ENABLING THE FUTURE

LINKING SCIENCE AND TECHNOLOGY TO SOCIETAL GOALS

SEPTEMBER 1992

A Report of the

CARNEGIE COMMISSION
ON SCIENCE, TECHNOLOGY, AND GOVERNMENT

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ISBN 1-881054-02-0

Printed in the United States of America

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FOREWORD

It has been nearly a half century since Vannevar Bush provided President Franklin Roosevelt his visionary report on the future of science and technology. At the time that *Science —The Endless Frontier* was published, the Second World War, the driving force behind many scientific and engineering accomplishments, had just ended and the United States faced fundamental questions about the interactions of universities, industry, and government in furthering science and technology. In Bush's words, "The government should accept new responsibilities for promoting the flow of new scientific knowledge and the development of specific talent. . . ." Science, Bush argued, should serve society, and in turn, society should provide the financial support to assure the advancement of science, particularly basic research. Today, with the end of the Cold War and the major fiscal challenges facing our nation, we are again asking ourselves about the role of science in society.

Science is indeed an "Endless Frontier"—each advance, large or small, builds on those of the past and provides a foundation for the accomplish-

ments of the future. No one can predict the future of science. As this report points out, science is a voyage of discovery, and as Joseph Priestley wrote in the late 1700s, "in completing one discovery we never fail to get an imperfect knowledge of others of which we could have no idea before."

No one can accurately predict the future of science, but the collective ingenuity of scientists and engineers can be directed toward the challenges facing society. In a sense, science can be the vehicle that drives us to the future, but society must articulate the general direction in which it wishes to go. This report suggests some practical approaches to linking science and technology to the goals of our nation. We hope that these approaches will help catalyze an ongoing discussion among scientists, engineers, and other individuals throughout society about our long-term national goals and the ways that science and technology can contribute in achieving them.

William T. Golden, Co-Chair
Joshua Lederberg, Co-Chair

PREFACE

This report of the Carnegie Commission on Science, Technology, and Government was prepared by its Task Force on Establishing and Achieving Long-Term Goals and was adopted by the Commission at its meeting on June 30, 1992. The members of the Task Force were:

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The Task Force also wishes to thank the many individuals within and outside of the Commission who commented on drafts of this report and provided numerous thoughtful suggestions. In particular, the Task Force appreciates the encouragement of David Hamburg, President of Carnegie Corporation of New York, throughout the development and review of this report. The Task Force would like to thank the various experts who reviewed drafts of this report and offered suggestions and comments. These include Frank Press, Robert White, Kenneth Shine, Richard Barke, Daryl Chubin, Barry Gold, Lionel Johns, Stephen Merrill, and Daniel Sarewitz.

The Task Force is grateful to Jeffrey D. Porro for writing and editorial contributions, to Jane Godshalk and Pamela Kulik for administrative assistance, and to Bonnie Bisol and Maxine Rockoff for guiding the production and distribution process. Jeannette Aspden provided the group with excellent editorial assistance throughout the publication process. The Task Force would also like to acknowledge the helpful suggestions made by David Z. Robinson and Jesse H. Ausubel.

EXECUTIVE SUMMARY

> As for the Future, your task is not to foresee, but to enable it.
> —Antoine de Saint-Exupéry, *The Wisdom of the Sands*

The end of the Cold War, the rise of other economically and scientifically powerful nations, and competition in the international economy present great opportunities for the United States to address societal needs: policymakers may now focus more attention on social and economic concerns and less on potential military conflicts. In the next decade and those that follow, the United States will confront critical public policy issues that are intimately connected with advances in science and technology. Policy decision making will require the integration of numerous considerations, including accepted scientific knowledge, scientific uncertainty, and conflicting political, ethical, and economic values. Policy issues will not be resolved by citizens, scientists, business executives, or government officials working alone; addressing them effectively will require the concerted efforts of all sectors of society. As Vannevar Bush wrote in his 1945 report to the President, *Science: The Endless Frontier*:

> Science, by itself, provides no panacea for individual, social, and economic ills. It can be effective in the national welfare only as a member of a team,

> whether the conditions be peace or war. But without scientific progress no amount of achievement in other directions can insure our health, prosperity, and security as a nation.[1]

The task force recognizes that many sectors of society contribute to the setting and achievement of long-term science and technology (S&T) goals, particularly the state governments and the industrial sector. Many policy areas with which state governments have had decades of experience, such as transportation, education, and agriculture, have come to the top of the national policy agenda. Nearly every state has a science and technology policy advisor or economic development program centered on science and technology, and it is through the states that many of our national S&T policies are implemented.[2] Even though the private sector is largely influenced by shorter term economic forces, it still employs the majority of scientists and engineers in the country and performs most of the nation's R&D. As a consequence, industry plays an important role in establishing and achieving long-term S&T goals.

Furthermore, we feel that it is important to recognize the role of international cooperation and development in government decision making in S&T. As discussed in a recent report by the Carnegie Commission, the distinction between "domestic" and "foreign" goals for science and technology is obsolete in the face of the explosion of global technology, information, capital, and people. If they are to be forward-thinking, our policies must now integrate national and international views.[3]

With this consideration in mind, our report focuses primarily on the role of the federal government in establishing and achieving long-term S&T goals. It also suggests some ways in which current problems can be managed and future issues can be identified and addressed. We discuss opportunities for opening the science policy process to a broader spectrum of society by creating and institutionalizing a forum for exchanging ideas. We also present mechanisms through which society and public officials can deal with the inevitable and continuing conflicts in goal-setting.

VOYAGES OF DISCOVERY

Basic scientific research is a voyage of discovery, sometimes reaching the expected objective, but often revealing unanticipated new information that leads, in turn, to new voyages. Some might say that setting long-range goals may harm basic researchers by overcentralizing and removing flexibility from the system. Long-range S&T goal-setting certainly should not hamper, but rather encourage, this freedom to discover. Furthermore, goal-setting should be a pluralistic, decentralized process.

The federal government is largely responsible for setting major goals and broad budget priorities between and among major disciplines (for example, biology and physics). It also plays a major role in setting priorities within disciplines (for example, particle and solid state physics), and must encourage the symbiotic combinations of differing fields (for example, biology and chemistry with respect to biotechnology products).

The relationships between scientific and technological advancement and government support are complex, and the stakes in these decisions are high, not just for scientists and engineers, but for society as a whole. Consequently, a better understanding of the process of articulating goals, both within and outside science, is vital.

THE CHOICE FOR AMERICA

We believe that America faces a clear choice. For too long, our science and technology policies, apart from support of basic research, have emphasized short-term solutions while neglecting longer-term objectives. If this emphasis continues, the problems we have encountered in recent years, such as erosion of the nation's industrial competitiveness and the difficulties of meeting increasingly challenging standards of environmental quality, could overwhelm promising opportunities for progress. However, we believe there is an alternative. The United States could base its S&T policies more firmly on long-range considerations and link these policies to societal goals through more comprehensive assessment of opportunities, costs, and benefits.

We emphasize the necessity for choice because there is nothing inevitable about the shape of the future: the policy decisions we make today will determine whether historic opportunities will be seized or squandered. American science could repeat its past successes: in the past three decades, American S&T has helped eradicate diseases, reverse the pollution of many of our rivers and lakes, reach the moon, launch the computer age, and spread the Green Revolution around the world. We may be able to achieve a new age of vitality and leadership in the world community. Or the problems of recent years—such as the loss of technological and commercial advantage to other nations, or our continuing dependence on foreign energy supplies—could prove irreversible. In short, the future is limited only by our ingenuity. As Frank Press, President of the National Academy of Sciences, said recently, "Without a vision of the future, there is no basis for choosing policies for science and technology that will be appropriate for the years ahead."[4]

This report seeks ways to improve the knowledge, understanding, and information available to the federal government on the long-term na-

ture of the S&T enterprise as it relates to societal goals. As the government goes about the complex annual process of setting budget priorities and developing program plans for the S&T enterprise, it could use this knowledge, understanding, and information to ensure that both long- and short-term objectives are taken into account.

The report focuses on an interconnected set of ideas that, if implemented, would help accomplish this aim. The underlying theme of the set of recommendations is an effort to improve the capacity of the federal government to establish and achieve long-term S&T goals. At the core of our report is the recognition that there are significant efforts already under way within the federal government, but departments and agencies must be encouraged to direct more attention to long-term thinking. We describe the activities of several units of both the executive and legislative branches of government, recommend ways to strengthen their capabilities, and suggest mechanisms through which long-range, strategic planning can help federal departments and agencies fulfill their missions.

In addition to our recommendations directed to established governmental units, we have proposed the creation of a National Forum on Science and Technology Goals that would bring representatives of the science and technology community together with others from a broad set of fields who are interested in societal activities that have major S&T components. The Forum would work to identify ways in which science and technology can contribute to the definition and refinement of societal objectives and to their realization. Ultimately, it would try to articulate S&T goals, monitor efforts to achieve them, and maintain sustained support for particular objectives. The Forum would also define and develop criteria in support of dynamic goals such as the future needs of the several components of the science and technology base—basic research, generic technology, education and training, research facilities, and information dissemination, to name a few—in an effort to ensure their long-term health.

Several key considerations underlie our recommendation for a National Forum. The first is that a private forum must have long-term continuity in order to become an important contributor to federal policies. There are inherently long lead times associated not only with goals but also with the dynamics of major technological change. It is the mismatch between these realities and more immediate economic and political concerns that must be wrestled with. The second key consideration is the recognition that many organizations exist, both within and outside government, that do some long-term strategic planning. The Forum should make maximal use of these worthwhile efforts.

Furthermore, if the products of the Forum are to be useful, it must have strong linkages to the executive and legislative branches of the federal

government as well as the state governments. Finally, a balanced and effective interaction is needed between the scientific and engineering communities and those representing a broad range of other societal interests.

Our report does not address the issue of setting specific societal goals, because we believe this is primarily a political process. We do list a broad set of societal goals to indicate the general directions toward which S&T should be applied. Most of our report is devoted to the *process* of establishing S&T goals; however, we do present some examples of S&T goals for illustrative purposes.

RECOMMENDATIONS

Although this report touches on a number of goal-related themes, our recommendations focus on a few key issues: improving our national capacity to define and revise long-term S&T goals; linking S&T programs and goals more closely and clearly to broader societal goals; and building more effective linkages between governments (especially the federal government) and other sectors of society in debating, articulating, and pursuing these goals while assessing progress toward their achievement. To this end, we present a set of interconnected recommendations. We believe that each recommendation, in itself, is useful and should be implemented; however, the recommendations have been designed to support and strengthen each other and should be viewed as a whole.

In developing recommendations in this report, we sought to identify mechanisms to bring the major sectors of society—government, industry, academia, nongovernmental organizations, and the public—together to examine ways in which science and technology can be focused on achieving the nation's long-term objectives. Centralization of planning is not the answer, as the failures of command economies have demonstrated. However, we badly need a focusing of national attention and resolve. We also need to ensure that we are taking full advantage of the knowledge resulting from our national research and development efforts as we work to achieve societal objectives. Bridging the gap between research and policymaking is essential, and the assessment process is an effective bridging mechanism that must be used more frequently in the future as policymakers work to devise strategies for achieving long-range goals.

Throughout our work, we have been mindful of the great diversity of processes that help define the direction of national policy. There is no simple way to promote systematic long-term thinking about policy directions. For this reason we devote our recommendations to a variety of mecha-

nisms within and outside government to foster discussion and debate about potential long-term S&T goals and the means of achieving them.

■ **A nongovernmental National Forum on Science and Technology Goals should be established to facilitate the process of defining, debating, focusing, and articulating science and technology goals in the context of federal, national, and international goals, and to monitor the development and implementation of policies to achieve them.** The National Forum, as we envision it, would be responsible for undertaking several key activities (see Box 6 on p. 50). The Forum would convene individuals from industry, academia, nongovernmental organizations, and the interested public to explore and seek consensus on long-term S&T goals and the potential contribution of scientific and engineering advances to the achievement of societal goals.

The importance of the long-term goal-setting task is matched by the difficulty of carrying it out. For example, great diligence, fair-mindedness, and imagination would be needed to ensure that the Forum did not become either a vehicle for self-promotion by scientists and engineers or a venue for lodging grievances arising from technological change. The goal-setting process must involve individuals who have exhibited the ability to take a broad statesman-like view of complex issues.

We suggest two options for administering the Forum: the National Academies complex or a new, independent, nongovernmental organization. Regardless of the option chosen, we believe that the activities of the National Forum should be overseen by a Board of Directors responsible for selecting the members of the Forum's Council. The Council should be made up of representatives of a broad spectrum of our society who are appointed for fixed length, rotating terms. The Board should ensure that the Council is provided with the necessary institutional facilities, financial management, personnel, and other administrative backing to carry on the Forum's mission. We envision the Council as the leadership organization for the Forum.

■ **Congress should devote more explicit attention to long-term S&T goals in its budget, authorization, appropriation, and oversight procedures.** Congressional support is key to the long-term productivity of science and technology. Budget, authorization, appropriation, and oversight procedures are complex and highly decentralized, and there are opportunities to improve the ways in which Congress addresses S&T issues. We have not, however, focused too closely on these opportunities. The Committee on Science, Technology, and Congress of the Carnegie Commission will address these issues in an upcoming report.[5]

We believe that one of the most effective ways for Congress to consider S&T issues in the longer term would be for the House Committee on Science, Space, and Technology, which has responsibility for cross-cutting science policy considerations, to hold a series of hearings, on an annual or biennial basis, on long-term goals for science and technology. The purpose of these hearings would be to step back from the budget process and near-term political considerations and consider science and technology from the long-term perspective. However, we also believe that each legislative committee in the House and Senate that has jurisdiction over major segments of federal S&T activities should periodically, perhaps biennially, devote formal attention to more specific questions regarding long-term S&T goals in its area of responsibility.

Congressional committees could ask the appropriate federal agencies and a full spectrum of responsible nongovernmental interests for their views on long-term S&T goals, hold hearings, and issue reports embodying the committees' conclusions. As the proposed Forum matures and gains public confidence, the leadership of the Senate and the House of Representatives may wish to develop mechanisms to use the Forum's output throughout congressional S&T policymaking activities.

■ **In order to provide Congress with the information, analysis, and advice necessary to make policy decisions in this area, the Office of Technology Assessment and other congressional support agencies should evaluate national efforts to establish and achieve long-term science and technology goals in the context of societal goals.** The support agencies should work with congressional committees to consider what kinds of analyses of long-term S&T goals would help inform their legislative agendas. OTA, in particular, should apply its well-tested assessment process to analyzing long-term S&T goals and the procedures by which federal agencies articulate and work toward their achievement. The Congressional Budget Office (CBO), although it has limited responsibilities for S&T policy, has considerable expertise in economic analysis, which is an essential component of the goal-setting process. CBO should put its expertise to use in evaluating economic considerations with respect to long-range science and technology policy.

More specifically, we believe that CBO and OTA should establish an ongoing coordinated activity designed to combine their strengths in analyzing economics and science and technology in order to evaluate goals and budget priorities for science and technology. Furthermore, because we believe that interactive linkages are the key to solving complicated problems, we suggest that OTA, with the cooperation of the other congressional support agencies, assist congressional committees and the congressional leadership in reviewing and evaluating the products of the Forum.

■ **The Office of Science and Technology Policy (OSTP) and the Office of Management and Budget (OMB) within the Executive Office of the President should actively contribute to the establishment of federal science and technology goals and should monitor the progress of departments and agencies in attaining these goals.** Establishing long-term goals and communicating them to the federal agencies is a process that must be conducted separately from the annual budget process. With specific goals in mind, the agencies can create a budget that balances their vision of the future with the realities and constraints of the present.

OSTP and OMB should communicate long-term S&T goals to departments and agencies before the beginning of the budget cycle each year. In addition, both OSTP and OMB should work with these departments and agencies throughout their budget-planning processes to assure that long-term S&T goals are considered and advanced in their internal policy-planning activities.

OSTP should also monitor, critically evaluate, and report to the President and Congress on the progress of federal programs in achieving long-term S&T goals. In particular, OSTP should function as one liaison point between the National Forum and the Executive Branch. With OSTP leadership, the Federal Coordinating Council on Science, Engineering, and Technology (FCCSET) should extend its promising efforts in shaping long-term S&T goals involving more than one federal agency and emphasize the articulation of specific long-term goals through a more explicit planning process. Furthermore, the President's Council of Advisors for Science and Technology (PCAST) should play a more extensive role in guiding the goal-setting process within the Executive Office.

■ **Federal departments and agencies should enhance their policymaking efforts, integrating considerations of long-term science and technology goals into annual budgeting and planning efforts.** Federal agencies should enhance their strategic planning capabilities and develop explicit long-term S&T goals in the context of broader national goals established by Congress and the President. In order to do this, open communication and cooperation among the senior R&D administrators of departments and agencies should be encouraged. These individuals should meet periodically to discuss longer-term objectives and ways in which their work might contribute to or compete with broader goals and stated policies. If this approach proved effective, it could become a more formal step in the policymaking process. Furthermore, federal agencies should be required to present publicly each year an analysis of how their planned activities relate to their long-range S&T programs. Resource requirements to support the achievement of these goals should be incorporated into annual budget plans.

In addition, we recommend that federal agencies support extramural policy studies that can aid in developing and evaluating long-term S&T goals. The National Science Foundation (NSF) should develop and monitor indicators of the health and productivity of the science and technology enterprise and its contributions to societal goals. NSF should expand its competitive grants program in science and technology policymaking and work to involve scientists and engineers in the S&T goal-setting process. NSF, in conjunction with OSTP and other federal agencies, should establish continuing programs to develop the information base necessary to monitor progress in achieving long-term S&T goals. Furthermore, the National Science Board should assume greater responsibility for devising approaches to setting long-term goals with respect to the S&T base.

1
LINKING SCIENCE AND TECHNOLOGY TO SOCIETAL GOALS

LOOKING TOWARD THE FUTURE

The end of the Cold War, the rise of other economically and scientifically powerful nations, and competition in the international economy present great opportunities to address societal needs as policymakers focus more attention on social and economic concerns and less on potential military conflicts. In the next decade and those that follow, the United States will confront critical public policy issues that are intimately connected with advances in science and technology.

Knowledge resulting from basic research must be exploited to improve the efficiency and effectiveness with which applied research and technological development are directed to societal goals. Policy decision making will require the integration of numerous considerations, including accepted scientific knowledge, scientific uncertainty, and conflicting political, ethical, and economic values. Policy questions will not be resolved by citizens, scien-

tists, business executives, or government officials working alone; addressing them effectively will require the coordinated effort of all sectors of society. As President John F. Kennedy said, "Scientists alone can establish the objectives of their research, but society, in extending support for science, must take account of its own needs."

Our report focuses primarily on the role of the federal government in establishing and achieving long-term S&T goals; it also suggests some ways in which current problems can be managed and future issues can be anticipated, identified, and addressed. We look to opportunities to open up the science policy process to a broader spectrum of society through the institution of a forum for exchanging ideas. We also suggest ways in which society can deal with the inevitable and continuing conflicts in goal-setting and make reasoned judgments.

A CLEAR CHOICE

We believe that America faces a clear choice. For too long, our science and technology policies—apart, perhaps, from support of basic research—have emphasized short-term solutions while neglecting foresight and planning. If this emphasis continues, the problems we have encountered in recent years, such as erosion of the nation's industrial competitiveness and the difficulties of meeting increasingly challenging standards of environmental quality, could overwhelm promising opportunities for progress. We believe there is an alternative. The United States could base its S&T policies more firmly on long-range considerations and link these policies to societal goals through more comprehensive assessment of opportunities, costs, and benefits.

We emphasize the necessity for choice because there is nothing inevitable about the shape of the future: the policy decisions we make will determine whether the historic opportunities will be seized or squandered. American science could repeat its past successes: in the past three decades, American S&T has helped eradicate diseases, reverse the pollution of many of our rivers and lakes, reach the moon, launch the computer age, and spread the Green Revolution around the world. We may be able to achieve a new age of vitality and leadership in the world community. Or the problems of recent years—the loss of technological and commercial advantage to other nations, or our continuing dependence on foreign energy supplies—could prove irreversible. As Frank Press, President of the National Academy of Sciences, said recently, "Without a vision of the future, there is no basis for choosing policies for science and technology that will be appropriate for the years ahead."[6]

LONG-TERM S&T GOALS

Science and technology alone are seldom, if ever, sufficient to achieve societal goals, but they can play a major role when applied appropriately. The responsibility for pursuing long-term goals lies not only with the scientific and engineering communities, which must better demonstrate that their work is instrumental to the nation's goals,[7] but also with government, industry, academia, and the public, which all share an interest in the application of S&T and the achievement of societal goals. Furthermore, we recognize that even the most exciting and valuable S&T advances often have unintended consequences, and that goal-setting must be approached responsibly. We agree with the two principles that Bernadine Healy emphasized in her testimony before the Subcommittee on Science of the House Committee on Science, Space, and Technology regarding strategic planning processes:

> First, there will be no finality to the strategic planning. It must be an ongoing, living, breathing, growing process. This process must be capable of rapidly accommodating new scientific opportunity and responding to . . . emergencies. Second, the plan is not to be a rigid blueprint; rather, it will serve as a compass to guide us in our course of discovery.[8]

Finally, we believe that it is the process of articulating, refining, and achieving objectives that is the key to any success, and that without this process, goals can become rigid and outdated.

DEFINITIONS

An important first step in discussing long-term planning is agreeing on definitions. We derived a set of definitions for the purpose of clarifying some of the later discussions. Of primary importance to understanding this report, we have defined long-term goals as objectives that can be achieved over a period of 10 to 50 years or more, and near-term goals as objectives that can be achieved in less than 10 years. Priorities, on the other hand, refer to near-term resource allocations and policy objectives. Other definitions can be found in Box 1.

PAST ACCOMPLISHMENTS

A number of past accomplishments illustrate the importance of setting long-term S&T goals. In the early 1960s, President John F. Kennedy captured the minds of Americans with his famous announcement: "I believe this nation

Box 1. Definitions

In our view, **goals** are projected ends. To achieve them requires assembling and sustaining a manageable consensus on future objectives. The goal-setting process depends on focusing, sequencing, and committing resources to a vision of where we want to be some years in the future. We have defined **long-term goals** as objectives to be achieved over a period of 10 to 50 or more years, and **near-term goals** as objectives that can be achieved in less than 10 years. **Priorities**, on the other hand, refer to near-term resource allocations and policy objectives. **Budget priorities** attempt to order or position objectives within a given framework of externalities. Thus, establishing goals and assigning priorities are distinct but parallel processes. Annual or biennial budget priorities should be set in the context of relevant near-term and long-term goals.

It is useful to consider two major categories of long-term objectives: directed and dynamic.

- **Directed goals** aim to achieve particular, well-defined ends, such as mapping the human genome or executing a manned mission to Mars.
- **Dynamic goals** aim to achieve broader states or conditions that must be pursued continually or maintained once they have been achieved. Examples include optimal research facilities, an appropriate number of scientists and engineers in particular disciplines, and a viable, well-coordinated federal environmental R&D effort.

We have postulated a set of **societal goals**, those broader goals pursued for the improvement of society or some sector of society. This set includes several types of objectives:

- **International goals**, such as the worldwide eradication of smallpox, are those goals derived and pursued by a number of nations in concert.
- **National goals** are broad goals pursued mainly by one nation that derive from a domestic consensus on "what is good for the country." Securing and maintaining energy independence is an example of a possible national goal.
- **National S&T goals** are objectives of the nation's S&T enterprise; for example, the development of an operational commercial nuclear fusion reactor by the year 2040.
- **Federal goals** are more specific objectives, guided by the political process at the level of the federal government, that are established and achieved in order to attain national and international goals. An example is the goal of maintaining coal as a competitive energy source while meeting environmental, health, and safety requirements (an objective of the 1991/1992 National Energy Strategy).
- **Federal S&T goals** are objectives of federal research and development programs that are established to help attain federal goals. The demonstration of a low-CO_2-emitting coal-fired power plant by the Department of Energy is an example of a hypothetical federal S&T goal.

Finally, we have followed the recommendations of a 1988 report by the National Academy of Sciences (*Federal Science and Technology Budget Priorities: New Perspectives and Procedures*)[11] in broadly defining the **S&T base** to include not just personnel and facilities, but also the conduct of basic research and the development of generic or capability-enhancing technologies. These activities, in addition to their support of substantive areas of S&T that in turn support various societal goals, also directly advance the fundamental societal goal of increasing human knowledge and thus improving our quality of life.

should commit itself to achieving the goal, before the decade is out, of landing a man on the moon and returning him safely to earth." Largely because of the strategic political and military appeal of a contest with the Soviet Union, a societal goal that would not command the same attention in today's political and economic circumstances, an extraordinary national consensus was achieved and tremendous scientific and technological resources were marshalled to meet the challenge.

At the international level, the worldwide eradication of smallpox demonstrates how a long-term S&T goal can be established and achieved. In 1959, the Twelfth World Health Assembly resolved to pursue the goal of global smallpox eradication. In the early years, there was little progress, as natural and political problems took their toll and the difficulties of designing and maintaining coherent international programs became clear. However, in 1966 the World Health Organization committed itself fully to pursuing the final eradication of the disease. By May of 1980, the World Health Assembly was able to declare that smallpox had at last been eradicated.[9]

Long-term goals need not be limited to well-defined endpoints (directed goals) such as putting a man on the moon or eradicating smallpox, nor must the course to achieving them necessarily begin with a public pronouncement. Of special importance are the dynamic goals that aim to achieve broader states or conditions that must be pursued or maintained continually once they have been achieved. For many decades the United States has worked to build a strong and resilient academic research and engineering enterprise. From the early visions of Thomas Jefferson, to the "Endless Frontier" described by Vannevar Bush, to doubling the budget of the National Science Foundation in an effort aimed at preserving the gains of the past 200 years and assuring the future, the nation has worked to build and maintain an academic infrastructure that is second to none. Nevertheless, many feel that this infrastructure is showing signs of age and erosion. The dynamic goal remains, but because of periods of inattention, we may be farther from achieving it than we once were.

SCIENCE, TECHNOLOGY, AND SOCIETAL GOALS

It is not the purpose of this report to formulate societal goals nor to choose between them. However, we do discuss broad, general goals to which S&T can contribute. In Box 2 several such societal goals are grouped under four general headings: quality of life, health, human development, and knowledge; a resilient, sustainable, and competitive economy; environmental quality and sustainable use of natural resources; and personal, national, and international security.

Box 2. Examples of Major Societal Goals to Which Science and Technology Contribute

Quality of Life, Health, Human Development, and Knowledge

- Education and diffusion of knowledge
- Personal and public health and safety
- Personal development and self-realization
- Exploration and expansion of knowledge
- High standard of living
- Creation and maintenance of civic culture
- Cultural pluralism and community harmony
- Population stabilization

A Resilient, Sustainable, and Competitive Economy

- Economic growth
- Full employment and workforce training
- International competitiveness
- Modernized communications and transportation
- International cooperation and action

Environmental Quality and Sustainable Use of Natural Resources

- Worldwide sustainable development
- Resource exploration, extraction, conservation, and recycling
- Energy production and efficiency in use
- Environmental quality and protection
- Provisions for public recreation
- Maintenance and enhancement of productivity of the biosphere
- Maintenance of urban infrastructure
- Energy security and strategic materials

Personal, National, and International Security

- Personal security and social justice
- National and international security
- Individual freedom
- Worldwide human rights

In the past, for most of the areas of endeavor we have considered, the nation has been reasonably successful in establishing *near-term* S&T goals. However, insufficient consideration has been given to establishing *long-term* S&T goals and to linking them to societal goals in the context of changing social values and proliferating technical choices and opportunities. Yet even

when goals are established, efforts to monitor progress in achieving them are often very limited. Long-term S&T goals are needed to provide a more meaningful context for defining near-term S&T goals and for better assessing the investment strategies required for their achievement.

By linking goals more closely with societal needs, necessary trade-offs between different federal, national, international, and other S&T goals—for example, between short-term economic gain and long-term environmental damage—can be made more carefully and systematically. At present, the mechanisms for making such trade-offs are haphazard, weak, and poorly defined and are frequently inconsistent among different areas of activity. For example, recent work has identified many areas where environmental improvement enhances rather than competes with economic development.[10] Creative use of technology can present new solutions that avoid a win–lose choice among equally valid goals and minimize the negative trade-offs.

An improved process of setting long-term S&T goals and incorporating them into societal goals will allow us to maintain a balance between continuity and flexibility in our future policies. The goal-setting process should never become so rigid that it cannot be altered by an unexpected breakthrough, by disappointing results that downgrade the priority of an area, by unforeseen advances in scientific knowledge, or by a sudden change in international or domestic politics. Linking S&T and societal goals is a dynamic, iterative, interactive, and adaptive process. Societal and S&T goals influence each other, and, once defined, they must be continually evaluated to determine if modifications are necessary. Not all long-term S&T goals are necessarily deducible from societal goals. Societal goals are heavily influenced by what is technically feasible and by the identification of new societal problems and challenges through research. There must be a continuous mutual adjustment between societal and S&T goals. Progress results from the skillful matching of societal problems that need solutions with scientific advances in search of applications. Thus, goal-setting works best when bottom-up and top-down strategies are pursued simultaneously, with wisely orchestrated interactions between the two.

In the long run, our ability to work in the applied areas of science and technology is dependent on the strength and quality of our S&T base—the human resources, facilities, and institutions that form the foundation of our research and development enterprise.[11] The supply of scientists and engineers for the applications areas, and the fundamental scientific knowledge on which they build, comes from the base (Box 3 lists the major components of the S&T base). Educating and training a scientist or engineer takes decades, from elementary school to postdoctoral training.[12] Equipping each successive generation of scientists and engineers with the latest research, design, and measurement tools is demanding and time-consuming. Research

Box 3. Major Components of the Science and Technology Base

- General science and mathematics education
- Scientific literacy of the public
- Higher education in science, engineering, and the social sciences
- Human resources (scientists, engineers, and technical personnel)
- Facilities and institutions
- Basic research and development of generic technology
- Diffusion of scientific and technical information

breakthroughs do not spring forth out of nowhere but are preceded by decades of gestation and the synthesis of knowledge from many sources and technical disciplines. Microelectronics, for example, grew out of solid state physics and chemistry, and biotechnology and genetic engineering evolved from molecular biology and biotechnology.

Linking S&T goals more closely to societal goals will also help to promote a strong and resilient S&T base. Without a solid and continually evolving base, the S&T enterprise cannot fulfill its role in advancing societal goals—that is, in enabling the future. This connection can work the other way, too. Strengthening the link between the S&T base and societal interests can help the public better understand how essential many activities of the S&T base—training scientists, modernizing research facilities, funding basic research, and so forth—are to the attainment of goals such as better health care, a cleaner environment, and economic security.

The executive and legislative branches formulate policies, initiate programs, and establish priorities for government activities, and they work to establish favorable conditions for nongovernmental activities as well. Normal political processes work reasonably well in this regard. However, we believe that all sectors of society should contribute to a longer-term examination of the ways that science and technology can contribute to the achievement of societal goals. We also believe that such mutual examination may, in the long run, be essential to public support for the S&T enterprise.

2

SETTING S&T GOALS

VOYAGES OF DISCOVERY

Basic scientific research is a voyage of discovery, sometimes reaching the expected objective, but often revealing unanticipated new information that leads, in turn, to new voyages. Some might say that setting long-range goals may harm basic researchers by overcentralizing and removing flexibility from the system. Long-range S&T goal-setting certainly should not hamper, but rather encourage, this freedom to discover. Furthermore, goal-setting should be a pluralistic, decentralized process.

The federal government is responsible for setting budget priorities between and among major disciplines (for example, biology and physics). It also plays a major role in setting priorities within disciplines (for example, particle physics and solid state physics), and must encourage the symbiotic combinations of differing fields (for example, biology and chemistry with respect to biotechnology products). Conflicts sometimes arise in the attempt to balance the researcher's freedom to discover, vital national needs, and the

government's own responsibilities. A better understanding of the process of articulating goals, both within and outside science, is needed.

Goal-Setting: A Complex Task

Goal-setting for both science and technology is a complex—even daunting—task because the relationship between S&T goals and societal goals is neither self-evident nor transparent. It often requires difficult trade-offs among goals with different time horizons.

First, a balance between continuity and flexibility is essential. The S&T base must be built and nurtured over long periods of time. Sponsors must recognize the need to maintain support for fundamental research, because gaps in support for major components of the base can produce detrimental effects in later decades. At the same time, they must also be aware of the unpredictability of breakthroughs and must incorporate an element of resilience and flexibility to accommodate changes as they occur.

Second, it is reasonable for sponsors to expect results in a shorter time for directed research or development. Directed R&D is tied to specific expectations of applicability shared by practitioner and sponsor and is based upon the state of current knowledge.

Third, the amount of time required to produce usable results from each category of research and development may vary among and within fields according to the scope of the problem being addressed. For example, some energy production technologies may take as long as 50 years to achieve significant market penetration, while the dominant design of computer chips, or the market penetration of video cassette recorders, personal computers, and facsimile machines may occur in only a few years because of either improved materials or better architecture.

Fourth, the expectation of success in S&T efforts always includes an element of uncertainty. Prudent policy will often call for parallel pursuit of alternative approaches to the same goal. Finally, long-term S&T goals must be rationalized with other policy decisions, since they are intertwined with societal needs.[13]

Goals for Science, Goals for Technology

It should also be remembered that goals for science differ from goals for technology. Technological goals are usually linked to well-articulated social purposes. Scientific goals, on the other hand, are frequently multipurpose, exploratory, and primarily explanatory, contributing in multiple and often dimly anticipated ways to many different long-term societal goals. Thus,

different policy frameworks are required for science and for technology—and, indeed, for technology-driven science, as compared with science driven by knowledge itself. Yet the innumerable feedbacks and cross-fertilization between science and technology preclude sharp differentiation between them because the relationship often evolves rapidly as new knowledge appears. Hence, both the societal goal-setting and S&T goal-setting processes are highly iterative and must be continually revisited by the scientific and policymaking communities in collaboration.

THE CONTEXT OF GOAL-SETTING

This report focuses on explicit goal-setting in many contexts. Sometimes there is a widely recognized problem that demands an urgent response, such as a military threat, a widespread disease, or a perceived loss of U.S. leadership in a critical field. A recent Carnegie Commission report noted, "American commercial manufacturing leadership has eroded in many sectors—particularly the automotive, electronic, and semiconductor industries—at the same time that growth in the world technology base and the globalization of industrial activities have increased international economic interdependence."[14] Such situations require a clear articulation of national goals and more aggressive policies to relate the science and technology enterprise to them.

Long-term goal-setting efforts may also be needed when existing programs and activities are not working effectively or are proceeding in different or even conflicting directions. For example, despite more than two decades of concern, the United States still lacks a coherent energy policy, and different branches of government often seem to be working at cross-purposes. In such situations it is necessary to seek a new consensus on a common set of long-term goals toward which all parties can work cooperatively.

A third context, and perhaps the most difficult to respond to, relates to situations in which important needs or problems are clearly seen by some (for example, some part of the S&T community or a public interest group) but are not universally recognized, and there is no consensus on the seriousness of the problem or on how to address it. The current question of how to respond to predictions of global climate change may be an example of this.

THE PROCESS OF SETTING S&T GOALS

Since goal-setting is a dynamic process, we believe that policymakers must analyze, identify, articulate, and ensure support for long-term S&T goals, while remaining alert to the contingencies and surprises that may emerge

along the way toward achieving them. Long-term S&T goals have been established by various groups in the past. However, such efforts have been sporadic and inconsistent. Furthermore, goal-setting has rarely been followed up by a sufficient effort to achieve consensus in support of these goals and to monitor progress in achieving them.

Top-Down or Bottom-Up?

Policymakers must also be aware of the interrelationship between "bottom-up" and "top-down" approaches to setting goals. Basic research in most fields is largely initiated by individual scientists and engineers, with investigators setting their own agendas and seeking funds accordingly, and grantmaking or supporting institutions choosing among the requests. Much of the applied research and development, particularly that conducted by the private sector, is "top-down"—the agenda is determined by external criteria such as political, social, or economic utility. As the Organization for Economic Cooperation and Development recently concluded,

> [The] bottom-up approach has not been entirely satisfactory: while choices within a given area of science can be made on the basis of the quality of research teams or proposals, there is no 'scientific' criterion for ranking the importance of distinct fields. . . . But the top-down . . . approach has also proved impracticable, not simply because scientific progress and its applications are extremely hard to anticipate but also because the various fields of science do not advance independently of one another, and the most significant breakthroughs often occur at the interface of two or more fields. In its internal structure, science is an ever changing complex system.[15]

Stages of Goal-Setting

The process of establishing and achieving long-term S&T goals is rarely precise or orderly. At times it is opportunistic, at times reactive, and occasionally it is based on true foresight and inspiration. The desired outcome of the goal-setting process is not just the selection, definition, and articulation of a goal. It also involves the success of the entire process, including testing the goal through review mechanisms, building and maintaining a consensus of acceptance, and securing sustained support for achieving it.[16]

The process of goal-setting involves three major stages: articulation, introduction, and implementation (see Box 4). In carrying out these steps there are several fundamental considerations that deserve special emphasis as guiding principles for establishing long-term S&T goals:

Box 4. Establishing and Implementing Long-Term S&T Goals

Articulation

1. Define the problems and decide whether the establishment and articulation of long-term S&T goals would be a meaningful and constructive step in addressing them. The stakeholders and interested parties should be identified and their views on the pertinent issues given full consideration.

2. If establishment and articulation of a long-term S&T goal appears desirable, formulate the proposed goal and subject it to rigorous review to determine if it is realistic, economically feasible, and achievable. Assess the goal relative to other societal and S&T objectives and modify it if necessary.

3. Produce a statement clearly articulating the proposed long-term goal, including an explanation of the problem and why it is important, the need for actions over many years to address it, and the reasons for adopting the proposed goal and for supporting the measures needed to achieve it.

Introduction

4. Publicize and debate the proposed goal and consider modifications to strengthen it. Organize support for the proposed goal from stakeholders and others whose support is required for adoption and achievement.

5. Introduce the proposal into the pertinent approval processes of the organizations whose acceptance, approval, or support is required.

6. Support the proposal in the various review processes, with modification as necessary to secure approval.

Implementation

7. After initial approval, work to achieve and maintain support for the goal over time.

8. Create new institutions and/or change existing institutions to achieve the goal.

9. Reexamine the goal at suitable intervals for revalidation, modification, or complete revision.

- There should be a clear identification and understanding of the broader goals to which the S&T goals and activities are intended to contribute.
- Long-term S&T goals should be realistic in terms of the possibili-

ties and opportunities envisaged by the scientific and engineering communities.

- The mutually supporting functions of science and technology should be recognized: science creates new knowledge that enables new technologies, and new technologies, in turn, shape science.
- Any potential negative effects of proposed S&T goals should receive careful attention, and the necessary tradeoffs should be clearly identified (e.g., economic, social, and environmental costs and benefits, complementary non-S&T measures required, alternative ways of achieving the goals, and impacts on other goals).
- The time frame and costs required to achieve long-term goals must be defined and properly aligned with precursor near-term goals and available resources.
- Potential international implications of national S&T goals must be given full consideration.
- In order to achieve long-term goals, milestones and interim targets should be established to aid in monitoring and evaluating progress. Such a continuous process is likely to lead to periodic revision of both goals and the strategies to attain them. Without benchmarks, milestones, and explicit targets, it is very difficult to measure progress, to establish budget priorities, or to take advantage of experience.
- Finally, once long-term goals are approved, explicit provisions should be made for periodic reexamination of the goals and for modification and even abandonment of them if changed conditions warrant.

THE PLAYERS IN THE PROCESS

All major institutions in the science and technology communities—whether in federal or state government, industry, academia, or nongovernmental organizations—share the responsibility of ensuring long-term progress in their fields. Government and industry, which support research and development activities in approximately equal proportion, have particular responsibilities for strengthening the long-range vision of science and its applications and for ensuring enlightened policies and practices designed to optimize the contribution of science and technology to societal objectives. Furthermore, the U.S. S&T community shares responsibility with the S&T communities in other nations for articulating and working toward international objectives.

THE EXECUTIVE BRANCH

The executive branch, through its mission agencies, is responsible for directing the federal R&D enterprise toward broad societal objectives. However, the annual budget process dominates the policymaking process, and long-term goals receive relatively little attention. Also, potential goals that may involve several federal agencies are frequently overlooked because of the decentralization of the policy planning process.

Office of Management and Budget

Over the past thirty years, a set of coordinating mechanisms has been created within the Executive Office of the President to improve the direction of programs that cut across federal agencies. Although the primary responsibility of the Office of Management and Budget (OMB) is overseeing the annual budget process, a job that rarely results in systematic consideration of long-term, interagency concerns, OMB does participate in executive branch decisions to establish new goals or modify existing long-term ones.

Office of Science and Technology Policy

The original statute establishing the Office of Science and Technology Policy (OSTP), the National Science and Technology Policy, Organization, and Priorities Act of 1976, mandates a central role for the office in achieving national S&T goals. It states that

> the Congress declares that the United States shall adhere to a national policy for science and technology which includes. . . . The continuing development and implementation of strategies for determining and achieving the appropriate scope, level, direction and extent of scientific and technological efforts based upon a continuous appraisal of the role of science and technology in achieving goals and formulating policies of the United States and reflecting the views of State and local governments and representative public groups.[17]

OSTP was also expected to be a source of expert S&T advice close to the President and his senior staff, an institutional device to ensure expert involvement in both "science for policy" and "policy for science," and a framework for addressing S&T issues that cut across agency boundaries. OSTP has performed these several functions on a selective basis, addressing a limited menu of issues and initiatives, but it does consider some long-term goals in developing S&T policy, primarily through the activities of the Federal Coordinating Council on Science, Engineering, and Technology (FCCSET), with advice from the President's Council of Advisors for Science and Technology (PCAST). In recent years FCCSET has devoted considerable effort to ar-

ticulating certain presidential initiatives known as "Grand Challenges" and to defining the role of S&T in meeting these challenges.

CONGRESS

Congress, like the executive branch, devotes most of its institutional energy to addressing issues specific to the mission of particular agencies. The annual budget process dominates the congressional agenda; hence, attention to long-term S&T goals is relatively limited. Congress, however, has had a long-standing interest in promoting the development of science policy in the context of longer range considerations.[18]

The Budget Committees

Within the legislative structure, the budget committees play a quasi-leadership role in policy development, parallel to OMB's role for the executive branch, shaping the spending priorities of different committees into a coherent package. Their charge to set broad spending priorities and leave line-item details to other committees tends to give them a longer-range perspective and a greater awareness of issues that transcend the jurisdiction of individual committees or agencies. Furthermore, since it is the responsibility of the budget committees to examine tax and spending priorities in light of overall economic conditions, they have an analytic basis for discussing long-term policy implications. The authorization and appropriations committees occasionally articulate long-term objectives. For example, environmental laws frequently require that the federal agencies work to achieve specific goals.

Congressional Support Agencies

Congress relies on analysis and advice from the four congressional support agencies: the Office of Technology Assessment (OTA), the Congressional Research Service (CRS), the General Accounting Office (GAO), and the Congressional Budget Office (CBO).[19] These agencies have varying degrees of S&T expertise. OTA is most active in this area, devoting all of its resources to science and technology policy issues. It undertakes studies and assessments of the impacts of technology or technological programs as well as alternative management programs. OTA also highlights areas where additional research or data collection is required for better assessments.

THE STATES

The evolving role of state governments in developing, financing, and deploying science and technology has roots as far back as the mid-19th century. The 1940s debate over the role of governments in supporting science and technology drew the states even more directly into the process of S&T policymaking, as many of the societal concerns, such as agriculture, transportation, and education, that were being impacted by science and technology were considered the responsibility of state governments. Recently, many of these policy areas, with which state governments have had decades of experience, have come to the top of the national policy agenda. Nearly every state has a science and technology policy advisor or economic development program centered on science and technology, and it is through the states that many of our national S&T policies are implemented.[20] Any effort to establish long-term S&T goals should actively involve representatives of state governments.

ACADEMIA

The academic sector provides unmatched reservoirs of the talents required to suggest long-term S&T goals, analyze them, and help achieve them. At present, with tensions running high about funding and other issues, there is little cooperative effort devoted to effective goal-setting by universities, government, and other sectors. Nevertheless, one institution, the Government–University–Industry Research Roundtable (GUIRR) in the National Academies complex, has helped explore the research community's goals, roles, and responsibilities.

INDUSTRY

Industry employs the majority of scientists and engineers in the country and performs most of the national R&D. Industry, almost of necessity, takes a very short-term perspective in most of its activities. The technological goals of the private sector are strongly influenced by macroeconomic forces, ranging from tax policy to interest rates to consumer preference, as well as by other forces, such as regulation and the court system. The primary concern of individual firms is thus not long-term national S&T goal-setting, nor linking such S&T goals into the network of broader societal goals. However, industrial executives and R&D managers are an important resource that should

be tapped during the process of attempting to articulate long-term national S&T objectives.

NONGOVERNMENTAL ORGANIZATIONS

Scientists and engineers from the public as well as private sectors have formed their own organizations to facilitate direct political participation and to engage in forecasting the impacts of developments in S&T. Increasingly, these nongovernmental organizations have sought to create committees or sponsor studies on the subject of the interrelationship between science and technology and societal needs. Professional societies and trade associations like the American Institute of Aeronautics and Astronautics, the Ecological Society of America, and the Institute of Electrical and Electronic Engineers have devoted attention to long-term S&T goals in their areas of interest. Given their ties to the more active members of their professional communities, these groups are in an ideal position to evaluate research needs in the context of societal objectives and to discuss and develop long-term goals. This would bring diverse new perspectives, including those of individuals in the industrial sector, into the goal-setting process. Environmental policy-oriented nongovernmental organizations such as Resources for the Future, the World Resource Institute, and the World Wildlife Fund have established extensive networks with individuals and organizations within the public and private sectors. Groups such as these can play an important role in the process of articulating long-term S&T-related goals.[21]

The premier nongovernmental organization affecting S&T policy is the National Academies complex, which includes the National Academy of Sciences, the Institute of Medicine, the National Academy of Engineering, and the National Research Council. Most of the funding for the Academies complex is derived from governmental contracts for studies ranging from narrow technical assessments to broad policy reviews. The expert panels operating under the umbrella of the National Research Council provide a widely accepted vehicle for ascertaining the mainstream scientific consensus on technological issues and on public policy issues of high technological content.

INTERNATIONAL PLAYERS

Formally organized intergovernmental activities in science and technology, such as those sponsored by agencies of the United Nations system, have proven to be an effective mechanism for articulating and achieving certain long-term international goals. The eradication of smallpox, for instance, could

not have been accomplished without a tightly integrated, highly professional, and robustly cooperative effort in which the United States was a committed participant. Establishing and achieving this goal was facilitated by clear analysis and a durable consensus on the importance of attaining global health objectives through cooperative international efforts; the requisite expertise and resources could then be brought to bear.

3
THE NEED FOR LONG-TERM GOALS: SELECTED ILLUSTRATIONS

It is not the purpose of this report to argue in favor of any particular long-term S&T goal, but to suggest ways of improving the *process* of setting long-term S&T goals. We have identified twelve key policy areas (see Box 5), and have chosen four of these to illustrate the arguments made and concepts introduced in earlier sections; they are therefore only heuristic, and *should not be construed as specific policy recommendations.*

ENVIRONMENT AND NATURAL RESOURCES

Public interest in and support for efforts to maintain and improve environmental quality have risen steadily over the past two decades. This concern arises from societal interest in protecting public health and promoting the conservation of key ecosystems needed to sustain the productivity of the bio-

Box 5. Policy Areas That Would Benefit from the Articulation of Long-Term S&T Goals

- Environment and natural resources
- Health and social welfare
- Economic performance
- Food production and distribution
- Energy supply and utilization
- National and international security
- Basic and continuing education
- Transportation
- Public infrastructure
- Telecommunications and information management
- Exploration and expansion of knowledge
- S&T base (including facilities and personnel)

sphere for human sustenance in the future, and from the desire to enjoy the quality of life provided by contact with relatively unspoiled nature. Legislation directed at the protection of the environment and natural resources has proliferated rapidly, often expressing goals that outrun the current capacity of science and technology. At first, national objectives focused on the local environment and on the more visible forms of degradation such as smoke, visibly polluted water, and unsightly landfills. However, this concern rapidly expanded to embrace regional and eventually global environmental deterioration, as well as more subtle forms of invisible pollution that could be detected only with sensitive measuring instruments.

With the aid of increasingly sophisticated scientific and technological tools, substantial progress was made in reducing both the visible and some of the less visible forms of pollution, such as the particulate loading of the atmosphere, the contamination of food and water by pesticides, and dangerous waste sites containing toxic chemicals. Despite much progress, growth in population and economic activity continues to cause degradation of the natural resource base, including soils, water resources, fisheries, forests, and the atmosphere. Although science and technology have so far helped to minimize the depletion of reserves of mineral resources, or have led to the development of substitutes or better recycling techniques, concern remains about the future availability of so-called nonrenewable resources.

More recently, environmental issues that are truly global have risen to the top of the public policy agenda. These include stratospheric ozone depletion, the buildup of greenhouse gases, and loss of biodiversity due to the accelerated extinction of species through the destruction of their habitats. These threatened species not only enrich our cultural life, but some

of them may prove indispensible to advances in agricultural productivity, medicine, and industry.

In a world of sovereign nations, political institutions are only just beginning to struggle with environmental issues, and science is only just beginning to come to grips with the complex interactions between the economy, the environment, and the production and consumption of energy.[22] Concrete political action is frequently inhibited by scientific uncertainties and the resulting controversies over the urgency of immediate action. Some countries have worked actively to develop long-range environmental objectives and programs to achieve them. The Dutch government, for example, has devoted considerable effort to a long-range environmental policy plan.[23]

Science and technology contribute to efforts to address global environmental problems in three general ways. First, multidisciplinary research can elucidate and help to anticipate changes in the natural environment. It can do this through study of the earth's climate and hydrologic systems, biogeochemical dynamics, ecological systems and their dynamics, the earth's past history, and all the complex interactions between human activity and natural systems, including the determinants of population growth, energy demand and supply, changes in land use, and industrial production and its resource demands and residues. These are some of the objectives of the federal Global Change Research Program, a multiagency research program initiated in 1990 and coordinated by FCCSET within OSTP.

Second, progress in science is indispensable in the detection and monitoring of pollution, which, as we have indicated earlier, is less and less amenable to detection by the unaided human senses. It is also essential for quantifying and understanding the effects of environmental change on people, which in turn is essential for setting priorities for regulation and control of environmental impact. We can no longer afford to do at once everything that might be desirable or beneficial. We therefore increasingly need a more rational means of selecting priorities than the latest newspaper headline or an attention-getting environmental incident.

Third, new industrial and agricultural technologies—information technologies, biotechnologies, materials technologies, energy generation technologies and advances in end-use efficiency in the consumption of energy, transportation and communication technologies—can lead to dramatic reductions over time in the amount of environmental deterioration per unit of output of goods and other human amenities. Furthermore, reduction in environmental impact per unit of output often leads to improvement in labor and productivity as well. To permit sustainable economic growth and welfare improvement, however, requires the continual, and indeed accelerating, production of new knowledge and its rapid diffusion and application in every industrial sector and in the public infrastructure. But constant iteration be-

tween scientific findings, the social agenda, and the scientific research agenda are required to make this happen.

There are a number of successful historical examples of goal-setting in the environment and natural resources area, leading to establishment of linked S&T goals. A recent example is the goal in the Montreal protocol of total phaseout of CFCs, halons, and carbon tetrachloride production by the year 2000 in industrialized countries and by the year 2010 in developing countries. This international treaty has already resulted in aggressive action by industry worldwide to introduce economically and environmentally acceptable substitutes for CFCs. Some of the development work in industry and elsewhere has anticipated the actual formalization of targets. The task force believes that similar goal-setting is possible and desirable in other areas of environment and natural resources policy. While targets and dates have a certain amount of public appeal, which can help focus effort, they may carry an implication that, once achieved, the work has been done and efforts can thereafter be relaxed.

Scientific and professional societies can do much to establish goals for progress in their own disciplines that are tied to long-term societal goals. Some efforts have been made over the last two decades, but the goals should be clearly articulated and updated periodically to account for achievements in other disciplines.

The Ecological Society of America recently undertook an organized effort to devise ecological research goals and priorities in the context of national and international environmental objectives. According to its authors, the Sustainable Biosphere Initiative (SBI) "is intended as a call-to-arms for all ecologists, but it also will serve as a means to communicate with individuals or other disciplines with whom ecologists must join forces to address our common predicament."[24] The SBI presents a vision for the future of the ecological sciences and sets priorities for the acquisition of ecological knowledge, communication of this knowledge to the public and decision makers, and incorporation of this knowledge into policy and management decisions in government, industry, and other institutions. SBI has already met with success, moving forward from the concept stage into an active and growing project office. This initiative on the part of ecologists to think about and plan their future activities in the context of national needs and the activities of other scientific disciplines serves as a useful model for other scientific and engineering organizations.

Another forward-looking effort is under way in the federal government. The new Future Studies group within the Office of Policy Planning and Evaluation of the Environmental Protection Agency is charged with identifying and examining alternative futures of society, exploring the environmental impacts and implications of these futures, including these implica-

tions for research needs, and examining policy options for risk reduction and management for the different scenarios. Furthermore, to ensure access to a full range of perspectives, the group is seeking the views of a large number of forward-thinking experts in both the public and private sector. We feel that this program should be closely monitored as a potential model for parallel studies by other agencies.

HEALTH AND SOCIAL WELFARE

The health of the American people, as judged by life expectancy, has been improving since the turn of the century. Initial improvements in longevity primarily reflected diminished mortality from infections and were largely attributable to improvements in sanitation and nutrition and to the development of effective vaccines. Sulfonamides, penicillin, and other antibiotics contributed to a further decrease in death rates. In recent years, increases in life expectancy have resulted primarily from reductions in cardiovascular death rates from stroke and coronary artery disease. These improvements reflect control of hypertension, a decrease in the prevalence of smoking, decreases in the intake of fats and cholesterol, better weight control, and healthier lifestyles. There have also been substantial reductions in death rates from certain types of cancer, owing to improvements in surgery, radiation, and chemotherapy. Unfortunately, increases in lung cancer due to smoking have approximately canceled out the successes with other forms of cancer.

The ability to intercede successfully in an ever-increasing array of diseases results in no small part from our success in pursuing long-term national and S&T goals that are often implicit in the public support of biomedical research, which is administered primarily through the National Institutes of Health (NIH). Since the early 1950s, the NIH budget has shown steady real growth, increasing by more than 40 percent in the 1980s. Historically, this growth has been an expression of societal interest in improving personal and public health.[25] In the last decade, support for life science research has also begun to reflect national interest in U.S. economic competitiveness in the global biotechnology industry (the products of biotechnology, of course, have applications in agriculture and animal husbandry as well as in the diagnosis and cure of disease). The investment in the foundation of basic biomedical knowledge has been the key to our ability to plan systematic attacks on newly identified health problems such as AIDS.

However, despite U.S. leadership in virtually every aspect of biomedical science, its clinical applications, and the underlying basic science, there is growing dissatisfaction in the country with our inability to deliver its benefits to all our people, and with the rapid growth of the burden placed on the

U.S. economy by health care costs, a burden not borne by many other countries with which we compete in the world marketplace.

There is a mismatch between the long-term societal goals necessary for our society's well-being in the 21st century and many of the present scientific goals of the research. The implications for biomedical research of a new social goal of cost-effective and equitable health care delivery to the entire U.S. population have not yet been carefully analyzed. Undoubtedly, one implication is much more emphasis on the understanding of social and behavioral factors in health status, and the methods by which individuals can be persuaded to take a greater responsibility for their own health. Another may be intensification of the search for preventive technologies.

Recently, NIH, under its director, Bernadine Healy, has put considerable effort into developing a strategic plan for the institutes. The goal of the plan is to develop a vision that transcends immediate concerns and ensures the future strength and vigor of biomedical research. In developing its plan, NIH has been aware of the importance of flexibility, and has sought to develop a strategy that neither imposes rigid timetables nor relies on predictions about the future. Instead, it creates a framework for cohesive thinking and for successful preparation for the future. Furthermore, NIH has sought active participation of the extended biomedical community as well as the public in shaping and implementing the plan. The process is only in its early stages, but it is a bold step forward, consistent with the themes of this report.[26]

This section of our report is entitled "Health and Welfare" rather than just "Health." This is deliberately intended to suggest the intimate relationship that exists between health and social welfare, and the need for this relationship to be better incorporated into the long-range research goals that include health.

ECONOMIC PERFORMANCE

"Economic performance" covers a wide variety of important societal goals and associated policy areas. The Carnegie Commission recently released a report on the role of science and technology in enhancing economic performance.[27] Long-term goals in these areas are mostly what we have defined as the dynamic or continuing type, such as maintaining a good rate of per capita economic growth, a strong international competitive position, and employment security. Although the goals tend to be formulated in national terms, they are actually international in nature because of the growing interdependencies in the world economy. U.S. economic performance depends

to an increasing degree on the performance of the world economy, including the growth of markets in the Third World.

Economic performance goals vary widely in the degree to which S&T can be expected to contribute to their realization. The overall performance of the economy, in both the near and long term, is critically dependent on fiscal and monetary policies and on initiatives and decisions of our industry and business leaders and their foreign competitors, many of which concern the creation, acquisition, and the deployment of technology. In the words of a 1987 report for NSF by the National Governors' Association, "one area of consensus is that U.S. investments in research and education will be critical in the long-term as the United States seeks to maintain and improve its competitive position in the world economy."[28]

Goal-Setting in the Private Sector

Establishing specific directed goals in science and technology to enhance economic performance is, in the U.S. economic system, a major function of individuals and organizations in the private sector. This goal-setting necessarily takes place in the context of decisions on overall business strategy, in which the cost and prospective benefits of the S&T activities are only two of many factors. The many uncertainties in forecasting future economic, market, regulatory, and competitive positions tend to force an emphasis on near-term goals and to militate against major commitments to long-term goals (at least in the U.S., though this is much less true in Germany and Japan).

Federal S&T Goals and Economic Performance

Long-term federal S&T goals linked to national goals can make significant contributions to the nation's economic performance. For example, during World War II, significant funds were devoted to the development of radar and computational capabilities. The outcome of pursuing these goals has had a profound impact on the economy in the ensuing decades. The commitment to the advancement of aeronautical science and technology embodied in NASA's programs reflects the acceptance since the establishment of the National Advisory Council for Aeronautics (NACA) in 1915 of a national "dynamic" goal of continuous advancement of aeronautical S&T for the benefit of U.S. civil as well as military aviation. Similarly, federal support of the development of nuclear energy was designed to support the development of an important new source of energy and to promote the development of a strong and competitive nuclear industry. Most recently, there have been a number of initiatives within the federal government, most notably

the legislated Critical Technologies Institute, to identify emerging critical technologies and to support their development.

We believe that careful further study is needed to identify S&T areas of special significance for economic performance in which establishing long-term federal goals is desirable. What areas of S&T warrant the establishment of major federal undertakings comparable to those in aeronautics and nuclear energy? What should our long-term S&T goals in these areas be? Are there significant gaps in the range of generic technology programs now supported by government and private consortia? Do the existing programs need more clearly defined long-term goals?

Strengthening the U.S. Manufacturing Base

Finally, we note that one area that appears to deserve special attention is manufacturing technologies that can make U.S. industries more efficient and thus more competitive in world markets. The new high-technology industries require not only large research and development investments but also massive capital investment in plant facilities. To sustain profits, these industries must use superior process technologies and flexible manufacturing systems that involve high fixed costs and rapid innovation cycles. The U.S. manufacturing base is weaker than its foreign competitors' in the automobile, semiconductor, and consumer electronics industries, and stronger in the aerospace, computer, chemical, and pharmaceutical industries. In general, the U.S. manufacturing base requires continued strengthening through the modernization of facilities and the injection of new technologies, capital, and trained people. This is in large part ensured by the workings of the marketplace, but federal and state economic policies also have a role to play.

To strengthen the U.S. manufacturing base, long-term S&T goals—especially federal goals—must emphasize creation of generic technologies, diffusion of knowledge throughout the U.S. industrial economy, and support for basic research in universities and industry. Examples of generic or capability-enhancing technologies include computer-based tools for automated design, nondestructive test methods, software engineering tools, materials characterization and synthesis, and semiconductor manufacturing processes.

THE S&T BASE

The task force agrees with the 1988 study by the National Academy of Sciences[29] in its recognition that the maintenance of a robust, resilient S&T

base is a *sine qua non* if science and technology are to fulfill their potential for contributing to societal goals. A good deal of the knowledge needed for achieving societal goals is not acquired with these goals explicitly in mind; rather, it is the result of efforts to answer questions posed within science.

Configuration of the S&T Base

The S&T base should be configured to foster individual creativity, to permit the organization of large-scale team efforts when necessary, and to focus attention on practical applications and generic technology development as well as on basic research. Its various elements in government, universities, and industry must be linked by effective communications networks and underpinned by healthy facilities and institutions. It should also provide for continual regeneration and revitalization through a constant supply of well-trained younger scientists, engineers, and technicians. Only with such a robust, resilient S&T base can both the predictable advances and the unexpected breakthroughs in science and engineering be integrated effectively into organized efforts to achieve national and societal goals.

A fundamental question that the nation must address is the size and general composition of the S&T base that should be maintained in federal agencies, universities, nonprofit organizations, and industry. Should our goal be to maintain or expand the present base or to find the least damaging ways of contracting it to conform to probable future budget constraints? Should our goal be equalization of geographic distribution or concentration of resources in a more limited number of centers of excellence?

Science, Engineering, and Technical Personnel

Specific long-term goals are essential with respect to scientific, engineering, and technical personnel. Balancing the demographics of supply with realistic forecasts of demand is a major challenge. Recent studies indicate that the United States is lagging behind other nations in K–12 science and mathematics education. If this is allowed to continue, not only will the result be a scientifically illiterate public, but the number of young scientists and engineers entering the pipeline could be affected.[30]

Long-term S&T goals are also needed with respect to R&D facilities and institutions. For example, the absence of clearly established policies and long-term goals with respect to the maintenance and modernization of research facilities in our universities has led to a confused situation in which universities are increasingly turning to direct political action to secure funding through congressional earmarking.

BASIC SCIENCE AND GENERIC TECHNOLOGY

In the case of basic science and generic technology development, where applications to specific societal goals are not clearly foreseen, the establishment of long-term goals may not be necessary or helpful—the unfettered, curiosity-driven imaginations of scientists and engineers may best be left alone.

But long-term goals may be important in at least two situations. When specialists conclude that significantly greater progress can be made through the coordinated efforts of many scientists, a clear articulation of the long-term goals towards which all should work may be crucial. The human genome project may be an example. Establishment of long-term goals in basic science may also be necessary in fields where research facilities are limited or very costly; planetary exploration and high energy physics are examples. If the long-term S&T goal is only to increase knowledge, goal-setting may be left to the scientific and technical specialists. However, if other S&T or national goals become significant factors, a broader community must be involved in the process.

THE ROLE OF A NATIONAL FORUM

We have presented these case studies merely to illustrate the kinds of issues that a National Forum on Science and Technology Goals could address; they are neither recommendations nor examples of the products of a Forum process. As these four illustrations suggest, the policymaking process would benefit greatly from a broader discussion of future directions for science and technology and a clear articulation of long-term goals and the resources required to achieve them.

4
RECOMMENDATIONS

While this report touches on a number of goal-related themes, our recommendations will focus on several key issues: improving our national capacity to define and revise long-term S&T goals, linking S&T programs and goals more closely and clearly to broader societal goals, and building more effective linkages between governments (especially the federal government) and other sectors of society in debating, articulating, and pursuing these goals while assessing progress toward their achievement. To this end, we have put forth a set of interconnected recommendations. We believe that each recommendation, in itself, is useful and should be implemented; however, the set of recommendations should be viewed as a whole, as they have been designed to support and strengthen each other.

In developing our recommendations, we have sought to identify mechanisms to bring the major sectors of society—government, industry, academia, nongovernmental organizations, and the public—together to examine ways in which science and technology can be focused on achieving the nation's

long-term objectives. Centralization of planning is not the answer, as the failures of the command economies have demonstrated. However, we badly need a focusing of national attention and resolve.

Throughout our work, we have been mindful of the great diversity of processes that help define the direction of national policy. There is no simple way to promote systematic long-term thinking about policy directions. For this reason we devote our recommendations to a variety of mechanisms within and outside government to foster discussion and debate of potential long-term goals and the means of achieving them. Within the federal government, we propose mechanisms for institutionalizing long-term S&T goal-setting as an inherent part of the congressional and executive branch S&T policymaking processes. Outside government, a common theme of our recommendations is the involvement of all sectors of society and the citizenry in an ongoing dialogue on future directions for science and technology in the context of societal needs and aspirations. We believe that the National Forum on Science and Technology Goals, as described below, would be a useful mechanism for achieving consensus among various sectors of society on future directions for science and technology.

NATIONAL FORUM ON SCIENCE AND TECHNOLOGY GOALS

▪ **A nongovernmental National Forum on Science and Technology Goals should be established to facilitate the process of defining, debating, focusing, and articulating science and technology goals in the context of federal, national, and international goals, and to monitor the development and implementation of policies to achieve them.** The National Forum, as we envision it, would be responsible for undertaking several key activities (see Box 6). The Forum would convene individuals from industry, academia, nongovernmental organizations, and the interested public to explore and seek consensus on long-term S&T goals and the potential contribution of scientific and engineering advances to societal goals.

Because of the difficulties of defining societal goals, it may be desirable to consider a preliminary function for the Forum to be the identification and assessment of the explicit and implicit long-range objectives and goals of federal research and development as revealed by annual budgets. This would show which R&D efforts lack clear long-range objectives and which are based on faulty assumptions; it would point out specific requirements for long-term goal-setting in order to resolve ambiguities and provide better direction.

We further believe that the Forum should focus its attention ini-

Box 6. Key Activities of a Proposed National Forum on Science and Technology Goals

- Assemble a broad-based and diverse group of individuals who are both critical and innovative, and who can examine societal goals and the ways in which science and technology can best contribute to their achievement.
- Conduct or sponsor discussions with individuals representing a diversity of perspectives on future directions for our nation and the role of science and technology in meeting alternative societal goals. Conduct or sponsor analytic and background studies. Consider the tradeoffs involved in working toward particular goals, including competition for funds and personnel, and the possibility of negative impacts on other goals.
- Articulate and propose specific long-term S&T goals in both national and international contexts, and identify milestones in achieving them.
- Encourage efforts by the media to improve public understanding of and participation in the process of establishing S&T goals.
- Identify and evaluate promising breakthroughs in basic research and new technologies to ensure that they are taken into full account in the formulation of societal and S&T goals.
- Communicate the products of the Forum's work to those who directly influence the direction of science and technology policy, including the executive and legislative branches of the federal government, key officials in all state governments, and key executives and research directors in industry and universities.
- Monitor and report on progress and problems in achieving long-range S&T goals and on the contributions of S&T to societal goals.
- Periodically examine S&T goals in the context of new developments in science and technology or changing social, economic, or political concerns.

tially on goals in two or three policy areas (taking into account the health of the S&T base in achieving these goals). We recognize that certain topics, particularly those dealing with issues of national and international security, do not lend themselves easily to an open forum process. Fortunately, there are already mechanisms in place that focus on long-term issues in the security area. The Forum will be able to consider some of these issues and work with appropriate organizations to bring the benefit of a forum process to the defense R&D policy area.

It would be essential for the Forum, as we envision it, to have numerous links to the federal government, links designed to enhance com-

munication without placing the Forum within the official hierarchy. This would put the Forum in an ideal position to critique the budgets of departments and agencies periodically, perhaps annually, focusing on the extent to which they consider long-term goals and act to advance them. Another objective of the Forum would be to define and develop criteria in support of dynamic goals such as the future needs of the several components of the science and technology base—basic research, education and training, and information dissemination, to name a few—in an effort to ensure their long-term health. This is especially important because the S&T base is the foundation of future scientific and engineering advances.

The importance of the long-term goal-setting task is matched by the difficulty of carrying it out. For example, great diligence, fair-mindedness, and imagination would be needed to ensure that the Forum did not become either a vehicle for self-promotion by scientists and engineers or a venue for lodging grievances arising from technological change. Many institutions could contribute directly to the Forum's activities. The National Academies complex, the congressional Office of Technology Assessment, the White House Office of Science and Technology Policy, and the Smithsonian Institution (because of its extensive activities pertaining to the public understanding of S&T issues) are among the specialized organizations that are clearly central to the long-term S&T planning process. No single agency has all the characteristics and capabilities required. Moreover, regardless of the final form or location of the Forum, it will require congressional and executive support. We have considered two possible approaches to organizing a National Forum.

Option 1. The National Academies complex may be the best place to establish and administer a National Forum, with the active participation of many other organizations. The Academies complex (including the National Academy of Sciences, the National Academy of Engineering, the Institute of Medicine, and the National Research Council) has a well-respected network of science and technology leaders from academia, industry, and government, proven support staff and operational capabilities, and an ability to obtain and combine satisfactorily both public and private funding.

One of the great advantages of the Academies complex is that it is an existing organization with many of the needed assets—administration, staff, and committee panel structure—already in place. Furthermore, the Academies complex has often played the type of catalyzing role envisioned here. A four-year pilot operation might be conducted to determine the feasibility of the forum concept; this would provide the experience for designing an alternative organization if a different structure proved to be desirable. A possible disadvantage of using the Academies complex is its image as an S&T-focused organization with weak links to the non-S&T communities con-

cerned with national goals, although it has frequently engaged individuals from those communities in carrying out its studies.

Option 2. An alternative would require establishing *de novo* an independent, nongovernmental organization. A new nongovernmental organization would have the benefit (as well as the shortcoming) of operating independently of an existing institution and could be custom-designed to carry out the functions of the Forum. This arrangement would require developing new administrative and program staffing capabilities, which would be more difficult than building on those of an existing organization. As with the first option, a four-year pilot program might be appropriate.

Deciding where to site the National Forum requires a judgment about where, among a number of likely organizations outside government, three critical requirements appear most robust: (a) deep and well-tested analytical resources, (b) ability to get and hold government's attention, and (c) demonstrable capacity for integrated scientific, technological, and environmental assessment.

Given these demanding requirements, we are strongly drawn to siting the Forum process within the National Academy of Sciences complex. Moreover, we prefer the Academy because it has demonstrated, in recent years, striking flexibility and initiative in its organization and process. Among such initiatives, four are notably related to the long-range goals agenda: the Government–University–Industry Research Roundtable; the Committee on Science, Engineering, and Public Policy; the Mathematical Sciences Education Board; and the Board on Science, Technology, and Economic Policy. In sum, the Academies complex brings together strong research and analytic capacity with responsible quality control practices plus the institutional accountability deriving from the special governmental relationship stipulated in its 1863 congressional charter. This convergence of organizational assets appears well-suited to the difficult and complex task of tackling long-range goals.

Although we believe that the Academies complex is best suited to organize and launch the Forum process, we do not have in mind a closed enterprise; nor, we are certain, would the Academies leadership put their organization in such a position. There should be in a workable Forum "system" much sharing of roles and functions with responsive institutional partners—for example, with an entity such as the National Science Board from time to time, or with a cluster of policy studies centers located in university settings, as well as with nongovernmental organizations with substantial and contrasting informational and advocacy strengths and different perspectives.

Regardless of the organizational option chosen, we expect that funding

for the Forum would eventually originate from a variety of public and private sources. Furthermore, the activities of the National Forum should be overseen by a Board of Directors. In the case of option 1, the Board might include the Presidents of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine, and other national leaders in the public policy arena. In the case of option 2, the Board of Directors might include the President of the National Academy of Sciences, the Director of the White House Office of Science and Technology Policy, a representative of Congress chosen by the congressional leadership (for example, the Director of the Office of Technology Assessment), and the Secretary of the Smithsonian Institution.

In either case, the Board of Directors would be responsible for selecting the members of the Forum's Council, a group made up of representatives of a broad spectrum of our society appointed for fixed-length, rotating terms. The Board should ensure that the Council is provided with the necessary institutional facilities, financial management, personnel, and other administrative backing to carry out the Forum's mission. We envision the Council as the leadership organization for the Forum. The Council should meet regularly with the Board to report on its activities and to seek advice on future activities. In addition, the Council should take full advantage of such National Research Council groups as the Government–University–Industry Research Roundtable, the new Board on Science, Technology, and Economic Policy, and the several international boards and committees that operate through NRC sponsorship.

If the activities of the Forum are to be worthwhile, its products must be welcomed and used by senior officials in the executive and legislative branches of the federal government. To this end, it would be desirable to establish ties directly with offices that would act as focal points for receiving, requesting, and responding to the products of the Forum. In the executive branch, we feel that OSTP and OMB should serve as focal points in the Executive Office of the President. The Forum should also maintain close contact with individual executive branch agencies responsible for particular policy issues.

In the legislative branch, we feel that the congressional committees with major S&T responsibilities, such as the House Committee on Science, Space, and Technology, the House Committee on Energy and Commerce, and the Senate Committee on Commerce, Science, and Transportation, would be the appropriate focal points. Ties with the budget committee and key appropriations committees are also very important. The congressional support agencies, OTA in particular, should also play a direct role by undertaking analyses, at the request of congressional committees, of the issues and advice that the Forum generates.

It would be highly desirable if, early in a new administration, the Assistant to the President for Science and Technology and the leadership of Congress or the chairmen of key committees requested that the Forum undertake its activities. Alternatively, Congress could request or "authorize" the Forum's activities through a concurrent resolution, a nonbinding indication of the opinion of Congress. In this way, the Forum would operate on a four-year cycle, with a continuation of activities being contingent on future requests or "authorizations" from the executive and legislative branches of government. Recognition of this kind would help assure the utility of the Forum's products.

We believe that initial funding for the Forum should be sought primarily, although not exclusively, from private foundations. Once the Forum process has proven itself, activities might be funded jointly by the federal government and private foundations.

ROLE OF CONGRESS

■ **Congress should devote more explicit attention to long-term S&T goals in its budget, authorization, appropriation, and oversight procedures.** Congressional support is key to the long-term productivity of science and technology. Budget, authorization, appropriation, and oversight procedures are complex and highly decentralized, and there are opportunities to improve the ways in which Congress addresses S&T issues. We have not, however, focused too closely on these opportunities. The Committee on Science, Technology, and Congress of the Carnegie Commission will address these issues in an upcoming report.[31]

We believe that one of the most effective ways for Congress to consider S&T issues in the longer term would be for the House Committee on Science, Space, and Technology, which has responsibility for cross-cutting science policy considerations, to hold a series of hearings, on an annual or biennial basis, on long-term goals for science and technology. The purpose of these hearings would be to step back from the budget process and consider science and technology from the long-term perspective. However, we also believe that each legislative committee in the House and Senate with jurisdiction over major segments of federal S&T activities should periodically, perhaps biennially, devote formal attention to questions of long-term S&T goals in its area of responsibility.

Congressional committees could ask the appropriate federal agencies and a full spectrum of responsible nongovernmental interests, including the proposed National Forum on Science and Technology Goals, for their views

on long-term S&T goals. They could also hold hearings, and issue reports embodying the committees' conclusions. Specifically, as the proposed Forum matures and gains public confidence, the committees with significant responsibility in S&T areas could serve as focal points for communication with the Forum in the legislative branch.

These committees, along with leadership of the Senate and the House of Representatives and supported analytically by OTA and the other support agencies, may wish to develop mechanisms to use the Forum's output throughout congressional S&T policymaking activities. This might include ensuring that long-term goals as articulated by the Forum and other groups are considered as the various congressional committees plan their hearings and legislative agendas, and ensuring that critical science and technology issues are taken into account when the leadership determines the legislative agenda for each session of Congress.

ROLE OF THE CONGRESSIONAL SUPPORT AGENCIES

■ **In order to provide Congress with the information, analysis, and advice necessary to make policy decisions in this area, the Office of Technology Assessment and other congressional support agencies should evaluate national efforts to establish and achieve long-term science and technology goals in the context of societal goals.** The support agencies should work with congressional committees to consider what kinds of analyses of long-term S&T goals would help inform their legislative agendas. OTA, in particular, should apply its well-tested assessment process to the task of undertaking analyses, convening expert panels, and monitoring progress in the establishment and achievement of long-term S&T goals. The Congressional Budget Office (CBO), although it has limited responsibilities for S&T policy, has considerable expertise in economic analysis, which is an essential part of establishing and achieving long-term S&T goals. CBO should put its expertise to use in evaluating economic considerations with respect to long-range science and technology policy.[32]

More specifically, we believe that CBO and OTA should establish an ongoing coordinated activity designed to combine their strengths in analyzing economics and science and technology, respectively, in order to evaluate goals and budget priorities for science and technology. Furthermore, because we believe that interactive linkages are the key to solving complicated problems, we suggest that OTA, with the cooperation of the other congressional support agencies, assist congressional committees and the congressional leadership in reviewing and analyzing the products of the Forum.

ROLE OF OSTP AND OMB

■ **The Office of Science and Technology Policy and the Office of Management and Budget within the Executive Office of the President should actively contribute to the establishment of federal science and technology goals and should monitor the progress of departments and agencies in attaining these goals.** Establishing long-term goals and communicating them to the federal agencies is a process that must be conducted separately from the annual budget process. With a goal in mind, the agencies can create a budget that balances their vision of the future with the realities and constraints of the present.

OSTP and OMB should communicate long-term S&T goals to departments and agencies before the beginning of the budget cycle each year. In addition, both OSTP and OMB should work with these departments and agencies throughout their budget planning processes to assure that long-term S&T goals are considered and advanced in their internal policy-planning activities.

OSTP should also monitor the progress of federal programs in achieving long-term S&T goals and report its findings to the President and Congress. In particular, OSTP should function as one liaison point between the National Forum and the Executive Branch. With OSTP leadership, the Federal Coordinating Council on Science, Engineering, and Technology (FCCSET) should extend its promising efforts in shaping long-term S&T goals involving more than one federal agency. Furthermore, the President's Council of Advisors for Science and Technology (PCAST) should play a more extensive role in guiding the goal-setting process within the Executive Office.

Efforts to monitor the success of government programs can be greatly aided by the establishment of specific goals. Legislation is pending in Congress that would require federal departments and agencies to establish a "performance standards and goals plan" for major budget expenditure categories. A key element of these plans would be performance indicators that could be used to track progress in achieving goals.[33]

ROLE OF THE FEDERAL DEPARTMENTS AND AGENCIES

■ **Federal departments and agencies should enhance their policymaking efforts, integrating considerations of long-term science and technology goals into annual budgeting and planning efforts.** Federal agencies should enhance their strategic planning capabilities and develop explicit long-term S&T goals in the context of broader national goals established by Congress and the President. In order to do this, open communication and coopera-

tion among the senior R&D administrators of departments and agencies should be encouraged. These individuals should meet periodically to discuss longer-term objectives and ways in which their work might contribute to or compete with broader goals and stated policies. Furthermore, federal agencies should be required to present publicly each year an analysis of how their planned activities relate to their long-range S&T programs. Resources to support the achievement of these goals should be incorporated into annual budget plans.

In addition, we recommend that federal agencies support extramural policy studies that can aid in developing and evaluating long-term S&T goals. The National Science Foundation (NSF) should develop and monitor indicators of the health and productivity of the science and technology enterprise and its contributions to societal goals. NSF should expand its competitive grants program in science and technology policymaking and work to involve scientists and engineers in the S&T goal-setting process. NSF, in conjunction with OSTP and other federal agencies, should establish continuing programs to develop the information base necessary to monitor progress in achieving long-term S&T goals. Furthermore, the National Science Board should assume greater responsibility for devising approaches to long-term goal-setting with respect to the S&T base. We note that the National Science Board has the authority to establish special commissions and committees to focus on specific policy questions.[34] The Board could periodically convene such panels to examine, for example, the long-term directions of certain scientific disciplines.

5
GOAL-SETTING, S&T, AND SOCIETY: A LOOK AT THE FUTURE

At the beginning of this report we said that America faces a choice between business-as-usual in science and technology policy and a new approach that would place more emphasis on long-term S&T goals and on clarifying the linkages between the S&T enterprise and societal goals. We believe that this choice is especially critical because of the historic opportunities our nation has been presented with, both by the end of the Cold War and by the dramatic developments in U.S. technology that could, if properly managed, revolutionize so many aspects of our society.

MAKING BETTER CHOICES

We believe that implementation of our recommendations will help America make better choices and move toward a new age of vitality and leadership

in the world community. We are well aware that even if these recommendations are adopted, success will not come easily. The United States faces a host of pressing issues tied to science and technology. Some relate to our domestic economic performance and to international competitiveness: How can the nation modernize its industrial infrastructure? Can and should we maintain the strong position we hold in certain key high-technology industries and also reclaim a strong position in others? Some issues have come to the fore because of the end of the Cold War: How can funds for defense R&D be shifted to civilian R&D? Can some of the weapons-related R&D activities of the Department of Energy's national laboratories be shifted to support other priorities, such as environmental technology development?

Still other pressing issues, which have received less public attention, concern the S&T base: How can we improve math and science instruction in our schools? Are we producing the right mix of scientists and engineers? How can we replace aging research facilities?

Other issues have been developing slowly but are becoming more urgent: balancing environmental concerns with the search for cheaper energy, controlling the costs of high-technology medicine, dealing with global climate change, confronting the telecommunications revolution. Too often in the past the goal-setting process seemed to stop once a goal had been agreed upon. The result has been that competing short-term political and economic interests have sidetracked or distorted agreed-upon objectives. Effective goal-setting requires that policymakers continue to work to achieve and maintain support for a goal over time, monitoring developments to ensure that progress continues toward the goal.

PERSISTENT CHALLENGES

While the recommendations made here should help the United States seize a historic opportunity and deal with pressing issues, they will not solve all of our science and technology policymaking problems. In particular, we see three areas that will present persistent challenges.

COMPETITION FOR FEDERAL FUNDS

The first challenge grows out of the continuing competition for federal funds for S&T. Because of this competition, we can expect that scientists within specific disciplines will contend with each other for resources and that they will appeal to long-range societal needs to win greater funding. Consider

biology, for example. Supporters of the human genome project believe that sequencing the human genome will serve key societal goals related to quality of life, health, human development, and knowledge. In particular, they feel that the sequence would create a complete library of information that biologists could search as they strive to understand human gene expression; and the sequenced genome would enable researchers to understand the mechanisms underlying genetic diseases, eventually allowing the development of therapies to treat them. Other biologists appeal to similar societal goals, but argue that sequencing the human genome would take resources from other research activities. Some argue that human health and well-being would be better served by devoting more resources to understanding fundamental developmental biological processes, or to cataloguing biodiversity, or to more research on epidemic diseases, especially AIDS or cancer. This kind of debate is sure to recur elsewhere.

There will be similar conflicts between the sciences, with each side appealing to a societal goal, often the same goal, in an effort to secure scarce resources. For example, recapturing America's economic leadership is a goal most Americans would agree is especially important. Biologists have argued that biotechnology is one key to restoring American competitiveness. It is clearly a growing field and one in which the United States is a leader. Physicists and electrical engineers, on the other hand, argue that the United States should not overlook superconductivity, another highly promising area. Unless government and industry devote resources to developing this field, it is argued, we may lose out once again to foreign competitors. Clearly, different scientific disciplines may have equally valid claims on a particular societal goal, while having to compete for limited resources.

Choosing between Goals

The second area where problems are sure to persist involves choosing between goals. While this is outside the scope of this report, it is clear that in order to achieve long-term S&T goals the public and their elected representatives will have to decide which societal goals are most important. Sometimes science and technology policy can help society only if the public is willing to make a tough choice, supporting one goal over another. Some political observers have argued that Americans have in recent years become unwilling to make these kinds of choices. They trace the deadlock over the federal budget, for example, to the public's desire to have lower taxes *and* larger entitlement programs. An unwillingness to choose between societal goals will clearly make it difficult to choose between long-range S&T goals that are linked to societal aspirations.

PUBLIC ENTHUSIASMS

The third area of continuing problems is the sudden swing in public enthusiasm for specific goals. For example, the oil shortages of the 1970s placed energy efficiency and alternative fuels high on the list of societal goals. Resources flowed into solar power, oil shale, geothermal energy, and other alternative energy sources. But public concern declined rapidly during the 1980s, and resources for alternative fuels began to shrink. Sudden swings of enthusiasm and commitment make it difficult for S&T to support national objectives effectively.

A SHARED BURDEN

All major institutions in the science and technology communities share the burden of ensuring long-term progress in their fields, and they should work together to achieve broad societal objectives. As Albert Einstein said, "the concern for man and his destiny must always be the chief interest of all technical effort: Never forget it among your diagrams and equations."[35] In our report, we have sought to highlight the importance of linking the "diagrams and equations" developed by scientists and engineers more closely with the aspirations of the public for health, prosperity, and security in an effort to help our nation enable its own future.

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13. Richard Brandon, "Establishing Operational Processes for Long-Term S&T Goals: Inserting Vision in an Ecology of Games," a background paper for the Task Force on Establishing and Achieving Long-Term S&T Goals, Carnegie Commission on Science, Technology, and Government (March 1991).

14. Carnegie Commission on Science, Technology, and Government, *Technology and Economic Performance: Organizing the Executive Branch for a Stronger National Technology Base* (September 1991), p. 6.

15. Organization for Economic Co-operation and Development, *Choosing Priorities in Science and Technology* (Paris, 1991), p. 7.

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18. See, for example, Jurgen Schmandt, "The Five Year Outlook as a Policy Document: Historical and Comparative Perspectives," *Technological Forecasting and Social Change* 20, 113–138 (1981).

19. For an expanded discussion of the role of the Congressional support agencies, see Carnegie Commission on Science, Technology, and Government, *Science, Technology, and Congress: Analysis and Advice from the Congressional Support Agencies* (October 1991).

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25. Indeed, there is some evidence that the public believes that improving health should be S&T's top priority. A 1981 pilot study by Daniel Yankelovich of focus groups of "average" citizens yielded the following hypotheses for further analysis: "From the public's perspective, a contribution to human health is the highest value science can serve." John Doble and Daniel Yankelovich, "Science Policy Priorities and the Public," prepared for the project Assessment of Science: Development and Testing of Indicators of Quality, Harvard University Subcontract No. SRS-80-07378, by the Public Agenda Foundation (1981), pp. 6, 29.

26. Bernadine Healy, "NIH Strategic Planning: A Window on the Future," address presented at the 1992 AAAS Science and Technology Policy Colloquium, April 17, 1992.

27. Carnegie Commission on Science, Technology, and Government, *Technology and Economic Performance: Organizing the Executive Branch for a Stronger National Technology Base* (September 1991).

28. The National Governors' Association, *The Role of Science and Technology in Economic Competitiveness* (September 1987), p. 6.

29. National Research Council, *Federal Science and Technology Budget Priorities: New Perspectives and Procedures* (National Academy Press: Washington, D.C., 1988).

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Government, *In The National Interest: The Federal Government in the Reform of K–12 Math and Science Education* (September 1991).

31. The Carnegie Commission expects to publish the third report of its Committee on Science, Technology, and Congress in the spring of 1993.

32. For a broader consideration of the role of the congressional support agencies in S&T policy, see the Carnegie Commission on Science, Technology, and Government, *Science, Technology, and Congress: Analysis and Advice from the Congressional Support Agencies* (October 1991).

33. The proposed Federal Program Performance Standards and Goals Act of 1991 (S.20) was introduced by Senator Roth in the 102nd Congress.

34. For a specific explanation of the role envisioned for the National Science Foundation and the National Science Board in particular, see "National Science Foundation: Statutory Authority," a pamphlet prepared for reference (February 1989).

35. Rodney Nichols, "Our Academies are Responsible to Society as Well as to Science," Commentary in *The Scientist*, July 6, 1992, p. 12.

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ISBN 1-881054-02-0