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# NATIONAL PRIORITIES IN SCIENCE AND TECHNOLOGY POLICY

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Thank you, President Jackson for inviting me to speak today. For a few days last month, I thought I would not be able to fulfill my long-standing commitment to visit RPI, and I am very glad the arrangements worked out after all. RPI has a long history of collaboration with government, industries and other universities for regional development, a topic in which I am greatly interested. My first contact with RPI was in the early 1980's when President George M. Low had laid the political groundwork within New York State for a major commitment to technology-oriented economic development. In addition to the projects he created at RPI, George was a major force, perhaps *the* major force, behind New York's highly successful Centers for Advanced Technology (CAT) program, in which two CATs now exist at my own university at Stony Brook.

Revitalizing the economy is a top priority for this Administration. Just last week President Bush visited North Carolina to speak on the economy and the technical workforce. He said, among other things, that "the job of the government is to make sure that the entrepreneurial spirit of America is strong, make sure that people feel comfortable in taking risk, that they're willing to start a small business and grow it to a big business." The federal government fosters this process through R&D investments that create the foundation for the technology-intensive sectors of our economy, including information technology, manufacturing, pharmaceuticals, communications, and many others. It is up to the federal government to establish policies and laws to promote new business and ensure economic competitiveness. But the federal government cannot do everything. The states and the private sector also have important roles to play to maintain viable economies in a rapidly changing world. In my direct experience, New York State, and especially its capital region, has labored effectively for more than a quarter-century to harness the potential of its universities and its industries in service to economic development.

I am aware that last month RPI hosted a biotechnology symposium that examined "three building blocks to successful commercialization." I would summarize these as *technology-oriented research*, *technology-oriented commercialization*, and *technology-oriented business talent.* The point is that there is no law that requires the functions of research, commercialization, and entrepreneurship to work productively together. There has to be some guiding framework that fits the whole enterprise to the needs of eventual economic success. That is why regional consortia are so important. Universities are centers of research and training; regional industry understands its markets and its capabilities; state and local governments sponsor programs that can work to enhance the educational, research, and industrial assets. These assets have to come together in policies and practices within each component organization and institution. New York State has a long history of encouraging regional economic development linked to its outstanding research institutions. I was proud to participate in those efforts in the past, and look forward to helping in the future.

My purpose today is to speak generally about the framework for federal science policy formation and the prospects for funding technology-oriented research in universities and public and private sector research laboratories. Let me say a word first about general patterns of federal science funding. For more than four decades, the fraction of funds devoted to non-defense R&D from the Domestic Discretionary Budget has been practically constant at 10%. There are fluctuations above and below this figure, and we happen to be ahead of the curve today, but there is a remarkable stability in this number. The Domestic Discretionary Budget itself is also increasing in constant dollars, but on the average the increase has been linear, not exponential. That is, it has not increased by a constant percentage each year, on the average. But the rate of increase has been accelerating in recent years. Over a forty year time span, this part of the budget has increased on the average at about a half-billion dollars per year (in constant 1996 dollars). These historical trends provide some assurance that plans can be laid and policies can be formed that will permit regional planners and sponsors to invest their own resources in a relatively stable federal context. The federal government today spends a record $120 billion on research and development in all agencies, of which about half, or $58 billion falls in the category of "Federal Science and Technology" which excludes most development work – most of which is for weapons systems development in the Department of Defense. You are probably aware that industry's contribution today is more than twice the federal investment, and growing rapidly. University and non-profit contributions to R&D funding today are small, but are also growing rapidly.

I will say more later about how this S&T pie is distributed, but first I want to say a few words about how we got here. In the not-quite-chaotic world of federal budget making, there are two large forces toward coherence: the President's Annual Budget Request to Congress, and the inherent structure and status of science itself.

The intrinsic organizing power of science deserves more attention than it gets in discussions of science policy. In my frequent visits to universities, national laboratories, and topical conferences, I am always impressed with the efficiency of communication among working scientists, and the very high degree of coherence that emerges from the scientific, and more broadly, the technical enterprise. Leads are identified, publicized, followed up. Trends emerge spontaneously and in parallel in widely separated parts of the world. Good ideas are not ignored for long. Despite all the criticisms of peer review for programs, grants and journal publications, it seems to work. The market mechanisms of science in America are exceptionally efficient.

What this means for policy is that there is widespread agreement among scientists about the status and opportunities of science, and a remarkable degree of consistency in peer assessments and advisory committee recommendations worldwide. We owe a deep debt of gratitude to the many organizations, from the National Academies to the multi-branched organizations and professional societies, that make this machinery work. When I meet with my counterparts from other countries, I find that their plans and priorities are very similar to ours – not because they are copying from us, but because we all are paying attention to the same global science community.

This consensus about science opportunities, however, is not enough. Science has an insatiable appetite for resources, and at some point choices have to be made, including choices among opportunities in entirely different fields. The usual approach to this difficult task is to establish criteria at the policy level within government that are as self-evident as possible, and then apply them through expert committees. But that is difficult when it comes to judgments of value across different fields, which is ultimately what needs to be done.

A very important contribution to cross-field prioritization, by no means uncontroversial, appeared in an article by Alvin Weinberg, then Director of Oak Ridge National Laboratory, in a July 1961 issue of Science Magazine, "*The Impact of Large-Scale Science on the United States*." Weinberg collected similar thoughts in his book "*Reflections on Big Science*" that appeared later in the decade, but the article asked specific questions that have acquired new significance here at the dawn of the 21$^{st}$ century: (1) "Is Big Science ruining science?" [Weinberg thought so, but I don't.] (2) "Is Big Science ruining us financially?" [Weinberg thought it would if then-current trends continued, but they didn't.] and (3) "Should we divert a larger part of our effort toward scientific issues which bear more directly on human well-being than do such Big-Science spectaculars as manned space travel and high-energy physics?" You can hear Weinberg stacking the deck with these words, but he pointed out the need for balance among areas of science that were more and less related to societal problems. Recall that President Kennedy had given his historic speech launching the Apollo program earlier that same year, 1961, and NASA's budget was increasing at a rate that would soon put it way over the 10% trend line for the non-defense R&D share of the domestic budget. Medical research had also begun its historic rise, but it was still small, and overshadowed by the rise of Apollo.

In the four decades following Weinberg's article, the non-defense R&D budget has been dominated by NIH and NASA – Big Science on the one hand, and "science for human well-being" on the other. Other areas have grown, but only the growth in medical research has been both substantial and sustained, culminating in the recent doubling of the NIH budget. Weinberg asked his questions about Big Science at the leading edge of the huge growth in NASA budgets, when the sciences "bearing more directly on human well being" were still small. During the intervening decades, "Small Science" has grown up – and not only health research. The evolution of computing and instrumentation during the past four decades has accumulated astonishingly into a revolution that is transforming all science, but opens particularly attractive opportunities on what I like to call the *frontier of complexity*, which includes biotechnology, nanotechnology, large portions of chemistry and materials science, and even some aspects of the social sciences.

While all this change was taking place in the instrumental and information context of science, the Cold War was grinding its way to conclusion, and Congress began to reassess the rationale for federal support for all the sciences. The only visible impact on science funding patterns caused by the end of the Cold War was an acceleration in health research relative to other fields. At least part of the reason for this was a lingering conviction within Congress that the basis for support of physical science, particularly in the national laboratories, was national security, and national security needs were changing. I well recall the dire predictions of then-House Science Committee Chairman George Brown regarding the altered circumstances for federal science funding. During the early nineties, in the aftermath of the collapse of the Soviet Union, funding for research through the Departments of Defense and Energy stagnated, and funding for the National Science Foundation, and particularly the National Institutes of Health, advanced. Annual average increases from 1990 to 2003 were nearly 10% for NIH, and 6% for NSF compared with a 3.5% overall annual average increase for all R&D during those years. Compare that with just over 2% for DOE, the principal sponsor of physical science, and only 1.4% for DOD. The result is that today NIH "owns" nearly half of the $58 billion U.S. Federal Science and Technology budget. No other science agency has more than 15%. The Federal Science and Technology pie today divides as follows: NIH 47%; NASA 14%; DOE 11%; DOD 9%; NSF 7%; USDA 3%.

That post-Cold War soul-searching about federal support for physical science led to important studies and planning initiatives. A study of DOE's national laboratories in 1994-95 led by Motorola's Robert Galvin ("*Alternative Futures for the DOE National Laboratories*"1995) stimulated a massive, and I think largely successful, science and technology "road-mapping" exercise that reformed the missions of the laboratories. Today DOE's large multi-program laboratories at Argonne, Berkeley, Brookhaven, Oak Ridge, and Richland, Washington, all have coherent programs centered on large scale facilities serving large university and industry based user communities (not that the other laboratories don't, but except for SLAC at Stanford, they are more narrowly focused on single areas of science). The pace of similar movements in the Department of Defense is slower, but they do exist.

Before the end of the 1990's, economic analyses began to appear that showed how closely related the advance of important new technologies was to prior investments in basic research, especially in the physical sciences (see reports and summaries by NIST's senior economist, Greg Tassey, on the NIST website). The growing demand by medical researchers for access to instrumentation and information technology added to an increasing concern that physical science funding was falling behind. Today the post-Cold War uncertainty about the basis for physical science funding has been substantially resolved. Long term economic competitiveness has become a major, and in some cases the primary, justification for continued federal support. Weinberg's science that "bears more directly on human beings" has gained in stature as well as in scale.

The priorities of this Administration reinforce a realignment between physical and life sciences with specific initiatives, some with long histories. The inexorable advance and convergence of nano-, info- and bio-science and technology is one major driver for these priorities. Emerging concerns about terrorism is another. Explicit budget priorities also exist for energy, environmental and education issues that are part of the national discourse. RPI President Shirley Jackson has contributed substantially to this discourse, and my colleagues and I are grateful for her insights. In the immediate future, tight budgets will make it difficult to effect large changes quickly in the current pattern of funding, but the trends are clear, and I am confident that with time the efforts underway will succeed.

I intend to comment on federal programs in two of the most important emerging priority areas, and then answer questions about the others, as time permits. But before I do, let me take a moment to explain how my office, the Office of Science and Technology Policy, is involved in setting and implementing these priorities. We are a White House policy office with about 50 people, mostly science and engineering professionals, distributed among nine technical departments that span the entire spectrum of science and technology. We call together, under the authority of the President, interagency policy and coordination groups that collectively identify priorities and actions to address them. Each affected agency has representatives in the process so annual requests from the agencies to the Office of Management and Budget tend to reflect the consensus. As the agency proposals come in for inclusion in the President's budget request to Congress, OSTP works with OMB to make sure they are consistent with the priorities. After the President releases his budget, OSTP works with the Congressional appropriations committees to encourage alignment of the budget bills with the President's request. Meanwhile the interagency working groups are meeting to develop R&D priorities for the following year, which are condensed into an annual Memorandum of Guidance to Agencies issued jointly by OSTP and OMB.

This year's OSTP/OMB guidance memorandum to science agencies listed five specific interagency priority areas: *R&D for Combating Terrorism, Nanotechnology, Networking and Information Technology, Molecular Level Understanding of Life Processes, and Environment and Energy*. I will say a few words about the first two of these, but after my talk I would be glad to answer questions about any of them.

Under the "*Combating Terrorism*" R&D initiative, the guidance memo lists seven priority areas that may be of interest to this audience. They are:

(1) "enhancing detection, treatment, and remediation of chemical, biological, and radiological threats;
(2) "developing and transitioning technology to support first responders;
(3) exploiting the significant advances in human and microbial genetic sequencing to promote the development of novel or next-generation vaccines, therapeutics and diagnostics to counter biological threat agents;
(4) "converting the vast amount of intelligence data into actionable knowledge;
(5) "assessing the social and behavioral aspects of terrorism to help anticipate, counter, and diffuse threats to our homeland security;
(6) "facilitating inspection of cargo and people at ports-of-entry; and
(7) "securing critical infrastructure including information infrastructure.

These are priorities that apply to programs within any agency. For FY04, President Bush asked Congress for $920 million for R&D under the new Department of Homeland Security that would be disbursed under eight programs as follows:

- $88 million for the *National Biodefense Analysis and Countermeasures Center*—a "hub and spoke" system to increase the understanding of and improve measures against potential bioterrorism pathogens;

- $98 million for *Threat and Vulnerability Testing and Assessment* including $11 million for cyber security R&D;

- $75 million for the *Rapid Prototyping Program* to facilitate the rapid adaptation of commercial technologies for counter-terrorism measures by DHS and first responders;

- $70 million for the *Homeland Security Scholars and Fellows Program,* which will allow graduate and undergraduate students to pursue scientific studies in homeland security, and will fund the establishment of *Homeland Security Centers of Excellence* at universities across the country;

- $67 million for *critical infrastructure protection*, including $60 million for research, development, testing, and evaluation of anti-missile technology for commercial aircraft;

- $134 million for the development of sensors and other countermeasures *to prevent the unauthorized transport and use of radiological and nuclear materials* within the
- United States;

- $40 million for developing a *database of homeland security-related standards* for the private sector for devices such as radiation detectors, and protocols for analysis of high explosives, chemical agents, and toxic chemicals; and

- $15 million for the *Urban Monitoring Program*, also known as *Project BioWatch*.

I list these programs in detail because they help to define the character of the newest Federal science funding agency. The DHS Science and Technology office reports to Dr. Charles McQueary, Undersecretary for Science and Technology.

One of the central themes of the current homeland security S&T agenda is bioterrorism, which is funded primarily not through DHS, but through the NIH Institute for Allergenic and Infectious Diseases. This effort includes three bioterrorism-related interagency initiatives. *Project BioWatch* is a cooperative effort among DHS, EPA, and CDC to provide an early warning system for bio-threats. There are currently over 4000 atmospheric monitoring stations nation-wide for the detection of atmospheric pollutants, and under this project atmospheric samples in numerous cities are monitored around-the-clock for select agents. This network was established very rapidly and much work remains to be done to take full advantage of it, but it is functioning today. *Project BioSense* is intended to reduce the lag time between the detection of a possible bio-agent and an appropriate response. This project, still in its infancy, will depend on multiple streams of information to facilitate rapid decision making. The information will converge at the CDC's Biointelligence Center, first for analysis, and then, if warranted, for coordinated response. *Project BioShield* was unveiled by the President in his State of the Union address in January. The project spurs the development and procurement of "next generation" medical countermeasures against biological, chemical, radiological, or nuclear agents; facilitates the development and funding of promising areas of research in medical countermeasures for these agents; and establishes a new emergency use authorization for certain medical therapeutics not yet otherwise approved.

All of these initiatives might be described as *preparedness programs.* There is also a need for what I would call *prevention programs*. On June 12 last year, President Bush signed the *Public Health Security and Bioterrorism Preparedness and Response Act* which will increase security in facilities that hold significant biological agents that are defined on either the *select agent* list maintained by the CDC or the *high consequence pathogen* list maintained by the USDA. The law requires registration, and requires that facilities provide physical security measures. This law is an example of how preventing terrorism entails restrictions or constraints on activities that society would not choose to regulate in an ideal world. We in the

Administration understand that science progress includes securing the freedom to engage in open scientific discourse. At the same time, technical information that might be exploited by terrorists cannot responsibly be permitted to flow without any scrutiny whatever. The same society that supports our research also wishes to be protected from its undesirable consequences. To explore the implications of this responsibility, the National Academies convened an expert panel chaired by MIT's Gerald Fink—*The Committee on Research Standards and Practices to Prevent the Destructive Application of Biotechnology.* The Committee's recommendations for achieving these goals included educating the scientific community, reviewing plans for certain experiments, reviewing research results at the publication stage, creating a *National Security Advisory Board for Biodefense,* and controlling certain sensitive materials.

Since RPI has several strong programs that address homeland security, the advice from the Fink report and implementing their recommendations is partly your responsibility. I know that open yet responsible research is one of your goals. Three years ago, RPI launched the nation's first undergraduate degree program in Bioinformatics, and the Institute now offers masters and doctoral programs. In June 2000, RPI joined with the Wadsworth Center of the New York State Department of Health to form the Center for Bioinformatics, a partnership intended to stimulate collaborative research among computational and experimental biologists at the two institutions. You have a new $80 million Center for Biotechnology and Interdisciplinary Studies at the center of your campus. And your Center for Terahertz Research is conducting research in biomedical imaging, genetics diagnostics, microelectronics, and chemical and biological materials identification. Everyone who works in these fields, or more generally on issues related to bioterrorism, should be aware of the recommendations of the Fink committee report and take them to heart.

I will close with some remarks about the second of the current federal science and technology priority areas – nanotechnology. Here is what the OMB/OSTP guidance memo says about this area:

"The National Nanotechnology Initiative (NNI) continues to offer great promise broadly across many scientific fields and most sectors of the economy, and remains an Administration priority. The NNI supports both fundamental and applied R&D in nanotechnology and nanoscience across a broad range of areas, development of nanoscale instrumentation and metrology, and the dissemination of new technical capabilities to industry. Nanoscale R&D priority areas continue to include material science and research relevant to medical care and homeland security. Though research at the nanoscale offers natural bridges to interdisciplinary collaboration, especially at the intersection of the life and physical sciences, the Administration encourages novel approaches to accelerating interdisciplinary and interagency collaborations. Activities such as joint programs utilizing shared resources, as well as support for interdisciplinary activities at centers and user facilities, are encouraged."

Ten federal agencies currently support or conduct research and development on nanotechnology, including the Departments of Defense, Energy, and Commerce, along with the National Science Foundation and the National Institutes of Health. To coordinate these activities, the National Nanotechnology Initiative was established in FY 2001. The NNI is an interagency effort aimed at maximizing the return on the Federal government's investment in nanotechnology through coordination of funding, research, and infrastructure development activities at the individual agencies. In FY 2004, the President requested $849 million for nanotechnology R&D, an increase of 10% over his request in FY 2003, and an increase of more than 80% from the first year of the initiative. Congress is also very supportive of nanotechnology and both the House and Senate are considering bills that would authorize over $2 billion in funding through FY 2008 for nanoscience, engineering and technology research and development. The bills also recognize the need for education and training, as well as the study of social, ethical, and environmental implications of nanotechnology.

Speaking of societal implications, the U.S. government is committed to research in social implications as the nano-component of commercial products moves increases. The NNI annual investment in research on societal implications, including education and workforce preparation needs, is estimated at about $30 million, of which the NSF awards about $23 million. Nanoscale research related to the environment and environmental impacts was approximately $50 million in FY 2003. Together these expenditures accounted for roughly 10% of the NNI budget.

Perhaps the single largest area of research within the NNI is nanoelectronics. Already the dimensions of electronic circuits are on the nanoscale and the semiconductor industry anticipates that structures will need to be on the order of 10-nm in 2015 if we are to continue the Moore's law trend. This Administration believes the U.S. can and should maintain leadership in advanced electronics. Just last week, the NSF and the Semiconductor Research Corporation (SRC) signed a "statement of principles" outlining a partnership to support university research for future technologies. The partnership, "Silicon Nanoelectronics and Beyond," will support research needs identified in the International Technology Roadmap for Semiconductors and research in the integration of biological, molecular, and other emerging areas of electronics at the nanoscale.

I am sure you are aware that the electronics and IT industries, which play a large role in the U.S. economy by providing high-skill, high-wage jobs and value-added products, have suffered in the recent economic downturn. There has been a substantial migration of these jobs overseas. In March 2003, the President's Council of Advisors on Science and Technology (PCAST), which I co-chair with Silicon Valley venture capitalist Floyd Kvamme, formed a subcommittee to examine the issues surrounding this trend and make recommendations for increasing U.S. competitiveness. There *are* key opportunities here at home. In their draft report, the PCAST pointed out that in leading edge industries, such as IT, there is a high degree of interdependence between R&D and manufacturing. "Locations that possess both strong R&D centers and manufacturing capabilities have a competitive edge." Several major manufacturers told PCAST that they decided to locate new plants in the U.S. due to the proximity of leading university R&D capabilities. For example, in your own area there are:

- The joint University at Albany-RPI Focus Center at New York, established in 1998 and re-designated in 2001, which is part of a Semiconductor of America/DARPA driven Focus Center Research Program. This Focus Center is a strategic partnership between RPI and Albany, other NY universities that participate on a project-by-project basis, the New York State government; the federal government; and the microelectronics, optoelectronics, bioelectronics, and telecommunication industries.
- There is also RPI's Center for Broadband Data Transport Science and Technology, which was formed in 2002 through a partnership with IBM. IBM's contribution includes a major donation of computer hardware and software provided through its

Shared University Research program. Valuable access to IBM's device, processing, and packaging capabilities over the next five years will provide state-of-the-art technical support for the Center.

This morning I received briefings on other technology research and development programs at RPI, all of which are conducted with industrial partners, and in collaborations with other institutions. These are impressive programs, and appear to be aligned with current federal funding priorities.

In closing, I would like to thank Dr. Jackson again for inviting me to be the first speaker in her Presidential Lecture series. I congratulate you on the leadership RPI has shown in forming partnerships with government and industry to invigorate the economy and quality of life in New York's capital region.

Thank you.