CHAPTER FOUR

CONCLUSIONS AND RECOMMENDATIONS

Federally funded science and technology support the missions of every Federal department and agency and have enormous long-term impacts on the economy and the quality of life of American citizens. The growth in the national and global science and technology enterprise, the opportunities for discovery and innovation, and the changing Federal role in U.S. science and technology require the Federal Government to direct greater attention to ensuring its investments in research produce the greatest benefits over the long term to the public.

A deliberate, scientifically grounded process is essential for identifying opportunities and needs for Federal research. Needs include human resources, instrumentation and facilities, alignment of the portfolio of Federal investments with national priorities for research, effective distribution of funding among research modes and performing organizations, closure of gaps in research resulting from changes in department and agency programs, and addressing patterns of under-investment in vital areas of fundamental research.

The Board finds that mechanisms that have evolved based on the legislation that established OSTP and on the cooperation between OSTP and OMB represent valuable progress toward a more coherent and sophisticated system to inform major decisions on Federal research investments. The OMB/OSTP/PCAST must be provided with additional resources to expand activities for managing Federal S&T as a portfolio, especially for ongoing evaluation of the effectiveness of Federal investments in achieving Federal goals for research. Additional complementary resources to provide timely expert advice, analyses and data to inform congressional budget allocation decisions are also needed.

KEYSTONE RECOMMENDATION 1

The Federal Government, including the White House, Federal departments and agencies, and the Congress should cooperate in developing and supporting a more productive process for allocating and coordinating Federal research funding. The process must place a priority on investments in areas that advance important national goals, identify areas ready to benefit from greater investment, address long-term needs and opportunities for Federal missions and responsibilities, and ensure world class fundamental science and engineering capabilities across the frontiers of knowledge. It should incorporate input from the Federal departments and agencies, advisory mechanisms of the National Academies, scientific community organizations representing all sectors, and a global perspective on opportunities and needs for U.S. science and technology.

RESEARCH COMMUNITY INPUT ON NEEDS AND OPPORTUNITIES:

Steps can be taken in the short term to improve the information base for Federal research investments. A primary input to any process of priority setting for research is expert scientific advice on current and long-term opportunities and needs for research. Presently there is no widely accepted and broadly applied way for the Federal Government to obtain systematic input from the science and engineering communities for making priority decisions about support for research and research infrastructure.

There is insufficient opportunity and capability within the framework of existing mechanisms for Federal research priority setting to undertake timely and broad-based assessments of the needs for Federal investments. A more effective system for managing the Federal research portfolio requires adequate funding, staffing and organizational continuity.

RECOMMENDATION 2

A process should be implemented that identifies priority needs and opportunities for research—encompassing all major areas of science and engineering—to inform Federal budget decisions. The process should include an evaluation of the current Federal portfolio for research in light of national goals, and draw on: systematic, independent expert advice from the external scientific communities; studies of the costs and benefits of research investments; and analyses of available data; and should include S&T priorities, advice, and analyses from Federal departments and

agencies. The priorities identified would inform OMB in developing its guidance to Federal departments and agencies for the President's budget submission, and the Congress in the budget development and appropriations processes.

EXECUTIVE BRANCH ADVISORY MECHANISM:

The Executive Branch should implement a more robust advisory mechanism, expanding on and enhancing current White House mechanisms for S&T budget coordination and priority setting in OSTP and OMB. Enhanced resources should include an adequate professional staff, perhaps on a rotating basis modeled on the Council of Economic Advisors. It is particularly essential that the advisory mechanism include participants who are experienced in making choices among excellent opportunities or needs for research. (For example, vice provosts for research in universities, active researchers with breadth of vision, and managers of major industrial research programs would be appropriate in this role.)

Evaluation criteria should reflect Federal goals for science and technology funding. The evaluation should consider the effectiveness of the broad portfolio of Federal support to science and technology for:

- sustaining and enhancing U.S. world leadership across the frontiers of knowledge;

- assuring the long-term vitality of the U.S. science and technology enterprise by investments in important areas and activities unlikely to be funded by other sectors;

- aligning human resources for science and technology with needs of the S&T workforce in the Federal and other sectors;

- serving Federal departmental and agency missions;

and should identify:

- a well-defined set of top research priorities where enhanced Federal investments could yield high payoffs to society; and

- potential tradeoffs to provide greater funding for priority activities.

RECOMMENDATION 2A

An Executive Branch process for ongoing evaluation of outcomes of the Federal portfolio for research in light of Federal goals for S&T should be implemented on a five-year cycle.[14]   A report to the President and Congress should be prepared including a well-defined set of the highest long-term priorities for Federal research investments.   These priorities should include new national initiatives, unique and paradigm shifting instrumentation and facilities, unintended and unanticipated shifts in support among areas of research resulting in gaps in support to important research domains, and emerging fields. The report should also include potential trade-offs to provide greater funding for priority activities. The report should be updated on an annual basis as part of the budget process, and should employ the best available data and analyses as well as expert input. Resources available to OSTP, OMB and PCAST should be bolstered to support this function.

CONGRESSIONAL ADVISORY MECHANISM:

There is no coherent congressional mechanism for considering allocation decisions for research within the framework of the broad Federal research portfolio. The current system splits areas of research among numerous committees and subcommittees, each considering a limited portion of the portfolio, making impossible consideration of impacts of budget allocation decisions on national science and technology capabilities. While the need for analytical resources for science and technology policy tailored to the congressional process has been growing, available resources have been eliminated or reduced in recent years. And though improvements in the White House process—particularly expansion of activities and resources available to OSTP—would benefit Congressional allocation decisions, one or more Congressional mechanisms to provide expert input to research allocation decisions are badly needed.

RECOMMENDATION 2B

Congress should develop appropriate mechanisms to provide it with independent expert S&T review, evaluation, and advice. These mechanisms should build on existing resources for budget and scientific analysis, such as the Congressional Budget Office, the Congressional Research Service, the Government Accounting Office, and the National Academies. A framework for considering the full Federal portfolio for science and technology might include hearings by the Budget Committees of both houses of Congress, or other such broadly based congressional forums.

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[14] The designation of a five-year cycle for evaluation of the Federal portfolio reflects both the size of the effort, which would require more than an annual process, and the rapid changes in science, which demand a frequent reevaluation of needs and opportunities for investments.

Advice to Congress in developing its recommendations on Federal priorities and funding levels for research should make use of the best available data and analyses.

DEFINITIONS, DATA AND DATA SYSTEMS:

In addition to an enhanced process for expert advice and assessment, there is a long-term need to improve tools—databases and analytic methods—for effective management of the Federal research portfolio.

High quality data and data systems to monitor Federal investments in research would enhance the decision process. Such systems must be based on definitions of research activities that are consistently applied across departments and agencies and measured to capture the changing character of research and research needs. Flexibility in defining categories of research for tracking purposes is especially important for monitoring emerging areas and addressing the range of modes for research—from the individual investigator to the major center or facility. Timely collection of data and ease of access are critical to be useful to the allocation decision process.

Improving data and data systems is a long-term objective but one that is necessary and increasingly urgent for managing the large, diverse Federal research portfolio to serve the Nation. It will require long-term commitment to improve data systems, with input from potential users and contributors, and appropriate support.

RECOMMENDATION 3

A strategy for addressing data needs should be developed. Such a strategy supported by OMB and Congress and managed through OSTP and OMB would assure commitment by departments, agencies and programs to timely, accessible data that are reliable across reporting units and relevant to the needs for monitoring and evaluating Federal investments in research. Current data and data systems tracking federally funded research should be evaluated for utility to the research budget allocation process and employed as appropriate.

INTERNATIONAL COMPARISONS:

Both relative and absolute international statistical data and assessments should be included as a major component of the information base to support Executive Branch and congressional research budget allocation decisions.[15] International benchmarking of U.S. research performance and capabilities on a regular basis responds to the growing globalization of science and technology and the need for the United States to maintain a world-class science and engineering infrastructure. Maintaining world-class capabilities enables the Nation to take advantage of opportunities for rapid advancements in knowledge in targeted areas of research and to capitalize on breakthroughs wherever they occur worldwide. Although international data and methods of analysis are limited, they should be employed with sensitivity to those limitations and with a long-term commitment to developing better methods and data for monitoring U.S. performance and strength in science and technology.

International comparisons should include a range of measures of national research resources and performance to produce objective assessments of the relative strength of the U.S. in research areas important to national goals. For example, comparisons could include total national S&T investment as a share of Gross Domestic Product (GDP) or as a share of the high technology sector of the economy. Relative performance of individual fields important to national economic or defense priorities can be assessed using bibliometric methods and patent citations. Comparisons should be sensitive to the appropriate basis for comparing different economies, since the composition of the economy may be as important as its size as measured by GDP. For example, it might not be appropriate to compare S&T/GDP ratios for two economies that have very different manufacturing shares of total GDP. Of central importance is the comparison of human resources for research in priority areas in the United States and in other countries, including international migration of science and engineering personnel as well as participation by U.S. students in science and engineering studies in comparison with students in other nations.

Statistical trends are critical for evaluating the adequacy and direction of national research investments. Comparisons might include the following types of relative and absolute statistics:

- Total national S&T; Defense S&T; Civilian S&T; Basic (fundamental) research: National (U.S.) and Federal;

- Civilian S&T by functional categories of: health, energy, environment and natural resources, space research and technology, general science, transportation, agriculture;

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[15] National Science Board. Chapter 7, "Industry, Technology, and the Global Marketplace," in *Science and Engineering Indicators—2000* brings together a collection of indicators of national competitiveness.

- Basic science investment categories, such as: engineering, natural sciences, social science, and mathematical sciences; and

- Human resources engaged in or available for research by field, degree attainment, gender and nationality.

RECOMMENDATION 4

Input to Federal allocation decisions should include comparisons of U.S. research resources and performance with those of other countries. National resources and performance should be benchmarked to evaluate the health and vigor of U.S. science and engineering for a range of macroeconomic indicators, using both absolute and relative measures, the latter to control in part for the difference in size and composition of economies. Over the long term, data sources should be expanded and quality improved.

FEDERAL RESEARCH BENEFITS TO THE ECONOMY AND SOCIETY:

In addition to monitoring Federal expenditures for research, measuring the benefits to the public of funded research is essential for prudent management. Although there is an extensive literature on methods for measuring returns on research investments, usually in the private sector, these methods have not been widely applied in the Federal context for a number of reasons. With regard to economic methods, the difficulties include lack of sufficient data, questions of data quality, selection bias in case studies of specific industries and problems of time lags between research discoveries and their impacts on the economy. In the case of publicly supported research, many benefits cannot be expressed in terms of economic returns. Indicators and methods that have been used for measuring benefits of research include the following:

- *Asset-oriented measures*, which tally such system "assets" as research facilities and human resources for S&T resulting from Federal investments—for example, immigrant and native-born scientists and engineers, and graduate students supported on Federal research grants;

- *Outputs measures,* which track intellectual contributions and often employ bibliometric analysis—such as patent citations, publication counts, article citations, presentations at conferences—or honors received by researchers and research projects, e.g. Nobel prizes;

- *Outcomes or results measures*, including: (1) case studies and retrospective analyses, which are usually qualitative, tracing the inputs and the processes that produced an important innovation and (2) quantitative economic techniques such as production function analyses and surveys estimating economic impacts of public research within specific industries and enabling a better understanding of the channels and mechanisms whereby public research contributes to innovation.

Implementation of this recommendation should be coordinated with Recommendation 3 on definitions and data systems.

RECOMMENDATION 5

The Federal Government should invest in the research necessary to build deep understanding and the intellectual infrastructure to analyze substantive effects on the economy and quality of life of Federal support for science and technology. The research should include improvements to methods for measuring returns on public investments in research.

Federal support for research has been highly successful in contributing to the quality of life that we enjoy in the United States today. Continued national commitment to publicly supported research offers the promise of even greater benefits in the future. The expanding frontiers of knowledge demand careful evaluation to identify the highest priorities for investment of Federal research funds. It is therefore essential that the processes by which allocation decisions are made rest on the best possible information base that high technology and well-prepared minds can produce. The systematic participation of the scientific community in this process along with Federal agencies and departments, bringing its vision and understanding of the needs and opportunities for research, is critical to its success. The Board's recommendations describe a strategy for improving the quality, content, and accessibility of science and engineering input to decisions on the allocation of Federal research funds. We are aware that implementing these recommendations will be difficult and will require long-term commitment. In the interest of science and the Nation, we urge that the Federal Government and its partners in the research community embrace this difficult task.