in industry; $5 million would be authorized for the first year of this program, with following years authorized such sums as may be necessary.

Continuing education

A Division of Continuing Education in Science and Engineering would be established in NSF to sponsor continuing education programs. These would be carried out by industry, universities, nonprofit organizations, and scientific and engineering societies (sometimes in cooperation with one another). The programs would be designed to:

(a) bring scientists and engineers up to date on new developments in their fields; (b) equip them to participate more effectively in interdisciplinary activity; or (c) enable them to shift into different fields or acquire different kinds of functional responsibilities; $10 million would be authorized for the first year of this program, with following years authorized such sums as may be necessary.

Office of human resources planning in science and engineering

An Office of Human Resources Planning in Science and Engineering would be established within the NSF. This Office would gather relevant statistics and data on the utilization of scientists and engineers, analyze trends, and forecast future patterns of utilization. The results would be made available to other Government agencies to aid in their detailed program planning and implementation; and would be publicly disseminated through professional societies, universities, colleges, high schools, and the media to aid in educational and career counselling and guidance; $5 million would be authorized for the first year of this program, with following years authorized such sums as may be necessary.

Talent banks of scientists and engineers

The Office of Human Resources Planning would establish a nationwide system of talent banks of scientists and engineers. These banks would maintain computerized data on current employment of scientists and engineers and on professional job opportunities. They would be designed to assist scientists and engineers in matching their talents with the best available job opportunities, thereby enhancing overall national utilization of these valuable human resources. The system would be administered by the scientific and engineering societies on a matching fund basis. For each dollar spent on this system by the societies, the Federal Government would provide $3 matching; $7.5 million would be authorized for the first year, with following years authorized such sums as may be necessary.

Presidential commission on careers in science and engineering

The President would appoint a Commission on Careers in Science and Engineering to make recommendations designed to increase career flexibility and mobility, while enhancing professional security. The Commission would explore ways of increasing professional mobility among different sectors of society (academia, industry, nonprofits, Federal, State, and local government) through such means as internships and fellowships, as well as more lasting career transitions. The Commission would also consider such related issues as the academic tenure system, the "aging" of university faculties, professional job security in other sectors, and the possibility of vesting some form of tenure-equivalent in the scientific and engineering societies. The Commission would have a 2-year life and a total authorization of $5 million.

Title IV—Scientific and Technical Equipment

This title would promote the wider availability of high quality facilities, equipment, and instrumentation for use in research, development, and engineering. Specifically, it would: (a) establish a

national technical equipment bank to channel equipment owned by the Government or surplus to the needs of various organizations to other organizations (universities and small business firms) which could make better use of it; (b) increased Federal funds for the purchase of new equipment to be used by universities; and (c) permit business firms accelerated depreciation for facilities and equipment used in innovation.

National technical equipment bank

A national technical equipment bank would be established within the National Science Foundation (NSF). The bank would maintain a computerized inventory of scientific and technical equipment in Government laboratories, universities, and private organizations which were utilizing equipment purchased under Government grant or contract, the title to which was retained by the Government. When equipment owned by the Government became surplus to the needs of the particular organization which had been utilizing it, the bank would match that equipment with needs expressed by other organizations participating in the system; and when a proper match was found, transfer the equipment to the appropriate organization.

In those cases where title to the surplus equipment was in the hands of the utilizing organization, the bank could purchase it at cost less depreciation, with an appropriate allowance for inflation (provided that the equipment was determined to be in good condition). Equipment which was so purchased by the bank would become part of the general inventory and be available for allocation to other participants in the system. When equipment in the system was allocated to universities, it would be in the form of no-interest equipment loans. When equipment was allocated to small business technology corporations (as defined by the Small Business Administration pursuant to the provisions of title IX of this act), it would be in the form of low-interest equipment loans; $5 million would be authorized for the first year of this program, with following years authorized such sums as may be necessary.

New equipment for universities

In addition to reallocating equipment already within the bank's inventory, the NSF would also purchase new equipment to be used for upgrading the technical capabilities of universities. This new equipment (which would be chosen for its usefulness in areas of R. & D. which had been accorded national priority) would be entered into the bank's inventory and earmarked for no-interest equipment loans to universities. For the first year of this program, $10 million would be authorized in addition to any other funds that NSF might have available for university facilities and equipment, with following years authorized such funds as may be necessary.

Accelerated depreciation of facilities and equipment

Business firms would be permitted accelerated depreciation (over a 3 year period) of all plant, facilities, and equipment that is used in research, development, engineering, or production with the aim of developing or commercializing a technological innovation. The Internal Revenue Code would be amended accordingly.

Title V—Patent System

This title reshapes the patent system to enable it to play the pivotal role in propelling innovations into the marketplace. Specifically, it: (a) Expands the scope of patents to reflect the latest advances in science and technology; (b) modernizes the operation of the Patent Office to produce the more rapid issuance of legally reliable patents; (c) promotes the commercialization of the nearly 30,000 patents currently held by the Government by offering them for sale at public auction; (d) stimulates the imaginative matching of potential technologies with market needs and opportunities by creating a new category of prepatents; (e) increases the incentives associated with patents to encourage the risk taking necessary for innovation; (f) precludes the use of patents to stifle innovation; (g) promotes greater diffusion of innovations through mandatory licensing; and (h) ameliorates the process of patent litigation.

Scope of patents

Since innovations do not happen unless someone has the incentives to take the risks necessary to make them happen, and since the exclusive rights afforded by patents are essential to providing effective incentives—the Patent Office shall seek to award patents as widely as possible. The Patent Office shall periodically review and adjust, whenever necessary, its criteria for the award of patents in order to reflect as widely as possible the latest advances in science and technology. Thus, in order to reflect recent advances, the Patent Office shall henceforth award patents for: (a) Computer software; (b) the industrial applications of new life forms; and (c) use-specific chemical formulations which are based on unpatentable biologically active ingredients.

Patent advisory board

There is hereby established a Patent Advisory Board to advise the Patent Commissioner on desirable extensions and alterations in the scope of patents pursuant to the preceding section. The Board shall consist of 11 members of the public appointed by the President to reflect a balanced composition of distinguished scientists, engineers, inventors, industrialists, academicians, and members of the general public. Members shall serve for 4-year terms, with the initial terms staggered so as to provide an annual infusion of new members. In addition to the above duties, the Board shall advise the Commissioner on the delineation of guidelines and criteria for the award of the new category of "prepatents" established in the next section; and on any other aspects of the role of patents in the innovative process, on which the Commissioner may see fit to seek their advice. The Board shall elect a Chairman and Vice Chairman from among its members to serve for a term of 2 years.

New category of prepatents

In order to stimulate the matching of potential technologies with market needs and opportunities—a function which is central to the whole innovative process—there is established a new category of prepatents. A prepatent shall be awarded for the first filing of an original coupling or matching of a technological possibility with an economic

or social need or opportunity that could be met through actualization of that technological possibility. Whereas a patent is awarded only after the technological possibility has been actualized in a demonstrable form (i.e., reduced to practice), the prepatent is awarded for the original creative coupling of the concepts before the invention has been demonstrated in practice. There is established within the Patent Office a Division of Pre-Patents, which shall develop the guidelines and criteria for the award of prepatents (with the help of the Patent Advisory Board established in the preceding section). Prepatents may be awarded to individuals or corporations. Corporations shall be charged a reasonable fee for filing a prepatent; but individuals may make application free of charge to promote the widest possible creation of prepatent concepts. The owner of any prepatent shall be entitled to certain claims against the owner of any subsequently filed patent which makes use of the concepts contained in the prepatent, in accordance with the provisions set forth in a succeeding section of this title.

Title to prepatents

(1) A Government employee or corporate employee working under Government contract who conceives and files a prepatent, shall receive title to it, whether or not he conceived of it in the course of his work, except when it involves classified national security information, in which case the Government shall receive and retain title. (2) A corporate employee (not working under Government contract) who conceives and files a prepatent, shall receive title to it whether or not he conceived of it in the course of his work, except when he has entered into a prior employment contract with his employer concerning such rights and provided that said contract entitles the employee to a choice of (a) 50 percent of any future proceeds accruing to the prepatent, or (b) a fixed payment from his employer upon surrender of the rights to the prepatent in an amount mutually agreed upon between employee and employer.

Title to patents

(1) When a Government employee make a patentable invention in the course of his work, the Government shall receive title to it. However, with the exception of inventions dealing with classified national security information, the Government shall offer such inventions for sale at public auction. Following any such sale, the Government shall retain a nonexclusive license to use the invention for its own purposes, and the employee who made the invention shall receive 25 percent of the net proceeds of the sale. (2) When a patentable invention is made under a Government contract, the Government shall receive title to it. However, with the exception of inventions dealing with classified national security information, the Government shall offer such inventions for sale at public auction. Following such sale, the Government shall retain a nonexclusive license to the invention for its own purposes. Twenty-five percent of the net proceeds of the sale shall go to the employee involved unless he has a prior employment contract which precludes his receiving the full 25 percent. It that case the 25 percent shall be shared between the employee and the corporation, provided that the corporation may not receive more than one-half the amount received from the Government.

Government-owned patents

In order to achieve commercialization of patents currently owned by the Government, and thereby make their potential benefits available to the American public, the Government shall offer all such patents (currently 25,000 to 30,000) for sale at public auction, with the exception of those patents relating to national security matters. Regarding any patents which are sold through such auction, the Government shall retain a nonexclusive license to use the invention for its own purposes.

Duration of rights to prepatents

Any individual or corporation that is awarded or purchases a prepatent must, within a 3-year period, show the Division of Pre-Patents adequate evidence of substantial steps taken toward the development of technology based in whole or part on that prepatent. If evidence is not produced which satisfies such criteria as is developed and promulgated by the Division of Pre-Patents, then rights to the prepatent shall revert to the Government, which shall offer the prepatent for sale at public auction.

When the titleholder does show satisfactory evidence of substantial steps within the 3-year period, then he shall have an additional 7-year period by the end of which he must do either one of three things: (1) File a patent based in whole or in part on the prepatent; (2) incorporate the prepatent concept in commercial products, processes, services, or systems; or (3) sell the prepatent. If none of these is accomplished within the 7-year period, title shall revert to the Government, which shall offer the prepatent for sale at public auction. Thirty years after its initial award, each prepatent shall expire and may not be reconstituted.

Prepatent rights in related patents

If during the life of the prepatent, someone other than its owner shall obtain a patent which is based, in whole or in part, on the novel coupling expressed in the prepatent (as determined by the Patent Office), then the patentholder shall incur an obligation to the prepatentholder which must be discharged in either one of three ways: (1) The patentholder can pay a (mutually agreed upon) lump sum to the prepatentholder (in one amount or in installments over time), and thereby discharge the obligation in full; (2) the prepatentholder shall receive over the life of the patent or prepatent (whichever is shorter) a certain percentage of the net income accruing to the patentholder as a result of the patent; or (3) any combination of alternatives (1) and (2). The Patent Office shall develop guidelines for the establishment of appropriate percentages to be used in the second alternative, depending on the criticality of the prepatent to the patent (which also shall be determined by the Patent Office). Further, the Patent Office shall develop procedures whereby the patent- and prepatent-holders shall negotiate as to which alternative arrangement to enter into.

Duration of patent rights

Within 5 years from the acquisition of a patent, the patentholder either must: (a) Show the Patent Office satisfactory evidence of substantial steps taken to incorporate the patent in commercial products, processes, services, or systems; or (b) sell the patent. Otherwise, title to the patent shall revert to the Government, which shall offer the

patent for sale at public auction. If the patentholder provides satisfactory evidence within the 5-year period, he shall then have an additional 5-year period by the end of which, either he must: (a) Demonstrate actual use of the patent in commercial products, processes, services, or systems; or (b) he must sell the patent. Otherwise, title shall revert to the Government, which shall offer the patent for sale at public auction. From the proceeds of such sales as are set forth in this section, the Government shall first recover the costs of the sale, after which the patentholder shall be entitled to recover an amount equal to the costs he incurred to acquire and exploit the patent, less any value he has heretofore received from its possession; any additional proceeds shall accrue to the Government.

When compliance with Government regulations (such as those regarding health, safety, and the environment) results in a demonstrable delay of 1 or more years in the commercial use of a patent, then the total life of the patent shall be extended by the amount of such delay, and the two 5-year periods referred to above shall be adjusted as necessary.

When a patent is purchased directly from the owner or at public auction, the new owner shall be entitled to the same two 5-year periods referred to above, and the total life of the patent shall commence anew; provided, however, that no patent (regardless of how many owners it may have) shall be in existence for more than 35 years.

Mandatory licensing

In order to foster diffusion of innovation to industries or markets other than those in which it originated, mandatory licensing shall be employed in the following manner: Three years after a patent has been in commercial use in certain industries or markets, any party wishing to make use of it in other industries or markets can obtain a mandatory exclusive license for the sole purpose of using it in the stipulated industries or markets. The terms of such licensing shall be established under guidelines set forth by the Patent Office. If the licensee has not made commercial use of the patent within 3 years of obtaining his license, the license shall be voided; and others shall be entitled to apply for a similar license in those stipulated industries or markets.

Sale of prepatents and patents

The seller of any prepatent or patent shall be subject to a special innovation tax of only 10 percent of his net gain, provided that any prepatent or patent owner (other than the original owner) shall have held title for at least 6 months prior to sale. The Internal Revenue Code shall be amended accordingly.

Patent reexamination

In order to provide greater title reliability to patent owners and to reduce the burden of patent litigation on the courts, the Patent Office shall initiate a system for the reexamination of patents, taking account of prior art not previously considered by the Patent Office in the award of the patent. Such reexaminations shall be initiated upon the request of any party with an interest in the matter.

Commission on patent litigation

Since the high costs of patent litigation discriminate against those with insufficient financial resources, and since the lingering uncer-

tainties attendant upon such litigation serve to inhibit the risk-taking investments which are essential to innovation, it is desirable to reduce the costs, time periods, and wide variances in interpretation of patent law which are usually associated with patent litigation. Therefore, there is established a Commission on Patent Litigation to conduct a 1-year study and make appropriate recommendations regarding ways of ameliorating the process of patent litigation. The Commission shall consist of 15 distinguished lawyers (including members of the judiciary), inventors, corporate officials, and leaders of public affairs who shall be appointed by the President for the 1-year duration of the study. Staff support for the study shall be provided by the Patent Office.

Patent office operations

The Patent Office shall establish a Division of Prepatents and a Public Auction Staff to carry out the responsibilities with respect to these two functions set forth in this title of the act. The Patent Office shall expand and upgrade its staff as necessary to fulfill these functions, as well as to cope with the wider scope of patents and prepatents established under this title. The Patent Office shall fully computerize its search operations and take whatever other steps may be possible to modernize its operations. Fees for making application for prepatents and patents, as well as that portion of the net proceeds of public auctions which accrue to the Government, shall be retained in a special trust fund to be used only for the operations of the Patent Office.

Authorization

In addition to such other funds as may have been authorized or may be authorized for the normal operation of the Patent Office, $70 million is authorized specifically for the new functions and expanded responsibilities established under this title, for the first fiscal year following enactment of this act. Of that $70 million, $1 million is earmarked for support of the Commission on Patent Litigation.

Title VI—Industry Generic Research

This title would authorize the establishment of Industry Generic Research Institutes to conduct applied generic research on problems of common concern to an entire industry (such as steel) or a group of industries (such as homebuilding) or a set of industrial processes (such as computer-aided manufacturing).

These institutes would attempt to advance the state of the art so as to benefit all the firms involved. Such research could yield benefis with respect to productivity, cost control, product quality, use of resources, energy conservation, or ability of firms to compete abroad; and could benefit the entire economy through the generation of jobs or the achievement of particular social goals such as those in safety and the environment. The institutes would pursue only that generic research which individual firms involved would be unlikely to undertake on their own: either because it could not be expected to confer short-run competitive advantages or because they do not possess the resources of talent to tackle it.

The antitrust statutes and regulations would be amended or revised as necessary to facilitate firms cooperating together to form such in-

stitutes. The institutes would be established under guidelines set forth by the Secretary of Commerce. As a minimum general precondition for all such institutes, three or more firms, representing at least 20 percent of the dollar volume of the industry of group of industries involved, must apply for permission to incorporate an institute. The Secretary may establish more stringent conditions for particular industries or situations, as he sees fit. Any other firm in the industry would be eligible to join, upon payment of the appropriate membership contribution; the amount and nature of the contributions required would be established by the Secretary and would provide scaled requirements related to firm size.

The institutes would function as nonprofit corporations. Contributions to the institute from industry would be tax deductible. The Government would provide matching funds (on a one-to-one basis) with the contributions from industry, up to such maximum limits on the Federal contribution as the Secretary may prescribe. The institutes also would be eligible to receive grants and cooperative agreements from the Government for specific research projects. The institutes would be governed by boards of trustees, two-thirds of whose members would be chosen by the industries involved and one-third by the Secretary of Commerce.

Inventions arising from this research could be patented by the institute and would be licensed to any of the member firms for an appropriate fee. Nonpatentable information arising from the research would also be made available to the member firms for a nominal processing fee. Nonmember firms would be required to pay a higher fee for such information, and would be entitled to receive a license to a patented invention only after 3 years had elapsed from the time of licensing to member firms. The Government would automatically receive all information generated by research at the institutes free of charge, and would hold a nonexclusive license to all patents taken out by such institutes.

The Commerce Department is authorized to contribute up to $25 million during the first fiscal year of the program, and thereafter such sums as may be necessary.

Title VII—Advanced Technology Systems

This title would establish an Advanced Technology Systems Administration (ATSA), as an independent agency, to serve as the civilian analog to the Defense Department's Advanced Research Projects Agency (ARPA). ATSA would plan, stimulate, and manage the design, development, and demonstration of major advanced technology systems in priority national problem areas, such as alternative energy sources, energy conservation, automated mass transit, interurban high speed railroads, pollution controls, toxic waste disposal, et cetera.

ATSA would provide grants and enter into cooperative agreements with industry, universities, and nonprofit R. & D. organizations, as well as transfer funds to Government laboratories and R. & D. agencies, for the design, development, and demonstration of advanced technology systems. ATSA would direct its resources only

toward those systems which meet the following criteria: (1) aimed at meeting priority national needs; (2) responsive to specific market demands; and (3) beyond the capabilities or jurisdiction of other Government agencies to undertake. At each stage of its programs, ATSA would work closely with potential distributors and users of the projected system (in industry, State, and local government, and the nonprofit sector) to assure that the systems were in tune with market demands and requirements.

It is essential that ATSA be established as an independent agency in order to marshal full public support for its programs, convince potential markets that this will be a serious, sustained effort, and deal on a par with other Government agencies whose jurisdictions are involved. ATSA would be directed by an administrator (level II of the executive schedule) and a Deputy administrator (level III of the executive schedule), both of whom shall be appointed by the President with the advice and consent of the Senate.

ATSA would absorb the personnel, programs, and authorizations of two existing National Science Foundation Units: the Division of Applied Research and Engineering and the Division of Problem Focused Research. However, any of the ongoing programs of those divisions which did not meet ATSA's criteria would gradually be phased out.

In addition to authorizations transferred from NSF, ATSA would receive a new first year authorization of $50 million, and thereafter such sums as may be necessary.

Title VIII—Market Demand

This title is aimed at stimulating markets for technological innovation in high priority areas of national need. Specifically, this title: (a) authorizes the establishment of Public Technology Market Consortia to aggregate State, local, and regional governmental market demand for public technology systems in fields such as automated mass transit, water purification, and solid waste disposal and recycling systems; and (b) directs the concerted use of the Federal procurement power to generate large Government market demand for desirable innovations such as solar energy systems for Government housing or pollution controls for Government installations.

Public technology market consortia

This title establishes an Office of Public Technology Market Consortia within the Department of Commerce to develop guidelines and criteria and to administer this program. The program would provide planning grants to States, regional authorities, cities, and counties to help them plan for the establishment of Public Technology Market Consortia in fields such as automated mass transit, waste recycling and disposal, emergency health care, water purification, regional telecommunications systems, computerized public safety systems, fire fighting technology, and so forth

Each consortium which was established would be a nonprofit corporation whose board of trustees would be drawn from the governmental units which belonged to it. When such a consortium met the criteria established by the Secretary of Commerce, it would be eligible to re-

ceive Federal matching funds on a basis of 90 percent Federal for 10 percent consortium. With these funds the consortia would contract with industry and nonprofit R. & D. organizations to design public technology systems according to the performance specifications established by the consortia, with the technical assistance of the Federal Government. (The special technical expertise which was required for the particular consortium would be requisitioned from the appropriate agency (for example, Department of Energy for an energy conservation project) and channeled to the consortium by the Office in the Department of Commerce.)

Because of the large market potential represented by the participants in a particular consortium, industry would have a real incentive to make the investments necessary to design public technology systems to meet the performance specifications which had been established. Thus, these consortia would provide the same market-generating function in the civilian area that DOD and NASA have done for defense and space technology systems.

Since the consortia's contracting with industry would in many cases take the place of funds that normally would have been channeled through individual Federal agencies, or through revenue sharing, the Office of Management and Budget (OMB) shall transfer appropriate amounts of funds from specific agency budgets to this program in the Department of Commerce, for utilization as Federal matching funds to the consortia. In addition, $90 million in new funds is authorized for the first year's operation of this program, and thereafter such sums as may be necessary.

Federal procurement

In order to generate large Government markets for desirable innovations (which would then be expected to diffuse into nongovernmental markets), OMB's Office of Federal Procurement Policy (OFPP) shall develop guidelines whereby Federal procurement can be deliberately directed toward that purpose. Under those guidelines the General Services Administration (GSA) shall be required to develop performance specifications for certain high-priority items (for example, solar collectors for Government housing) and to widely publicize them. The prospect of large Government markets for items meeting those specifications is likely to stimulate industry to make the investment and effort necessary to produce the requisite technological innovations. Firms meeting the advanced technology specifications would be accorded special consideration in the procurement decision, in that innovative performance characteristics would be permitted to outweigh cost factors, within reasonable bounds.

Title IX—Small Business Technology Innovation

This title would aid small business technology firms in realizing their full potential in the innovative process. Specifically, it would: (1) assure them a greater share of Federal R. & D. funds; (2) afford them increased access to sources of venture capital; (3) provide them with a panoply of education and assistance programs in technical, managerial, and regulatory areas; (4) offer them "legal defender"

aid in dealing with patent litigation; and (5) structure a host of special incentives to (a) induce potential investors to want to invest in them; (b) embolden the firms to make the R. & D. investments and take the risks necessary to innovation; (c) encourage them to utilize patents; (d) enable them to recruit and retain high caliber executives; (e) stimulate them to diffuse the innovations they have developed; and (f) provide them with ample time to prove innovations out before the final reckoning of success or failure.

Small business technology innovation corporations

The Small Business Administration (SBA), in consultation with the Assistant Secretary of Commerce for Science and Technology, shall develop guidelines and criteria for qualifying small businesses as "small business technology innovation corporations." The criteria would include consideration of such factors as: The firm's past record of innovations introduced; patents awarded or acquired; amount of investment in R. & D. facilities, equipment, and instrumentation; relative expenditures for R. & D. activities; and relative numbers of scientists, engineers, and technicians. When a firm had applied to SBA and had qualified as a small business technology innovation corporation, then it would be entitled to participate in appropriate programs and receive applicable incentives, as set forth in this title.

Federal R. & D. small business set-asides

In the first full fiscal year following enactment of this act, each Federal agency conducting R. & D. procurement programs of $10 million or more shall increase the proportion of its total R. & D. procurement funds awarded to small business technology innovation corporations over the preceding fiscal year by at least 1 percent; and shall continue this process in each succeeding fiscal year until such time that the proportion equals or exceeds 10 percent.

Small business innovation bonds

Small business technology innovation corporations could apply to the SBA for permission to issue small business innovation bonds (SBIB's). Permission would be granted if the corporation met the special SBIB criteria established by SBA, including the requirement that the corporation showed evidence of an incipient or ongoing innovation venture requiring substantial new capital (relative to the existing capital of the firm or to the resources of the entrepreneurs who were establishing the firm).

Upon receiving the permit, the small business firm could issue Government-backed SBIB's, as 5-year convertible bonds, with interest set at prevailing market rates in accordance with SBA guidelines. The SBA would provide the firm with matching funds to help defray the interest on these bonds. The matching ratio would shift over the 5-year period as follows: The first year the Government would pay 90 percent of the interest and the firm 10 percent. The second year the Government share would be 80 percent and the firm's 20 percent. Third would be 70 percent to 30 percent. Fourth, 60 percent to 40 percent. And in the fifth and final year of the bond issue, the Government and the firm would each pay 50 percent of the interest due. At any time during the 5-year period, including at its conclusion, the holders of the bonds

could convert them into common stock in the firm, in accordance with such formulas as the SBA shall prescribe.

If the firm is incapable of redeeming those bonds which have not been converted by the end of the 5-year period, or if during the period, the firm is incapable of meeting its share of the interest payments, then holders of the SBIB's shall have precedence over any other holders of securities in the firm in any dissolution of the firm's assets. If such a dissolution were to occur and there was still a shortfall in fulfillment of obligations to the holders of SBIB's, then the SBA would reimburse the SBIB holders for the amount still due, provided that it did not exceed 50 percent of the face value of the bond.

The SBA is authorized $25 million for the first year of this program, and thereafter such sums as may be necessary.

Technology innovation education service

To provide small business technology innovation corporations with educational assistance in technical, managerial, and regulatory matters, there is established within the SBA, a technology innovation education service (TIES). TIES shall stimulate the formation of regional technology innovation education centers throughout the country. These TIE centers would be nonprofit corporations affiliated with a university or consortium of universities in a particular region. The board of trustees of each TIE center would include entrepreneurs, business executives, regional government officials, and members of the scientific, technical, and professional communities in the region. Under guidelines established by TIES, each TIE center would provide a spectrum of educational assistance programs for small businesses in the region. These would include: (1) technical, management and regulatory training courses; (2) innovation workshops; (3) technology demonstrations; (4) regional information systems; (5) consulting services, and (6) aid in interpreting and implementing Government regulations which impact on innovation. TIES would provide planning and establishment grants to help launch the regional TIE centers, and subsequent grants to help them on a continuing basis. However, these subsequent grants would be in the form of matching dollars for donations the centers would obtain from locally based, larger business firms and for contracts the centers would receive from Government agencies and industrial organizations.

In addition, TIES would sponsor an educational development program, through grants and contracts with appropriate organizations, to prepare a package of training and demonstration materials and courses which TIES would make available to the TIE centers for use in their programs. It is expected that each TIE center would supplement this general package of training materials with additional materials the center would develop to meet the specific needs of its own region.

In effect, TIES and the regional centers would perform an analogous service for small business technology firms to that which the Agricultural Extension Service has so ably provided for farmers over the past century. Fifty million dollars is authorized to SBA for the first year's operation of TIES, and thereafter such sums as may be necessary.

Patent legal defender's office

There is established within SBA, a patent legal defender's office to provide legal assistance to small business technology innovation corporations in defending their patent rights against the encroachments of other firms. The office would advise the small business corporations whether their case merited litigation. If so, the office would provide legal assistance in developing the case. The office would develop guidelines to assure that such legal assistance was provided only to those firms that would have otherwise been unable to afford adequate legal assistance; $5 million is authorized to the SBA for the first year's operation of this program, and thereafter such sums as may be necessary.

Small business innovation incentives

To stimulate small business technology innovation corporations with the incentives necessary to unleash their full innovative potential, the Internal Revenue Code and SEC regulations shall be amended to provide the following:

(1) Start-up losses from small business technology innovation corporations, which would otherwise be barred, may flow through to individual funding investors for tax purposes under section 1244 of the Internal Revenue Code (thereby attracting venture capital by enabling the investors to use the corporation as a tax shelter).

(2) When a small business technology innovation corporation sells the rights to an innovation, consisting of one or more related patents and a set of associated techniques or processes for utilizing those patents, then the sale of the entire innovation package shall be taxed at only 10 percent of the net gain (thereby facilitating the diffusion of innovations throughout the economy, and providing a strong inducement to the risk taking which is so necessary to innovation).

(3) As set forth in title IV of this act, all business firms shall be entitled to accelerated depreciation (over a 3-year period) of plant, facilities, and equipment utilized in innovation. This title provides small business technology innovation corporations with the additional incentive whereby, for tax purposes, they may write off expenditures for specialized R. & D. equipment and instrumentation and for the development or purchase of patents at any time and in whatever increments they wish during the lifetime of the items (thereby encouraging greater investment in R. & D. by enabling them to write off the expense at a profitable time). However, such writeoffs shall have to be completed within 10 years of the expenditure.

(4) Employees of small business technology innovation corporations who receive stock options shall have a maximum period of 10 years in which they may exercise the options, and the qualified stock option plan for key employees is restored for these firms (thereby helping the firms in attracting and retaining high caliber personnel).

(5) Small business technology innovation corporations may carry forward their losses for tax purposes for 10-year periods, thereby giving them more time to prove their innovations out before the final reckoning of success or failure.

Title X—Innovation Adjustment Assistance

This title provides aid to communities and workers in averting or adjusting to major economic dislocations due to technological innovation. Specifically, it would provide for: (1) Foresight and planning programs to afford early warning to communities and workers of impending economic dislocations due to innovation; (2) technical assistance to communities to aid them in their planning for and coping with the adverse effects of innovation; (3) preference rights in Federal procurements for firms located in communities which have been adversely impacted by innovation; (4) worker information and retaining programs to aid them in adjusting to innovation; (5) relocation assistance for workers who are forced to move because of innovation; and (6) supplemental unemployment compensation for workers who lose their jobs because of innovation.

Office of Community Adjustment to Innovation

There shall be established within the Department of Commerce, an Office of Community Adjustment to Innovation (OCAI). This office shall be responsible for exercising foresight and providing early warning of impending innovation adjustments in various industries, regions, and communities throughout the country: Through systematic data collection, analysis, and forecasting of technological innovation trends and developments. OCAI would apprise communities which are likely to be affected and would provide them with technical assistance in planning for and coping with such contingencies, by such means as stimulating alternative sources of business activity.

In collecting data to be used in innovation forecasts, OCAI would make maximum use of available data from within the Department of Commerce and other Government agencies: In order to preclude any unnecessary increase in the data collection burden on the American public, OCAI would also be responsible for: (a) Notifying the OMB Office of Federal Procurement Policy of those communities which were suffering significant economic dislocation due to innovation, in order to trigger the procurement preference rights set forth in the succeeding section of this title; and (b) affording early warning to the Labor Department's Office of Worker Adjustment to Innovation of impending dislocations due to innovation, and providing that Office with such analytical assistance as may be necessary, to aid in the discharge of its functions as set forth subsequently in this title. OCAI is authorized $5 million for the first fiscal year, and thereafter such sums as may be necessary.

Preference rights in Federal procurements

OMB's Office of Federal Procurement Policy (OFPP) shall establish procurement guidelines by which preferential treatment in Federal procurement competitions would be accorded to firms located in communities certified by OCAI as suffering significant economic dislocations due to innovation.

Office of Worker Adjustment to Innovation

There shall be established within the Department of Labor, an Office of Worker Adjustment to Innovation (OWAI). This office shall de-

velop guidelines and administer the Department of Labor's innovation adjustment programs as set forth in the succeeding sections of this title. In discharging its functions, OWAI shall receive early warning information, data, and analytical assistance from OCAI in the Department of Commerce.

Worker education and retraining

OWAI shall make grants and provide technical assistance to labor unions to enable them to: (a) Educate their members on innovation adjustment; and (b) conduct retraining programs for those of their members who must change jobs because of innovation. In addition, OWAI shall make joint grants to labor unions and management to enable them to conduct joint retraining programs for those workers who retain their employment, but who must cope with specific innovations in work patterns, processes, or products.

Relocation assistance

Firms moving their operations to other geographic locations as a result of technological innovation shall be required (in accordance with such regulations as OWAI may prescribe) to offer relocation expenses to any employee who has been with the firm for at least 3 years and whose skills are still required at the new location.

Supplementary unemployment compensation

When a union member loses his job as a result of technological innovation (as certified by OWAI), including those cases in which he has refused a company offer to move to a new geographic location, and when he has been employed by the company for at least 3 years prior to losing his job, then he shall be entitled to supplementary unemployment compensation as follows: Until such time as he is employed again, but not to exceed a 6-month period from the time of his termination, he shall receive whatever supplementary unemployment compensation may be necessary to assure that his total unemployment compensation shall equal 95 percent of his former compensation with the firm. Whatever supplementary unemployment compensation payments may be necessary under this provision, shall be borne 50 percent by the firm which terminated him and 50 percent by the OWAI.

The Officer of Worker Adjustment to Innovation is authorized $5 million for its first year of operations, and thereafter such sums as may be necessary.

Title XI—Community Technology

This title fosters community technology programs. Specifically, it provides technical assistance and Federal matching funds to community technology cooperatives throughout the country to aid them in the acquisition, installation, and utilization of community technology systems for the benefit of participating citizens.

There is established within the Department of Energy, an Office of Community Technology (OCT) to develop the guidelines and criteria and administer the program set forth in this title.

Community Technology Cooperatives (CTC's) may be established on a nonprofit basis by citizens in any community throughout the country. Upon application, if a CTC meets the criteria established by

OCT, it shall be eligible to receive technical assistance and Federal matching funds from OCT. The matching grants would be a 3 for 1 basis, that is, with the Federal Government providing 75 percent of the total funding. The CTC could obtain the other 25 percent of its funding from local government or foundation grants, business donations, or from its own members. Members could make their contributions in the form of things of use to the cooperatives which are donated by their members or in the form of the members' "sweat equity." Members could contribute their "sweat equity" by contracting with the CTC to provide a stipulated amount of their personal labor over a suitable time period. The labor would be valued at rates set in accordance with OCT criteria and consonant with prevailing labor rates in the particular community. The contracts for "sweat equity" would be counted by OCT in establishing the basis for the Federal matching contribution. The CTC's would install and operate community technology systems for the benefit of their members. Such systems could typically be a community solar, hydroelectric, or wind generating facility; biomass energy conversion; waste recycling; gasohol production; or a closed ecological system utilizing a greenhouse, pond, and solar collectors in conjunction to provide food and energy. OCT would provide the CTC's technical information kits; and, when feasible, send staff consultants to the CTC to advise on its technical problems.

The Office of Community Technology is authorized $12 million for its first year's program, and thereafter such sums as may be necessary.

Title XII—Office of Innovation Policy

This title establishes an Office of Innovation Policy (OIP) in the Executive Office of the President to guide and coordinate the formation and implementation of the innovation policies and programs of the Federal Government.

The Director of the Office, who shall also serve as Special Assistant to the President of Innovation Policy, shall be appointed by the President (at level II of the executive schedule) with the advice and consent of the Senate. Under the guidance of OIP, the National Science Foundation and the Departments of Commerce and Labor shall collect and analyze data and trends regarding technological innovation in the United States, and in comparison with other countries, to provide a sound basis for informed policy judgments. With the assistance of the National Science Foundation and the Departments of Commerce and Labor, OIP shall prepare an annual report to the President and the Congress on Innovation in America. OIP shall coordinate the activities of Federal agencies with respect to technological innovation through the establishment of an interagency coordinating committee, chaired by the Director of OIP and including the appropriate high-level officials from the various agencies concerned.

OIP is authorized $2.5 million for its first year's operations, and thereafter such sums as may be necessary.

Title XIII—General Provisions

This title contains the necessary general provisions of the act. Included in this title are sections on: Definitions of terms; administrative provisions; and amendments to existing law.

Summary or authorizations

Number and title	*In millions*
I. National innovation policy	0
II. Basic research	$10.0
III. Human resources in science and engineering	32.5
IV. Scientific and technical equipment	15.0
V. Patent system	70.0
VI. Industry generic research	25.0
VII. Advanced technology systems	50.0
VIII. Market demand	90.0
IX. Small business technology innovation	80.0
X. Innovation adjustment assistance	10.0
XI. Community technology	12.0
XII. Office of innovation policy	2.5
XIII. General provisions	0
Total authorization	397.0

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