PART 3

Budget and Policy Context for S&T in FY 2002

In Chapter 6, Representative Sherwood L. Boehlert (R-NY), chairman of the House Science Committee, discusses the Bush Administration's proposed science budgets. He begins: "The science budgets the Administration has proposed are too low. The numbers for the National Science Foundation (NSF) and the Department of Energy's Office of Science are especially disappointing." These statements notwithstanding, Boehlert believes that R&D funding is actually improving in the near-term. But he warns that long-term increases will require action by the scientific community to demonstrate that it is "bringing its enormous resources to bear on important national problems, especially education," and must "rededicate itself to addressing our most pressing and perplexing public need."

Chancellor Mark S. Wrighton of Washington University in St. Louis summarizes the responsibilities and challenges that research universities currently face. In Chapter 7, he expresses his concern over the lack of "balance" within the budget. He lauds the increases in funding for the National Institutes of Health (NIH), but is distressed over the funding levels of other areas of science and engineering, writing, "it is most likely that greater progress will be made through a balanced investment, not just the enhancement of research directly related to human biology." Because of the unique impact that universities have on the local and regional level, Wrighton suggests that universities have a role in correcting this imbalance, and should start by balancing their own "portfolio of scholarship," and strengthening diversity on their campuses. He proposes that given the major challenges related to "national security, environment, economic well-being, and education…we have an excellent case for a larger investment in university-based research."

In Chapter 8, Senator Jeff Bingaman (D-NM) continues the discussion balancing the nation's research portfolio. He states that while the march to double NIH's budget continues, "all the core basic physical science programs lose to inflation," indicating an "an imbalance in our nation's portfolio of science funding." In order to determine what a balanced science and technology (S&T) policy would be, Bingaman believes we need to answer the following three questions. What is the right mix in funding our nation's science portfolio? What is a reasonable funding level? And, who is going to advise Congress and the executive branch on the above decisions? He concludes, "these issues—our disciplinary mix of federal R&D funding, the overall level of federal R&D funding, and the mechanisms to ensure that both the President and Congress have the best in-house talent they can muster to understand both R&D budgets and the technical dimensions of broader policies—will be of crucial importance to the future of the scientific and technical enterprise in this country."

The executive summary of the National Science Board's "Federal Research Resources: A Process for Setting Priorities" comprises Chapter 9. The paper outlines the Board's recommendations for "improving the quality, content and accessibility of science and engineering expert advice, data, and analysis to inform decisions on priorities in the White House and Congress for federal investments across fields of research." Among its findings, the Board proposes: that the process for deciding on research allocation needs to be strengthened; that there is a need for regular evaluation of investments; and that additional resources are needed to provide policymakers with expert advice to inform their decisions on budget allocations for research. The Board closes, "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."

6 The Status of R&D Funding in Congress

Representative Sherwood L. Boehlert

The science budgets the Administration has proposed are too low. The numbers for the National Science Foundation (NSF) and the Department of Energy's Office of Science are especially disappointing. We know that those agencies can productively and efficiently absorb greater increases because they are doing so this year.

I am also very disturbed by the proposed slashing of the research budgets for alternative energy sources and energy conservation because advances in these areas must be an integral part of any sensible, comprehensive energy policy. I am still holding out hope that Vice President Richard Cheney's energy report may revisit these programs.

I am certainly willing to examine the energy programs to see if they can be made more effective. But they are not going to be made more effective by having far less money to spend. And they are not going to be made more effective by being told to tread water for a few years until they can be resurrected with royalties from the Arctic National Wildlife Refuge (ANWR), if they materialize. In any event we should not have to deplete one energy resource to find the money to develop another one.

We still do not know what the proposed numbers will be for research spending in the Department of Defense because they will not be determined until Secretary Donald Rumsfeld's review is completed. With the major exception of the National Institutes of Health (NIH), the proposed budget leaves a lot to be desired.

Why am I not more concerned? Because these numbers are going to get better. Most likely a little better this year and a lot better next year.

Sherwood L. Boehlert, Member, U.S. House of Representatives (R-NY), is chairman of the House Science Committee, and member of the House Transportation and Infrastructure Committee. *This article is based on remarks delivered at the 26th Annual AAAS Colloquium on Science and Technology Policy, held May 3–4, 2001, in Washington, DC.*

I say that because support for research and development (R&D) remains remarkably strong in both the Administration and Congress. The Administration's budget this year reflects the President's campaign priorities, which not surprisingly did not include R&D outside of NIH.

The budget does not reflect any hostility toward or ideological grudge against R&D spending. Indeed the budget language already signals an intention to increase spending for NSF in the next budget. Mitchell E. Daniels, Jr., the director of the Office of Management and Budget, has confirmed this impression.

Simply put, the numbers in this year's budget have been offered without prejudice. They were driven by factors outside of science policy. The Administration is already more focused on the need to invest in R&D, even as it continues to put together its science policy team.

Moreover, Congress remains committed to making strong investments in R&D. For example, the Senate voted to significantly increase spending for NSF, the National Aeronautics and Space Administration, and the Department of Energy in its budget resolution.

So what will come of all of these warm if fuzzy feelings toward science? For FY 2002, I think we will see some small improvements over the proposed budget. The final budget resolution provides for a five percent increase in overall domestic discretionary spending, one percentage point higher than what the President proposed. This means that more money will be available for science spending. I will be working with the Appropriations Committee to ensure that as much of that money as possible is allocated to research.

With all the budget machinery controlled by the Republican Party, this year will be different because we will stick to that overall domestic discretionary number. In the past few years, the budget numbers vanished each fall like the Cheshire cat, leaving only a mocking grin. Those days are over. People will have to pay more attention to the bottom-line numbers in the budget resolution than they have in the past.

My final point is a cautionary one. Even though science can draw on a remarkably large reservoir of goodwill, and even though science spending will grow more in FY 2002 and FY 2003 than the current numbers on the table might indicate, the scientific community still has its work cut out for it. That is because the overall projected growth in domestic discretionary spending for FY 2003 and beyond is only enough to cover inflation. The actual figure is likely to be higher than that, but spending growth will be constrained. That means that the competition for federal dollars will be fierce. Supporters of research need to reinforce the arguments for the federal investment in R&D both analytically and politically. Reinforcing the case for R&D analytically means providing good, solid arguments for specific levels of funding, not just throwing the word "doubling" around as if it casts a magic spell, and it means providing good, solid thinking about what it may mean to have a balanced federal research portfolio.

Reinforcing the argument for R&D politically means working with the Members of Congress back home in their districts and ensuring that business leaders are making clear their reliance on federal R&D. Leaders of the scientific community spend far too much time with their natural allies like me and far too little time convincing newer or more skeptical Members of Congress that R&D makes a difference in their districts and in the nation.

The scientific community must not be complacent and it cannot assume that inherently it has the greatest claim to or most self-evident argument for federal largesse. That is a recipe for failure.

The scientific community must demonstrate that it is bringing its enormous resources to bear on important national problems, especially education. The university community often talks about the link between research and education, but that must be more than just a rhetorical flourish. Universities must focus more on undergraduate education even as they continue to offer world-class graduate programs. Universities and businesses must play greater roles in improving K-12 education. I have introduced H.R. 1858, the *National Mathematics and Science Partnerships Act* to help encourage universities to work with our nation's school systems.

If research is going to continue to merit large-scale public support, as it must, then the research establishment must rededicate itself to addressing our most pressing and perplexing public needs. That attention will pay off because it will excite the natural curiosity of the young.

I am reminded of some letters I received from second-graders in Cooperstown, New York, (which is in my congressional district) just a few years ago. The second-graders had been asked to send me letters explaining why science is important. One wrote, "Without science, the world would be whacko. There might not even be gravity." This is someone who understands that a lot is at stake when we talk about science, and with his fractured second-grade logic, the student hit on a larger point as well. When we fail to analyze or understand the world around us, it is almost as if that world ceases fully to exist.

I urge the scientific community to help us understand the value of science, and to take the time to understand the world of politics and budgeting as well. That way each of our worlds can inform the other. In this way the scientific enterprise and the nation will thrive.

7 Science and Technology Issues: A University Perspective

Mark S. Wrighton

Introduction

America's research universities continue to make important contributions in education, research, and service to society. Federal support is a critical component of the resources received by such institutions. We have are compelling reasons to carefully examine the opportunities and challenges before us and to assess the level and balance of the research investment. President Bush has advanced a budget for FY 2002 that is basically level funding (or slightly lower when inflation is taken into account) for most science and technology areas. The exception is the National Institutes of Health (NIH), for which a substantial increase in funding is proposed. This chapter summarizes the responsibilities and challenges of the university within this context and from the perspective of a research university.

Balancing the Federal Research Investment: Meeting 21st Century Goals

The research universities of the United States are institutions of world-class stature engaged in addressing the most critical problems of the early part of the 21st century. Among the most important goals for this new century are the enhancement of human health and national security. The

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research and advanced education surrounding these two objectives provided the major rationale for substantial support to research universities for the past half century. During the Clinton Administration and now under the Bush Administration, the commitment to advancing human health (in part reflected in the growth of the NIH budget) continues to receive very strong support from Republican and Democratic Members of Congress. The growing investments in NIH have been well-placed, because the new opportunities for advancing human health are real and success in this research will significantly benefit American society. Because of this funding, research universities have been able to attract talented research faculty and students interested in pursuing exciting research areas that show much promise.

While significant budget increases have been supported for NIH, there is concern that the budget is not "balanced" with respect to the other areas of science and engineering, where important benefits will develop from the research enterprise. Indeed, a compelling case can be made that advances in the physical sciences and engineering will fuel more rapid progress in areas traditionally supported by NIH. Even in the areas of research supported by the Department of Defense, roughly level funding does not seem appropriate considering the importance of national security and the research opportunities in the physical sciences and engineering that support the technological developments arguably needed for defense.

Beyond the defense- and health-related research emphasized in the Bush agenda, the investment in research also contributes to improving economic strength and prosperity. Considering the strong arguments that acknowledge research as a critical financial investment with respect to the economy, the essentially flat budgets for science and engineering education and research at agencies like the National Science Foundation (NSF) are disappointing.

Addressing environmental challenges is also important. We can see truly innovative and exciting programs in this area, from "green chemistry" to plant science, where research universities can play a larger role. The public strongly embraces a commitment to enhancing the environment, and there are great opportunities for research. Although the Kyoto Protocol to the United Nations Framework Convention on Climate Change is a political lightning rod, it is certainly true that sustaining, if not enhancing, the environment should be a 21st century priority.

The mission of colleges and universities has long included a role for knowledge creation involving students. Science and engineering education and research are certainly intertwined at the graduate level, and research opportunities provide undergraduates with a deeper engagement in their major. In general, research enhances the educational mission and expands knowledge. Colleges and universities can play an important role in enhancing K-12 science education through teacher preparation programs and outreach efforts. These contributions hold the promise of advancing educational achievement in science for the entire population, an important 21st century goal. Programs like those at NSF that encourage graduate students to work with K-12 teachers and students make a contribution to achieving stronger science education programs at all levels.

An overarching 21st century goal, of course, is to advance the quality of life, both domestically and internationally. It is certainly the case that advances are possible, and that many of them will stem from investments in research at research universities. However, it is most likely that greater progress will be made through a balanced investment, not just the enhancement of research directly related to human biology. Sustained national security, an improved environment, and economic strength all require significant investments in research and a balanced portfolio to optimize success in all areas of national importance.

Universities: Meeting the Challenges

Research universities and their communities realize the importance of science, engineering, and medical research and education. Such institutions have sought significant private support for enhancing their research mission. As a result, private and public research universities have enjoyed substantial increases in their endowments and great success in fundraising campaigns of over $1 billion. The following schools have secured commitments of more than $1 billion in recent or current fundraising campaigns: Stanford, Harvard, the Massachusetts Institute of Technology (MIT), Washington University in St. Louis, Johns Hopkins, Northwestern, Duke, Columbia, and Yale, as well as public universities like the University of Michigan, University of Illinois at Urbana-Champaign, University of Texas at Austin, and the University of California at both Berkeley and Los Angeles. These fundraising successes have enabled research universities to remain responsive to new opportunities in research.

Universities have committed substantial support for the development of new teaching and research facilities in science, engineering, and medicine. Washington University is developing buildings for biomedical engineering, chemistry, and earth and planetary sciences, and it is building a new cancer center. These and other facilities are part of a capital projects plan involving the commitment of approximately $1 billion over ten years. Investments of similar scale are being made at MIT, Johns Hopkins, and Yale, among others. Included in these efforts are commitments to renew existing facilities, to enhance research infrastructure, and to invest in the information technology needed to contribute in advanced education and research.

Research universities are also making important financial contributions to intellectual renewal through their support for new faculty. Start-up packages for new research faculty in the sciences, engineering, and medicine, even for assistant professors, represent very sizeable one-time expenditures that are fully supported by universities. An assistant professor appointment might involve financial commitments of the order of $500,000, while senior faculty appointments may require several times that amount.

It is well-known that the costs of conducting research are not always fully met by the financial support received from the federal government or any other funding source. Thus, in order to be competitive, universities must be able to meet the requirements of overt and subtle cost-sharing in connection with sponsored research. Major equipment support from the federal government often requires matching support from the university. Such matching funds must come from unrestricted sources. Similarly, recovery of legitimate expenses associated with research results in a shortfall. The “underrecovery” of expenses, such as those for the research library, safety, compliance, and financial personnel, must also be met with otherwise unrestricted dollars from the university. At Washington University, it is estimated that every dollar of research provided by the federal government results in the commitment of 25 to 30 cents by the university. Thus, with about $300 million in federal expenditures annually, the university needs a very large, unrestricted revenue stream for research. Current gifts and spendable income from endowment provide the resources needed. Being able to provide the resources and facilities for research enhances the federal investment and brings a substantial benefit to society.

Universities, of course, have a compelling interest to recruit the best people possible and provide the best environment for their research activities. Such individuals will be those who compete most successfully for external support from the federal government, corporations, and foundations. The point is that substantial fundraising efforts of universities are being used to support the research and education enterprise and represent a very hefty commitment to meeting the challenges of the 21st century.

Balancing Scholarly Interests: Humanities, Arts, and Social Sciences

It is clear to many that universities are investing a large fraction of their unrestricted resources in the general areas of science and technology. There is legitimate debate in the academic community as to whether these large investments are equitable. In many settings important scholarly efforts in the humanities, the arts, and the social sciences receive a smaller share of a growing resource pie. Arguably, science and engineering education and research are fundamentally more costly than scholarly programs in the humanities and social sciences. Even so, there is a need to continue to balance the investments at research universities.

Perhaps surprisingly, many of the most creative and interesting applications of technology in education and scholarship are coming in the areas of the arts and humanities. From foreign language instruction to writing programs, from graphic design to music, new technology is being applied in very creative ways.

In the social sciences, scholarship and education regarding the impact of science and technology on society represent major opportunities and responsibilities for research universities. Further, advances in medicine pose many interesting ethical challenges for society. The sequencing of the human genome has opened up new frontiers in medicine to be sure, but these are accompanied by challenges for the medical, legal, and business professionals. Recently, stem cell research has raised much debate among political, religious, and research leaders. It is important that research universities remain places for the free exchange of ideas and forums for debating the issues facing society. Sustaining strength in all areas of higher education requires the same commitment to an overall, balanced portfolio of scholarship on our university campuses.

University-Based Research: New Products, Services, and Economic Impact

Most research universities have far more impact at the local and regional levels than at the national and international levels. Much of the revenue to universities is spent in the communities where they are located. Federal research dollars, in particular, represent economic impact that would not be present in the absence of the research university. Thus, many communities have come to value research universities for the positive effects on their economy. Many states strongly support their public research universities in order to assist them in being more competitive for federal research grants and contracts. Support for facilities, research infrastructure, and faculty plays a critical role in the success of research universities, and it is in the public interest that research universities be supported for these purposes.

Major visibility now surrounds the opportunities that stem from discoveries in science, engineering, and medical research that may have technological consequence. From new anti-cancer drugs, to procedures for genetic manipulation of plants, to advances in software, research universities are associated with important developments of intellectual property that have led to significant advances in local economies. The successes in Boston's Route 128 corridor, Silicon Valley, Research Triangle Park, and other parts of the nation have stimulated much interest in developing technology transfer efforts at research universities. Many new "science parks" and incubators are being developed around research universities to assist in the technology transfer effort. New companies from federally sponsored research not only create regional wealth, but also bring important benefits to society with the products they produce. Again, the overall federal investment is one that needs to be properly balanced in order to realize the maximum benefit for society, because exciting and significant opportunities remain across a wide spectrum of science and engineering.

Regarding the matter of balance, it is important to note that the strength of the American research university enterprise is the diversity among its institutions. Each university is encouraged to develop programs of importance in fulfilling its mission. The California Institute of Technology, for example, is largely a science-based institution, while the Massachusetts Institute of Technology places a much greater emphasis on engineering. Washington University in St. Louis focuses on the life sciences, with major programs in biomedical research, plant science, and biomedical engineering. The focus of a research university comes about from both conscious decisions and tradition surrounding the university. In some instances the focus of a university has particular relevance to the community in which it is located. This is true for Washington University, which is playing a key role in a region-wide initiative in the life sciences, which includes both human biology and plant science. As the academic cornerstone of the initiative, Washington University plays a critical role in attracting talented people to do research, encouraging the development of new companies, and investing in the region financially. These elements of community commitment are typical of America's research universities and further strengthen their partnership with the federal government.

With approximately 125 medical colleges in the United States, many research universities bring very significant and direct health benefits to the communities surrounding the academic health centers. On the list of the 2001 *U.S. News and World Report* top 15 hospitals all but one (the Mayo Clinic) of the adult hospitals are associated with the medical school of a major research university. Academic health centers provide their communities with the best medical care available and also help the public they serve understand the latest advances in medicine that may be applied to patient care. This service to society is arguably the most important direct benefit to the people in a community served by a research university with a medical school.

Human Resources: Are We Doing Enough to Attract Talented People?

Science, engineering, and medical research is done by people. This truism is sometimes forgotten, but the strength of the U.S. research effort depends on being able to draw on the rich human resources we enjoy in this country. For much of the 20th century, science, engineering, and medical research was conducted by white males, largely leaving out women and members of minority groups. By encouraging the participation of women and members of minority groups we significantly increase the available talent pool from which to draw a strong, vibrant research community. This fact alone is compelling, in terms of developing a commitment to building diversity in the science and technology work force.

Research universities have long supported the objective of strengthening diversity. They have made substantial commitments and there has been much progress. However, much more remains to be done, especially in advancing women and members of minority groups to major leadership roles. Universities welcome opportunities to partner with the federal government in expanding opportunities for women and members of minority groups.

With the growing strength of research universities in other countries, particularly in Asia, many of the talented people originally from those countries can be lured "home." Further, international students from Asia currently studying science and engineering will see increasingly strong, exciting, and well-supported opportunities back home. For these reasons we need to make special efforts to interest U.S. students in science and engineering. Developing such interest must begin in childhood. Research universities see opportunity and responsibility in this arena through teacher preparation programs and community outreach programs.

America's great world standing in science, engineering, and medicine depends on sustaining interest in the pursuit of these areas by talented people. The federal government should substantially enhance its investment in this area.

21st Century: The Age of Biology

What justification can be offered for the very substantial increases in federal support for health-related research? Partly, of course, the answer rests in the fact that decision-makers are like all others—interested in longer, healthier, more productive lives. The stunning advances in medicine in the 20th century, including the eradication of many infectious diseases and lengthened life expectancy, are rewards of earlier investments. But the last quarter century saw a revolution in biology of such significance that the first part of the 21st century will almost certainly be regarded as the Age of Biology.

In the early part of the 20th century physicists and chemists made tremendous advances in understanding the fundamental nature of matter. From those advances have come the development of much of what we now regard as established technology, from lasers to synthetic fibers to a remarkably powerful information and communications infrastructure. The Age of Biology will spawn its technologies, too, and the biotechnology industry is destined for continued rapid growth. The products from biotechnology hold much promise in continuing the advance on improving human health. However, it is noteworthy that the "hot" areas of biology—genomics, structural biology, biomedical engineering, and computational biology—all depend on continuing advances in areas that are not traditionally biology. Thus, federal support to fuel advances in chemistry, physics, mathematics, materials science and engineering, and computer science, arguably, needs to be enhanced, in order to ensure a brisk pace of advances in both the applications of biology and other areas of technological importance. Again, striking the right balance of investment in research is key to the overall success of American science.

The federal investment in medical research is easily justified on the basis of the impact of the research advances and their applications to treating, managing, and curing disease. Cancer and cardiovascular disease rank high among causes of death, and focused efforts here will very likely yield significant improvements in longevity. In addition, the world faces new challenges in the area of infectious diseases. AIDS is a worldwide threat, but an immediate threat of great significance to the continent of Africa. The work on the human genome project is an important step in the diagnosis of genetic diseases and the next era of advance will focus on treating these diseases. The ability to fend off diseases is known to be at least partially genetic, too, and thus much effort is being appropriately directed to drugs tailored to an individual's genetic makeup for treating cancer, for example. Finally, in the human health area, treatments for age-related diseases such as Alzheimer's, macular degeneration, and osteoporosis will be more important, owing to the changing demographics of the American population due to the success of lifesaving medical advances.

Important as human biology is, it is critical to underscore once again the need to invest in other sciences and in engineering in order to realize the promise of the Age of Biology. Even in biology itself, it is important to emphasize the opportunity in the general area of plant science. Plant genomes can be sequenced with the same technology applied to the human genome. Genetic engineering of plants has important practical benefits. This work has the potential to lead to a second "green revolution," dramatically enhancing crop yield. Genetically engineered plants can reduce the use of pesticides and fertilizers, thereby sustaining environmental quality. High-value products from plants such as nutriceuticals and advanced materials may be important outcomes from the research as well. When reviewing the balance of biological research, it is clear that the federal investment in plant science is well below what it should be to realize the potential from this area. Feeding the growing world population with healthier food while sustaining the environment will be an important 21st century challenge.

Conclusion

The federal government is the largest and most important sponsor of research at American research universities. The investment has brought great returns over the last 50 years, and enormous promise remains. The Bush science budget is basically flat, except for the National Institutes of Health. Considering the major challenges we face related to national security, environment, economic well-being, and education, coupled with the exciting and promising opportunities being presented by the research community, we have an excellent case for a larger investment in university-based research.

8 The Need for a Balanced Science Policy

Senator Jeff Bingaman

This chapter discusses the necessity of a balanced science and technology policy. I will outline this proposition in three steps. First, what is the right mix in funding our nation's science portfolio? There seems to be a growing disconnect between funding in the physical sciences and funding in the life sciences. Second, if we know a reasonable mix, then what is a reasonable funding level? Should not Congress, the holder of the purse, ask itself to explain more thoroughly to the American public why we seek to "double" the budgets of certain agencies? Third, given that we know how to frame the first two issues, who is going to advise Congress and the executive branch on the above decisions?

What Is the Right Funding Mix for Our Science Portfolio?

President Bush announced that he would continue the trend to double the budget of the National Institutes of Health (NIH) from the 1998 level of $13.6 billion to $27 billion in 2003. For FY 2002, the President will increase NIH's budget by $2.7 billion, or roughly 13.6 percent. Such an effort is admirable and essential to the health of our citizens. For example, these increases will double the funding for the Office of Research on Women's Health. The new National Institute of Minority Health and Health Disparities would receive a 20 percent increase to $158 million. The new Institute for Biomedical Imaging and Bioengineering would receive $40 million—up from $2 million just last year. But as Harold Varmus, the former director of NIH, noted some time ago, "Medical advances seem like wizardry. But pull back the curtain and there is a high energy physicist, a combinatorial chemist, or an engineer."

Jeff Bingaman is a member, U.S. Senate (D-NM). This article is based on remarks delivered at the 26th Annual AAAS Colloquium on Science and Technology Policy, held May 3–4, 2001, in Washington, DC.

The Institute for Biomedical Imaging is a perfect example of this statement. Its state-of-the-art medical equipment is designed by physicists, chemists, and engineers.

How did the other sciences fare in the President's 2002 budget? If you exclude the proposed defense increases, the nondefense sciences fell by three percent. Defense research and development (R&D), while receiving an eight percent or a $3.6 billion increase, would see its core basic R&D program rise by only about two percent. That two percent increase is comparable to the increase given to the National Science Foundation. The Department of Energy's (DOE's) Office of Science remained flat, but is actually considered a winner compared to DOE's overall energy supply R&D budget, which declines by 25 percent in 2002 and by 31 percent by 2006. But all the core basic physical science programs lose to inflation. These details indicate to me an imbalance in our nation's portfolio of science funding.

Some claim that U.S. industry is funding an increasing share of today's R&D. Hence, Congress needs to fund less R&D. These proponents cite National Science Foundation (NSF) statistics that indicate that industry funds 68 percent of the total U.S. R&D, or about $180 billion. These proponents claim that we should give R&D tax cuts to further stimulate funding by industry. I support R&D tax credits. But R&D credits stimulate only commercially focused research. Stimulating commercial R&D will only further deplete our pool of basic science. If we want commercially oriented research to flourish, it is imperative that we as a nation maintain the pool of basic science from which industry can draw upon.

This imbalance in our science portfolio is appearing in national trends. Between 1985 and 1995, the Council on Economic Competitiveness reported that the number of science and engineering degrees declined by four percent. In 1999, the National Science Foundation reports that for the first time in 14 years, the number of Ph.D.s in engineering and math declined by 8.5 percent. U.S. submissions to our prestigious physics journals declined to 25 percent while European and Asian submissions increased from 50 to 75 percent. These declines in our work force and intellectual property do not appear immediately. Over time they will erode our world leadership in nanoscience, chip design, advanced computing, bioinformatics and medical imaging. These are the physical sciences that Dr. Varmus would have us see by pulling back the curtain to reveal bioscience's supporting infrastructure.

What Is the Right Level for Funding Science?

What is the right level of funding? That is a hard question because the fundamental sciences are about innovation over the long term, even decades.

If we cannot answer this question, then where does our goal of "double the budget" come from? We are doubling the budget with NIH. Some of my Senate colleagues propose doubling for the National Science Foundation. I have co-sponsored R&D doubling bills in the Senate. I support doubling the budget for NSF and NIH. But I ask the question: What is the relationship between cause and effect? In other words, what does "doubling" give our nation?

I propose that we move one step beyond using the word doubling and define with more specificity the increases we need in a science agency's budget. It could be that certain science areas need more than doubling their budget to achieve their effect on our nation. Some may need less.

I would start this process of redefining doubling by asking ourselves what areas of science do we, the United States, want to lead the world in? These leadership roles should be in general areas such as electronic materials or proteomics. In my area of jurisdiction—energy policy—I would ask what amount of energy R&D funding could reasonably achieve a certain percentage reduction in energy consumption. Such a methodology is not unreasonable; it has been done before through the President's Council of Advisors on Science and Technology (PCAST). Indeed, the PCAST Energy Research and Development Panel, led by John Holdren of Harvard University, helped determine energy R&D funding levels that could reduce energy consumption by one-third in the year 2020. This PCAST study and its funding recommendations are the basis for the R&D authorizations in the Senate Democratic energy policy bill.

If we ask these questions and come up with reasonable answers, then Congress should fund science in a bipartisan long-term fashion.

Who Will Advise Us on the Above Science Policy Decisions?

The final question is the most important: Who is going to assist Congress and the President in making the above decisions?

The answer in the executive branch has been clear for many years now. This function has been exercised by the Office of Science and Technology Policy (OSTP). Over the last eight years, OSTP has developed or sustained national initiatives on nanoscience, global warming, and information science. The leadership of a presidential science advisor helped maintain a White House commitment to these initiatives that facilitated interagency cooperation and provide a coherent long-term focus.

I am concerned that this capability has been eroded. As of today, President Bush has yet to announce the name of his presidential science advisor. By the corresponding date in most previous Administrations since the re-establishment of the Office in the 1970s, the President's choice for a science advisor was known. (President Jimmy Carter announced his intent to nominate Frank Press on March 18. President Ronald Reagan announced his intent to nominate George Keyworth on May 19. President George Bush announced his intent to nominate Allan Bromley on April 20. And President Bill Clinton announced his intent to nominate Jack Gibbons on January 2, early enough to allow Gibbons a significant role as Clinton formulated his first budget.)

It is not as if the new Administration has put issues with significant technical content on the back burner for later review. For example, the Administration highlighted its view that the arsenic drinking water standard was not based on sound science when they withdrew it earlier this year. But major policy shifts in climate change, national missile defense, and energy all were decided upon with little or no apparent input from the scientific and engineering community.

One striking example of how the lack of a science advisor has led to confusion in this Administration was the unexpected announcement in the President's budget blueprint that he was considering shifting NSF's astronomy research to the National Aeronautics and Space Administration, without the advise of a science advisor. The result is that now the National Academy of Sciences is convening panels to resolve this ill-informed suggestion, which is a costly use of taxpayers' money.

I strongly encourage the President to make filling this critical position a real priority.

Congress also needs help in obtaining high quality science advice and objective long-term assessments on science and technology. At one time we had an entity to do this in the legislative branch—the Office of Technology Assessment (OTA). OTA had a distinguished bipartisan and loyal congressional advisory board, evenly divided between Members of the Senate and the House. Six years after it was abolished, the OTA technology assessment report is still used by Members of Congress and staff.

Today, the effect of technology in our policy debate is even more pronounced. I believe that it is time for Congress to reexamine how to reestablish some form of an OTA within the legislative branch. Three years ago, in the legislative branch appropriations bill, I offered a proposal to set up a scaled down version of the OTA. I do not believe that our only option is to reconstitute a 200-person staff organization, such as the OTA was at the time it was abolished in 1995. It could be a smaller, focused organization located in the legislative branch. But we Members of Congress are not fulfilling our oversight responsibilities in today's technology-dominant world if we do not have the learned bipartisan advice of an entity such as the OTA.

I believe that these issues—our disciplinary mix of federal R&D funding, the overall level of federal R&D funding, and the mechanisms to ensure that both the President and Congress have the best in-house talent they can muster to understand both R&D budgets and the technical dimensions of broader policies—will be of crucial importance to the future of the scientific and technical enterprise in this country. They are issues on which I would like to work with the scientific and engineering community. To the extent that this community can make its voice heard, either through individual interactions with Members or through organizations like AAAS, we may be able to make real progress on these issues.

9 Federal Research Resources: A Process for Setting Priorities

National Science Board

Executive Summary

Context and Framework for the Study

The Federal government's policy for investment in science and technology (S&T) over the last 50 years has yielded enormous benefits to the economy, national security, and quality of life in the U.S. The Federal share of total national science and technology investment is critically focused in areas that would be inadequately funded or not supported by the private sector. These include research to support Federal missions; research that is high-risk, requires long-term investment in the expectation of future high payoffs to society; unique, costly, cutting-edge research facilities and instruments; and academic research that, as a primary purpose, supports the education of the future science and engineering workforce.

Over $90 billion[1] was allocated to Federal R&D in the most recent budget—representing a little more than a quarter of all national R&D. With such a large investment of public funds, policy makers in Congress and the Executive branch are asking for convincing evidence of the effectiveness of Federal investments in the form of hard data on benefits. There is general recognition among policy makers that outstanding opportunities for excellent research far exceed any reasonable level of funding by the Federal government. Choices must be made. Wise, well-informed choices among alternatives will sustain a strong, balanced

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research infrastructure to enable the discoveries that will be a foundation for future prosperity.

The current system for priority setting in the Federal research budget lacks a coherent, scientifically based process for systematic review and evaluation of the broad Federal investment portfolio for effectiveness in achieving national goals. Moreover available data and analyses are often ill suited for informing budget allocation decisions that affect U.S. research infrastructure.

Decision-makers must rely on the scientific community to provide the best advice on the most promising research investment choices for the future. The form and timing of such advice is also important. Appropriate advice must include a reasonable estimate of the level of funding that would be required for adequate support of a new initiative over time, provide tradeoff options to enable funding for priorities, and must be available on a schedule compatible with the Federal budget process.

No process now exists for weighing the available evidence on competing research investment opportunities across broad fields of research. It is critical that the choices among such opportunities be based on a process that is transparent and credible with the scientific communities and the general public and its representatives. Such a function requires an organizational home, appropriate expert resources, and adequate financial support.

Since the mid 1990s, the National Science Board has been actively engaged in issues of priority setting for the Federal research portfolio.[2] In 1999, the Board charged its Ad Hoc Committee on Strategic Science and Engineering Policy Issues to undertake a study of research budget coordination and priority setting methodologies across fields of science and engineering in the U.S. and in other countries.

Conduct of the Study

The study, *Federal Research Resources: A Process for Setting Priorities* (NSB 01-156), which follows on recommendations of the Board's previous working paper on *Government Funding of Scientific Research* (NSB 97-186), responds to a request by the House Appropriations Committee[3] and the encouragement of the Office of Management and Budget (OMB). In its February 1999 *Strategic Plan* the Board identified this effort as a high priority for national science policy.

The Committee on Strategic Science and Engineering Policy Issues commissioned reviews of the literature in two areas.[4] The first focused on Federal research budget coordination, priority setting across fields of science and engineering, and available data and analytical tools to support priority setting. A second study of the same subject reviewed international models of S&T budget coordination and priority setting. It also included a symposium with presentations by S&T officials from eight foreign governments.

In addition to these studies, the Committee heard presentations by invited experts who discussed a wide range of methodologies and data to support budget allocation decisions for research. It also received written comments on its draft recommendations by mail and through the National Science Board website, and heard presentations broadly representative of stakeholders in Federal research. Stakeholder input culminated with a Symposium on May 21-22, 2001 on the Board's preliminary findings and recommendations, with more than 200 participants.

Principal Findings

- Federal priority setting for research occurs at three levels: 1) establishing Federal goals for research, 2) the budget allocation processes for research within the White House and Congress that in the aggregate produce the Federal research portfolio and 3) Federal agencies and departments in achieving their missions in accord with the President's priorities for research. This report focuses on the second level, that is, the White House and Congressional processes that in the aggregate produce the Federal portfolio of investments in research.

- The allocation of funds to national research goals is ultimately a political process that should be informed by the best scientific advice and data available.

- A strengthened process for research allocation decisions is needed. Such allocations are based now primarily on faith in future payoffs justified by past success. They are difficult to defend against alternative claims on the budget that promise concrete, more easily measured results and are supported by large and vocal constituencies.

- The pluralistic framework for Federal research is a positive aspect of the system and increases possibilities for funding high-risk, highpayoff research. An improved process for budget coordination and priority setting should build on strengths of the current system and address weaknesses in data, analyses, and expert advice.

- There is a need for regular evaluation of Federal investments as a portfolio for success in achieving Federal goals for research, to identify areas of weakness in national infrastructure for S&T, and to identify a well-defined set of the top priorities for major new research investments.

- Additional resources are needed to provide both Congress and the Executive branch with data, analyses, and expert advice to inform their decisions on budget allocations for research.

Recommendations

Implementation of a broad-based, continuous capability for expert advice to both OMB and Congress during the budget process would yield immediate benefits to decision-makers. There is also a long-term need for a regular, systematic evaluation of the effectiveness of Federal investments in achieving Federal goals for research through the Office of Science and Technology Policy (OSTP), drawing broad-based input from scientific experts and organizations in all sectors. Complementing both would be improved analyses on research opportunities, needs, and benefits to society; and timely data that trace Federal research investments through the budget process and beyond.

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:

Presently there is no widely accepted and broadly applied way for the Federal government to obtain systematic input from the science and engineering communities to inform budget choices on support for research and research infrastructure. The current system often fails to produce advice and information on a schedule useful to the budget process and responsive to needs for broad-based, informed assessments of the benefits and costs of alternative proposals for Federal support. 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. 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.

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.[5] 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. 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.

Definitions, Data and Data Systems:

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. Improving data will require long-term commitment with input from potential users and contributors, and appropriate financial 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 a major component of the information base to support Executive Branch and Congressional research budget allocation decisions. 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 U.S. to maintain a world-class science and engineering infrastructure.

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. 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.

Conclusion

The Board's recommendations provide a framework for improving the quality, content, and accessibility of science and engineering expert advice, data, and analyses to inform decisions on priorities in the White House and Congress for Federal investments across fields of research. We are aware that implementing these recommendations will be difficult and require long-term commitment and support. 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.

Endnotes

1. Office of Management and Budget, "Analytical Perspectives," *Fiscal Year 2002 Budget of the United States Government*, Table 7-2, Research and Development Spending.
2. *In Support of Basic Research*—NSB 93-127; *Federal Investments in Science and Engineering*—NSB 95-254 and *Statement on Federal R&D Budget Realignment*—NSB 95-26, were issued from 1993 to 1995, in addition to more recent papers.
3. Report 105-610, 105th Congress, 2nd Session, House of Representatives. To accompany H.R. 4194.
4. Steven W. Popper, Caroline S. Wagner, Donna L. Fossum, William S. Stiles. *Setting Priorities and Coordinating Federal R&D Across Fields of Science: A Literature Review* (DRU-2286-NSF). Washington, DC: RAND Science and Technology Policy Institute, April 2000; and H. Roberts Coward. *Final Report: Symposium on International Models and Budget Coordination and Priority Setting for S&T.* Washington, DC: SRI International, August 2000.
5. The designation of a five-year cycle for evaluation of the Federal portfolio reflects both the scale of the effort, which would require a longer time than an annual process, and the increasingly rapid changes in science that demand a frequent reevaluation of needs and opportunities for investments.