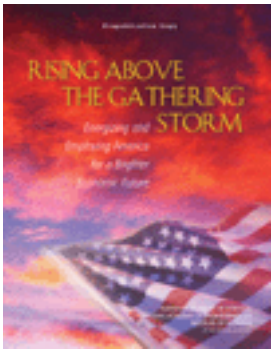

Rising Above The Gathering Storm: Energizing and Employing America for a Brighter Economic Future

Committee on Prospering in the Global Economy of the 21st Century:An Agenda for American Science and Technology, National Academy of Sciences, National Academy of Engineering, Institute of Medicine

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EXECUTIVE SUMMARY

The United States takes great pride in the vitality of its economy, which forms the foundation of our high quality of life, our national security, and our hope that our children and grandchildren will inherit ever-greater opportunities. That vitality is derived in large part from the productivity of well-trained people and the steady stream of scientific and technical innovations they produce. Without high-quality, knowledge-intensive jobs and the innovative enterprises that lead to discovery and new technology, our economy will suffer and our people will face a lower standard of living. Past economic studies have estimated as much as 85% of measured growth in US income per capita is due to technological change.[1]

Today, Americans are feeling the gradual and subtle effects of globalization that challenge the economic and strategic leadership the United States has enjoyed since World War II. A substantial portion of our workforce finds itself in direct competition for jobs with lower-wage workers around the globe, and leading-edge scientific and engineering work is being accomplished in many parts of the world. Thanks to globalization, driven by modern communications and other advances, workers in virtually every sector must now face competitors who live just a mouse-click away in Ireland, Finland, China, India, or dozens of other nations whose economies are growing.

CHARGE TO THE COMMITTEE

The National Academies Committee on Prospering in the Global Economy of the 21st Century was asked by several members of Congress to respond to the following questions:

What are the top ten actions, in priority order, that federal policy makers could take to enhance the science and technology enterprise so the United States can successfully compete, prosper, and be secure in the global community of the 21st Century? What implementation strategy, with several concrete steps, could be used to implement each of those actions?

This charge constitutes a challenge both daunting and exhilarating: to recommend to the nation specific steps that can best strengthen quality of life in America—our prosperity, our health, our security. The committee has been careful in its analysis of information. However, *the available information is insufficient for the committee's needs. In addition, the limited timeframe to develop the report (10 weeks from the time of the committee's meeting to report release) is insufficient to conduct an independent analysis. Even if unlimited time were available, analysis on many issues is not possible given the uncertainties involved.*

The recommendations in this report rely heavily on the consensus views and judgments of its committee members. Although the committee includes leaders from academia, industry, and government—several current and former industry chief executive

[1] Work by Robert Solow and Moses Abramovitz published in the mid-1950s demonstrated that as much as 85% of measured growth in US income per capita during the 1890-1950 period could not be explained by increases in the capital stock or other measurable inputs. The big unexplained portion, referred to alternatively as the "residual" or "the measure of ignorance," has been widely attributed to the effects of technological change.

officers, university presidents, researchers (including three Nobel prize winners), and presidential appointees—the array of topics and policies covered in this study is so broad that it was impossible to assemble a committee of 20 members with directly relevant expertise in each. Because of those limitations, the committee has relied heavily on the judgments of many experts in the study's focus groups, additional consultations via e-mail and telephone with other experts, and the unusually large panel of reviewers.

The committee believes its recommendations will help the United States achieve prosperity in the 21st century. The actions and programs proposed are the committee's views on how to implement these recommendations, although other groups of experts in each field may come up with a different set of proposals.

FINDINGS

Having reviewed the trends in the United States and abroad, the committee is deeply concerned that the scientific and technical building blocks of our economic leadership are eroding at a time when many other nations are gathering strength. We strongly believe that a world-wide strengthening will benefit the world's economy—particularly in the creation of jobs in countries that are far less well-off than the United States—but we are worried about the future prosperity of the United States. Although many people assume that United States will always be a world leader in science and technology, this may not continue to be the case inasmuch as great minds and ideas exist throughout the world. We fear the abruptness with which a lead in science and technology can be lost and the difficulty of recovering a lead once lost—if indeed it can be regained at all.

This nation must prepare with great urgency to preserve its strategic and economic security. Because other nations have, and probably will continue to have, the competitive advantage of low-wage structure, the United States must compete by optimizing its knowledge-based resources, particularly in science and technology, and by sustaining the most fertile environment for new and revitalized industries and the well-paying jobs they bring. We have already seen that capital, factories, and laboratories readily move wherever they are thought to have the greatest promise of return.

RECOMMENDATIONS

The committee reviewed hundreds of detailed suggestions—including various calls for novel and untested mechanisms—from other committees, from its focus groups, and from its own members. The challenge is immense, and the actions needed to respond are immense as well.

The committee identified two key challenges that are tightly coupled to scientific and engineering prowess: creating high-quality jobs for Americans and responding to the nation's need for clean, affordable, and reliable energy. To address those challenges, the committee structured its ideas according to four basic recommendations that focus on the human, financial, and knowledge capital necessary for US prosperity. The four recommendations and 20 actions to implement them are set forth in the following sections.

Some actions involve changes in the law. Others require funds that would ideally come from reallocation of existing funds, but if necessary new funds. Overall, the committee believes that the investments are modest relative to the magnitude of the return

the nation can expect in the creation of new high-quality jobs and in responding to the nation's energy needs.

TEN THOUSAND TEACHERS, TEN MILLION MINDS

Recommendation A*: Increase America's talent pool by vastly improving K-12 mathematics and science education*.

Implementation Actions

The highest priority should be assigned to the following actions and programs. All should be subjected to continuing evaluation and refinement as they are implemented:

Action A-1: Recruit ten thousand teachers, Educate ten million minds. Attract 10,000 of America's brightest students to the teaching profession each year each of whom can have an impact on 1,000 students over their career. The program would award competitive 4-year scholarships for students to obtain bachelor's degrees in the physical or life sciences, engineering, or mathematics with concurrent certification as K-12 mathematics and science teachers. The merit-based scholarships would provide $10,000–20,000 a year for 4 years for qualified educational expenses, including tuition and fees, and require a commitment to 5 years of service in public K-12 schools. A $10,000 annual bonus would go to participating teachers in underserved schools in inner cities and rural areas. To provide the highest-quality education for undergraduates who want to become teachers, it would be important to award matching grants, perhaps $1 million a year for up to 5 years, to as many as 100 universities and colleges to encourage them to establish integrated 4-year undergraduate programs leading to bachelors' degrees in science, engineering, or mathematics *with teacher certification*.

Action A-2: Strengthen two hundred fifty thousand teachers' skills, Inspire students every day. Use proven models to strengthen the skills (and thus compensation which is based on education and skill level) of 250,000 *current* K-12 teachers:

- *Summer institutes:* Provide matching grants to state and regional 1- to 2-week summer institutes to upgrade as many as 50,000 practicing teachers each summer. The material covered would allow teachers to keep current with recent developments in science, mathematics, and technology and allow for the exchange of best practices. The Merck Institute for Science Education is a model for this recommendation.
- *Science and mathematics master's programs:* Provide grants to universities to offer 50,000 current middle-school and high-school science, math, and technology teachers (with or without science, math, or engineering degrees) 2-year, part-time master's degree programs that focus on rigorous science and mathematics content and pedagogy over a 5-year period. The model for this recommendation is the University of Pennsylvania Science Teachers Institute.
- *Advanced Placement (AP), International Baccalaureate (IB), and pre-AP or pre-IB training:* Train an additional 70,000 AP or IB and 80,000 pre-AP or pre-IB instructors to teach advanced courses in mathematics and science. There are two models for this recommendation: the Advanced Placement Incentive Program and Laying the Foundation, a pre-AP program.

- *K-12 curriculum materials modeled on world-class standards.* Foster high-quality teaching with world-class curricula, standards, and assessments of student learning. Convene a national panel to collect, evaluate, and develop rigorous K-12 materials that would be available free of charge as a *voluntary* national curriculum. The model for this recommendation is the Project Lead the Way pre-engineering courseware.

Action A-3: Enlarge the pipeline. Create opportunities and incentives for middle-school and high-school students to pursue advanced work in science and mathematics. By 2010, increase the number of students in AP or IB mathematics or science courses from 1.125 million to 4.5 million, and set a goal of tripling the number who passes those tests, to 700,000, by 2010. Some approaches to improving K-12 science and mathematics education are already in use and should be expanded, including:

- *Statewide specialty high schools.* Specialty secondary education can foster leaders in science, technology, and mathematics. Specialty schools immerse students in high-quality science, technology, and mathematics education; serve as a mechanism to test teaching materials; provide a training ground for K-12 teachers; and provide the resources and staff for summer programs that introduce students to science and mathematics.
- *Inquiry-based learning.* Laboratory experience should be available to all students, and summer internships and research opportunities should be expanded to serve at least 2,000 middle-school and high-school students each year.

SOWING THE SEEDS

Recommendation B: ***Sustain and strengthen the nation's traditional commitment to the long-term basic research that has the potential to be transformational to maintain the flow of new ideas that fuel the economy, provide security, and enhance the quality of life.***

Implementation Actions

Action B-1: Increase the federal investment in long-term basic research, ideally through reallocation of existing funds but also if necessary via new funds by consenting to an increase of 10% annually over the next 7 years. Special attention should go to the physical sciences, engineering, mathematics, and information sciences and to Department of Defense (DOD) basic-research funding. This special attention does not mean that there should be a disinvestment in such important fields as the life sciences (which have seen growth in recent years) or the social sciences. A balanced research portfolio in all fields of science and engineering research is critical to US prosperity**.** So that the nation obtains the best return, this investment should be evaluated regularly to realign the research portfolio—unsuccessful projects and venues of research should be replaced with emerging research projects and venues that have greater promise.

Action B-2: Provide new research grants of $500,000 each annually, payable over 5 years, to 200 of our most outstanding *early-career* researchers. The grants would be made through existing federal research agencies—the National Institutes of Health (NIH), the National Science Foundation, the Department of Energy (DOE), DOD, and the National Aeronautics and Space Administration—to underwrite new research opportunities at universities and government laboratories.

Action B-3: Institute a National Coordination Office for Research Infrastructure to manage a centralized research-infrastructure fund of $500 million per year over the next 5 years to ensure that universities and government laboratories create and maintain the facilities and equipment needed for leading-edge scientific discovery and technologic development. Universities and national laboratories would compete annually for the funds.

Action B-4: Allocate at least 8% of the budgets of federal research agencies to discretionary funding that would be managed by technical program managers in the agencies and focused on catalyzing high-risk, high-payoff research.

Action B-5: Create in DOE an organization like the Defense Advanced Research Project Agency (DARPA) called the Advanced Research Project Agency-Energy (ARPA-E) which would report to the under secretary for science and would be charged with sponsoring specific research and development programs to meet the nation's long-term energy challenges. The new agency would support creative out-of-the-box transformational energy research that industry by itself cannot or will not

support and in which risk may be high, but success would provide dramatic benefits for the nation. This would accelerate the process by which knowledge obtained through research is transformed to create jobs and address environmental, energy, and security issues. Based on the historically successful DARPA model, ARPA-E would be designed as a lean and agile organization with a great deal of independence that can start and stop targeted programs on the basis of performance. The agency would perform no research or transitional effort itself but would fund such work conducted by universities, start-ups, established firms, etc. Its staff would turn-over approximately every 4 years. Although the agency would be focused on specific energy issues, it is expected that its work (like that of DARPA or NIH) will have spin-off benefits, including aiding in the education of the next generation of researchers.

Action B-6: Institute a Presidential Innovation Award to stimulate scientific and engineering advances in the national interest. While existing Presidential awards address lifetime achievements or promising young scholars, these awards would identify and recognize individual who develop unique scientific and engineering innovations in the national interest at the time they occur.

BEST AND BRIGHTEST

Recommendation C: ***Make the United States the most attractive setting in which to study, perform research, and commercialize technologic innovation so that we can develop, recruit, and retain the best and brightest students, scientists, and engineers from within the United States and throughout the world.***

Implementation Actions

Action C-1: Increase the number and proportion of US citizens who earn physical and life sciences, engineering, and mathematics bachelor's degrees by providing 25,000 new 4-year undergraduate scholarships each year to US citizens attending US institutions. The Undergraduate Scholar Awards in Science, Technology, Engineering, and Mathematics (USA-STEM) would be distributed to states on the basis of the size of their congressional delegations and awarded on the basis of competitive national examinations. The award would provide up to $20,000 for tuition and fees.

Action C-2: Increase the number of US citizens pursuing graduate study "in areas of national need" by funding 5,000 new graduate fellowships each year. NSF should administer the program and draw on the advice of other federal research agencies to define areas of national need. The focus on areas of national need is important both to ensure an adequate supply of doctoral scientists and engineers and to ensure that there are appropriate employment opportunities for students upon receipt of their degrees. Portable fellowships would provide funds directly to students, who would choose where to pursue graduate studies instead of being required to follow faculty research grants.

Action C-3: Provide a federal tax credit to encourage employers to make continuing education available (either internally or though colleges and universities) to practicing scientists and engineers. These incentives would promote career-long learning to keep the workforce current in the face of rapidly evolving scientific and engineering discoveries and technologic advances and would allow for retraining to meet new demands of the job market.

Action C-4: Continue to improve visa processing for international students and scholars to provide less complex procedures, carefully consider new regulations; and continue discussion with research institutions on visa categories and duration, travel for scientific meetings, the technology-alert list, reciprocity agreements, and changes in status.

Action C-5: Provide a 1-year automatic visa extension to international students who receive doctorates or equivalent in science, technology, engineering, mathematics, or other areas of national need at qualified US institutions to remain in the United States to seek employment, and should these students be offered jobs by U.S. based employers and pass a security screening test provide an automatic work permits and expedite their residency status. If students are unable to obtain employment within a 1-year time period, their visa would expire.

Action C-6: Institute a new skills-based, preferential immigration option. Doctoral-level education and science and engineering skills would substantially raise an applicant's chances and priority in obtaining US citizenship. In the interim, the number of H-1B visas should be increased by 10,000, and the additional visas should be available for industry to hire science and engineering applicants with doctorates from US universities.

Action C-7: Reform the current system of "deemed exports". The new system should provide international students and researchers engaged in fundamental research in the United States with access to information and research equipment in US industrial, academic, and national laboratories comparable with the access provided to US citizens and permanent residents in a similar status. It would, of course, exclude information and facilities restricted under national security regulations. In addition, the effect of deemed-exports regulations on the education and fundamental research work of international students and scholars should be limited by removing all technology items (information and equipment) from the deemed exports technology list that are available for purchase on the overseas open market from foreign or US companies or that have manuals that are available in the public domain, in libraries, over the Internet, or from manufacturers.

INCENTIVES FOR INNOVATION

Recommendation D: ***Ensure that the United States is the premier place in the world to innovate, invest in downstream activities, and create high-paying jobs that are based on innovation by modernizing the patent system, realigning tax policies to encourage innovation, and ensuring affordable broadband access.***

Implementation Actions

Action D-1: Enhance intellectual-property protection for the 21st century global economy to ensure that systems for protecting patents and other forms of intellectual property underlie the emerging knowledge economy, yet allow research to enhance innovation. The patent system requires reform of three specific kinds:

- Protect resources for the Patent and Trademark Office to give that office sufficient resource to make intellectual-property protection more timely, predictable, and effective.
- Reconfigure the US patent system by switching to a "first-inventor-to-file" system, and by instituting administrative review after the patent is granted. Those reforms would bring the US system into alignment with patent systems in Europe and Japan.
- Shield some research uses of patented inventions from infringement liability. One recent court decision could jeopardize the long-assumed ability of academic researchers to use patented inventions for research.
- Change intellectual property laws that act as barriers to innovation in specific industries, such as those related to data exclusivity (in pharmaceuticals) and those that increase the volume and unpredictability of litigation (especially in IT industries).

Action D-2: Enact a stronger research and development tax credit to encourage private investment in innovation. The current Research and Experimentation Tax Credit goes to companies that *increase* their research and development spending above a base amount calculated from their spending in prior years. Congress and the administration should make the credit permanent, and it should be increased from 20% to 40% of the qualifying increase so that the U.S. tax credit is competitive with that of other countries. The credit should be extended to companies that have consistently spent large amounts on research and development so that they will not be subject to the current *de facto penalties* for investing in research and development.

Action D-3: Provide tax incentives for United States-based innovation. Many policies and programs affect innovation and the nation's ability to profit from it. It was not possible for the committee to conduct an exhaustive examination, but alternatives to current economic policies should be examined, and if deemed economically beneficial to the United States, pursued. These alternatives could include changes to overall corporate tax rates, provision of incentives for the purchase of high-technology research and manufacturing equipment, treatment of capital gains, and incentives for long-term investments in innovation. The Council of Economic Advisors and the Congressional Budget Office should conduct a comprehensive analysis to examine how the United States compares with other nations as a location for innovation and related activities with a view to ensuring that the United States is one of the most attractive places in the world for long-term innovation-related investment.

Action D-4: Ensure ubiquitous broadband Internet access. Several nations are well ahead of the United States in providing broadband access for home, school, and

business. That capability will do as much to drive innovation, the economy, and job creation in the 21st century as did access to the telephone, interstate highways, and air travel in the 20th century. Congress and the administration should take action—mainly in the regulatory arena and in spectrum management—to ensure affordable broadband access.

CONCLUSION

The committee believes that the recommendations offered here merit serious consideration if we are to ensure that our nation continues to enjoy the jobs, security, and high standard of living that this and previous generations worked so hard to create in an economy with access to clean, affordable, and reliable energy. Although the committee was asked only to recommend actions that can be taken by the federal government, it is clear that related actions at the state and local levels are equally important for US prosperity, as are actions taken by each American family. The United States faces an enormous challenge because of the disadvantage it faces in labor cost. Science and technology provide the opportunity to overcome that disadvantage by creating scientists and engineers with the ability to create entire new industries—much as has been done in the past.

It is easy to be complacent about US competitiveness and preeminence in science and technology. We have led the world for decades, and we continue to do so in many research fields today. But the world is changing rapidly, and our advantages are no longer unique. Without a renewed effort to bolster the foundations of our competitiveness, we might lose our privileged position. For the first time in generations, the nation's children could face poorer prospects than their parents and grandparents did. We owe our current prosperity, security, and good health to the investments of past generations, and we are obliged to renew those commitments in education, research, and innovation policies to ensure that the American people continue to benefit from the remarkable opportunities provided by the rapid development of the global economy.