

NATIONAL INNOVATION INITIATIVE

Innovation Frontiers

Working Group Final Report

RECOMMENDATIONS IN BRIEF

For America to maintain its global leadership in innovation, the nation must revitalize its research efforts at the frontiers. The NII Innovation Frontiers Working Group recommends these important steps be taken:

- Allocate an increasing portion of future new research funding to multi- and interdisciplinary research and to the facility and research infrastructure that underpins it.
- The concept of a science of services and associated understanding of enterprise dynamics and transformation should be recognized as research disciplines. Government, industry, and universities should invest in these disciplines and develop a future class of education and research programs and centers.
- Stimulate breakthroughs in manufacturing by increasing future research investments in nano-scale production, multifunctional materials, and inter- as well as intra-facility process simulation. Access to research and infrastructure for innovation in manufacturing should be made available to small and large enterprises.
- Provide translational mechanisms and funds for commercialization of university-led innovations.
- Increase incentives, through mechanisms such as portable fellowships and innovation scholarships, to encourage more Americans from a diversity of backgrounds to become scientists and engineers.
- The federal government should institute proactive immigration policies in support of innovation goals, e.g. automatic work permits that would enable foreign students at U.S. universities to take scientific and technical positions with domestic companies.

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BACKGROUND

A robust national program of research at the frontiers is critical to U.S. success in innovation. “Innovation frontiers” refers to the discovery and application of new knowledge to areas with potential for explosive future growth or significant societal impact. This contrasts with productivity research, aimed at applying new knowledge to existing commodity goods or services, and invention, which applies new knowledge to patentable goods or services.¹

Publicly financed research has been the bedrock of American innovation. Many of the country’s most innovative industries were built on decades of research -- often in fields that had no discernible application at the time. No one imagined in the 1940s that the arcane field of quantum mechanics would launch the semiconductor revolution. The engineers that developed time-sharing and packet switching techniques probably did not envision the worldwide web or e-commerce. Investment infrastructure and instrumentation led to new research tools, such as lasers, high-performance computers, and atomic resolution microscopy. These, in turn, enticed the creation of whole new fields of application, e.g. laser chemistry, computational biology, and nano-technologies, and research in these fields promises to lead us to the industries of tomorrow.

CHALLENGES

Declining Public Investment

While U.S. capability in frontier research remains strong, the nation’s margin of global leadership is beginning to narrow. Our decades’ long commitment to research and development has weakened. The Federal government – the mainstay of long-term, frontier research – is spending less today on R&D as a share of national wealth than it did in 1985. Growth in R&D spending was slower over the last economic boom period than in any previous boom of the past 25 years. The government is also contributing a decreasing share of the nation’s total R&D budget; in real terms, the federal contribution has dropped from 46 percent in 1985 to around 25 percent today. Private-sector investments have more than offset these declines in government funding, but the bulk of industrial research activities focus on the development of new products and processes, not on basic discovery.

Industry relies heavily on public science for its own innovation. Over 73 percent of U.S. industry patents cite publicly funded science as the basis for an invention.² There is a risk that declines in federal research funding could impede industry’s progress in innovation.

Investment in physics, chemistry, math and many engineering fields has declined in real terms. The national goal of leading (or being among the leaders) in every major scientific

¹ P. Drucker, *Managing for the Future: The 1990s and Beyond*. New York: Penguin, 1992.

² F. Narin, K. Hamilton and D. Olivastro. “The Increasing Linkage between U.S. Technology and Public Science,” *Research Policy*, 26, 3, 1997, 317-330.

and technology field is threatened by uneven support for research across the major disciplines. Also, new technologies and products in many sectors, including the health sector, depend on concurrent advances across many physical science-related fields.

Industrial Frontier Research on the Decline

The “industry-university-government triangle” has played a dominant role in U.S. innovation since World War II, but the respective roles of the partners have shifted. Industrial laboratories were the prime movers of innovation throughout much of the 20th century, but this component of the national research infrastructure, with the exception of efforts by biotechnology and pharmaceutical firms, has been receding. Even though the overall levels of private sector R&D have increased, corporate commitment to world-class, long-term research has largely disappeared. Corporate investment, with the aforementioned exceptions, has shifted from industrial research laboratories to development efforts with much shorter time horizons.

As a consequence, universities are carrying a heavy load: They are called on to conduct the long-term research necessary for breakthrough business and economic innovations; they’re charged with addressing societal challenges in health care, natural resources, and other areas; and they are responsible for educating the next generation of scientists and engineers.

The federal government is still expected to provide financial support for long-term basic research and infrastructure, and officials are operating within increasingly tight budgetary constraints.

Need for Innovation Research into Services

America continues to shift towards a knowledge-based services economy. Services industries’ share of gross domestic product grew from 33 percent in 1950 to over 70 percent in 2000. While most past innovation research has focused on the goods-producing sector, the research foundation must now be laid to ensure U.S. global leadership in the knowledge-based services sector.³

Private Investment focuses downstream

Until the late 1990s, venture capitalists and other private investors provided funding for early stage ideas. The economic downturn of the early 2000s resulted in private investors’ increasing movement downstream in the value chain toward activities with near-term payoffs. Risk tolerance in today’s environment is a function of time. “Time to cash” is the major determinant of venture capital and other private investor support of early stage innovations.⁴

³ Gross Domestic Product: 1950 and 2002, U.S. Bureau of Economic Analysis; White Paper, op cit.

⁴ National Innovation Frontiers Working Group, Subgroup C, Research Funding, Washington, DC: May 26, 2004; National Innovation Frontiers Working Group, Subgroup B, Convergence for Innovation, Washington, DC: May 26, 2004

This retrenchment from early stage investment has particularly affected innovations flowing from university research. Many of these innovations form the basis of regionally focused science and technology clusters that combine industrial or university-based knowledge sources, technology transfer capabilities, and other factors (e.g., skills, infrastructure, other complementary inputs and outputs). These areas, such as Silicon Valley or Boston's "fertile crescent" around MIT, took decades to develop and have been major sources of economic growth. Since universities and their regional partners across the country rely upon private investment, reducing the time it takes to move frontier research to real innovation is imperative.⁵

Innovation Frontier Research evolving into Global Endeavor

For 50 years, America has led the world in research and development. However, other countries are attracting and developing the necessary talent to compete. China's growth rate in publications in 1999 was four times and South Korea's was 12 times that of the United States. In the late 1990s, patents filed in the U.S. by Chinese and South Korean organizations grew more than 40 times faster than did US patent applicants.

To be sure, U.S. publication and patent levels continue to dwarf those of other countries. In 1999, the number of American-authored publications was 163,500, compared to 17,400 Chinese and South Korea authored publications. Also that year, the number of U.S. patents was 87,600 compared to approximately 5,700 from China and South Korea.

Still, these dynamics suggest that in the next 50 years, R&D will be more of a global partnership. The United States must continue to draw upon international talent so that it can participate successfully in future R&D partnerships that will produce innovations that benefit the world economy and the U.S.⁶

FINDINGS & RECOMMENDATIONS

Because "innovation frontiers" represents such a large potential landscape, the Working Group focused on the following questions:

- How should we adjust our research investments to produce more breakthroughs in areas that require involvement from multiple disciplines?
- With services accounting for a dominant share of U.S. jobs and output, how should we invest to accelerate innovation in the service economy?
- How can we fundamentally advance the next stage of manufacturing progress?
- What new translational and funding mechanisms are there for transferring the next generation of research ideas to commercial reality?

⁵ National Innovation Frontiers Working Group, Subgroup B, op cit.

⁶ Diana Hicks, "S&T indicators reveal rapid strengthening in Asian research systems" 29th AAAS Forum on S&T Policy, Washington DC, April 22-23, 2004.

- As we protect the homeland, how can the U.S. assure that we remain an innovation magnet for the best global talent?

The Working Group recommends that government, university, and corporate leaders take the following recommended steps:

(1) Allocate an increasing proportion of future new research funding to multi- and interdisciplinary research and the facility and research infrastructure that underpins it.

Our nation faces many grand challenges and opportunities – in climate change, homeland security, global spread of disease, energy supply, water supply and quality, harnessing nanotechnology, quantum computing, and multifunctional materials. Progress in these areas and thus the foundation for 21st-century breakthroughs require research at the intersection of many disciplines. Multidisciplinary research crosses boundaries between discrete knowledge fields and stimulates the creation of new disciplines from the interaction of traditional disciplines, such as bioinformatics, which employs information technology to manage and understand biological data.

In addition, multidisciplinary research often crosses organizational boundaries between academia, business, and government. It is a challenge to coordinate funding for research shared by disparate organizations, and assignment of credit can be difficult.⁷ Advisory panels, peer review, project management, and oversight are typically organized around particular fields, and university tenure and promotion systems bolster traditional discipline boundaries.

Despite these impediments, various multidisciplinary program activities have been successfully launched:

- The Department of Defense's Multidisciplinary University Research Initiative (MURI) addresses large multidisciplinary research topics in future breakthrough areas.
- NSF's centers and programs foster capability building in selected research that crosses traditional boundaries.
- Some universities have selective cross-departmental collaborations. For example, Stanford's Bio-X program combines biology, clinical medicine, engineering, chemistry, physics, and computer science.
- The National Academies Committee on Science, Engineering, and Public Policy organized the Committee on Facilitating Interdisciplinary Research to study how universities and funding organizations can make cross-boundary research work.
- The Department of Energy's National Laboratories are another place where multidisciplinary work can be found.

⁷ Multidisciplinary Research Recommendation. NII Innovation Frontiers Working Group C – Research Funding. Presentation given at the NII Innovation Frontiers Working Group Meeting, Washington, D.C., August 31, 2004.

For the most part, however, multidisciplinary activities remain limited⁸ and are not central to our national research enterprise. All participants in the innovation enterprise must dedicate greater resources to cross-cutting activities.

Government's Role

We recommend that the federal government make multidisciplinary research an integral part of its research agenda and allocate a higher percentage of future increases in research funding to programs with multidisciplinary components and to programs that promote communication and collaboration among institutions and sectors. State governments investing in innovation research should do the same. This support is important to achieve advances in current frontier fields, including biotechnology, neuroscience and cognitive science, nanotechnology, energy, water, the physical sciences and engineering, and information technology as a horizontal supporting area.

Government funders should also give new emphasis to knowledge-integrative activities -- as distinguished from knowledge-creating or -accumulating activities. This would include support for creative work on theoretical integration of developing fields and for dissemination methods via conferences to make the knowledge available to all interested parties.⁹ Revised peer review and advisory structures will likely be required to support these new programs.

We also recommend that public sector attention be paid to the research and infrastructure that underpin these disciplines. In the research area, long-term basic research in the physical sciences and engineering, earth sciences, and social-behavioral sciences are needed because of their importance in supporting current frontier research and their essential role in helping reverse the decline in America's leadership in engineering and science. In the infrastructure area, we recommend that the federal government expand accessibility to large research instrumentation, high capacity computers, and other research infrastructure.¹⁰

On University Campuses

It is critical that university leaders recognize and reward interdisciplinary educational and research successes. Deans, chairs, and other participants in the review, tenure, and promotion processes should be encouraged to transform their structures to acknowledge excellence in work at the juncture of multiple disciplines and work that crosses institutional boundaries between academia and industry.¹¹ Universities should encourage the creation of education and research programs that cut across classical disciplinary structures and promote education and research at the boundaries of those disciplines.

⁸ Ibid.

⁹ S. Nelson, A Few Preliminary Comments for the 5/12/04 Teleconference, by Focus Group C: Basic Research Funding of the National Innovation Initiative's, Innovation Frontiers Working Group, May 11, 2004.

¹⁰ NII Innovation Frontiers Working Group C – Research Funding, op cit.

¹¹ Ibid.

They should facilitate and nurture government-industry-academia partnerships that are essential to achieving those goals.

Corporate Involvement

We recommend that industry executives provide financial support to encourage multidisciplinary research. This may involve setting up bridging positions with universities and government laboratories, creating innovation project teams with members from academia, structuring greater incentives and rewards for individual innovators, allocating a percentage of personnel time for research-driven projects, and organizing to take greater advantage of national laboratories, research centers, university research collaborations.¹²

The business community can also provide leadership by setting up “innovation institutes” or “innovation portals” to promote innovation activity across sectors. These entities would be chartered in partnership with academia and government and would work to identify and develop new innovation frontiers, undertake studies related to forecasting, monitoring, and enhancing innovation, explore and promote innovative thinking outside the traditional scholarly disciplines, and enable the movement of ideas from concept to commercial reality or solution to societal problems.¹³

2) The science of services and associated understanding of enterprise dynamics and transformation should be recognized as research disciplines. Government, industry, and universities should invest in these disciplines and develop a future class of funded education and research programs and centers.

With service industries accounting for more than 70 percent of GDP, steps must be taken to build a strong foundation for innovation in these industries. We recommend that scientific and technological research supporting the understanding of enterprise dynamics and creation of enterprise transformation be regarded as a distinct discipline.

Understanding enterprise dynamics and promoting enterprise transformation¹⁴ require work at the intersection of organizational processes, e.g. supply chain management, and information technology. Enterprise transformation poses questions such as: How do organizations continue to recreate themselves? How do organizations manage technological innovation? Can we simulate the most complex behavioral systems? Studies in the services sector that develop intellectual bases for business process design, organizational concepts, analytics supported decision-making, and leadership may constitute a new innovation frontier.¹⁵

¹² Ibid.

¹³ White paper op cit.

¹⁴ W. Rouse, “Enterprises (As) Systems,” Engineering Enterprise. Proceedings of the IFAC/ IFIP/ IFORS/ IEA Symposium on Analysis, Design, and Evaluation of Human-Machine Systems, Atlanta, Georgia, September 7-9, 2004.

¹⁵ White Paper, op cit.

“Service science” would encompass a wide variety of fields -- psychology, management, industrial/systems engineering, civil engineering, operations research, applied mathematics, computer science, political science, anthropology, and linguistics. These disciplines would provide the foundation for innovation in the services sectors through understanding of enterprise dynamics and enabling of enterprise transformation.

With the exception of NSF’s Science of Learning Centers, there are virtually no government-sponsored innovation research programs focused on services. Few if any universities have programs in the area. And there is but nascent private sector support to encourage service science capacity building in universities and governments. IBM’s Almaden Services Research Group is among the few business laboratories dedicated to the field.

Private industry’s leadership role is critical in stimulating the development of this field. It is envisaged that private industry will support real-world research projects and academic education and training. Corporate leaders should also convene summits on significant challenges in the field in the sector.

In Washington, officials in civilian and defense agencies should designate programs for advancing service science. These efforts should lead to the creation of new classes of centers in the field.

Universities should be encouraged to make investments in service science through pilot programs, interdepartmental workshops, and research centers. They should work towards designating majors in the field with the aim of preparing young people to assume important roles in the complex and growing services sector down the line. Executive conferences and professional development courses should also be established to disseminate learning to current and future practitioners.

3) Stimulate breakthroughs in manufacturing by increasing future research investments in nano-scale production, multifunctional materials, and inter- as well as intra-facility process simulation. Make research and infrastructure for innovation in manufacturing available to small as well as large enterprises.

Manufacturing is central to the U.S. economy. Not only does it account for 14 percent of gross domestic product, but it also stimulates demand for raw materials, intermediate manufactured goods, and service-sector outputs such as software, financial services, accounting, and transportation. Moreover, national defense and homeland security are intimately connected to the strength of the nation’s manufacturing sector. Manufacturing output has increased by six-fold from the 1950s to the 2000s, as manufacturers have cut costs, adopted lean production practices, raised quality levels, and patented new products and processes.

Even with these accomplishments, manufacturers are facing a fresh round of challenges. There are cyclical threats arising from the recent economic downturn; from 2000-2003, 2.6 million manufacturing jobs were lost. Structural challenges have also emerged with

the removal of trade barriers and the increasingly rapid rate of adoption of technological innovations in product design and production processes.¹⁶

The Working Group recommends that federal and state governments provide support for the creation of a new knowledge base to take manufacturing into the 21st century. Breakthroughs in molecular manufacturing call for new designs, fabrication tools, and manufacturing systems that integrate macro-scale and nano-scale environments. New materials with novel features will utilize self-assembly via nanotechnology processes, advances in photonics, and other materials-based developments to create products with “strength, flexibility, lightness, energy efficiency, and environmental sustainability.”¹⁷ As yet, it is not well understood how to manufacture such materials and integrate small-scale and large-scale manufacturing.

Many of the breakthroughs in the nanotechnology area will require the federal government to support increased multidisciplinary activity among mechanical engineering, electrical engineering, physics, chemistry, biology, biomedical engineering, and other fields. We also envision a greater role for government-industry collaborations to accelerate standard setting for atomic scale manufacturing, molecular-scale assembly, and micro-to-millimeter manufacturing technologies.¹⁸

The movement from mass production to mass customization and resulting shifts from centralized production to distributed production and inter-company collaboration require computation capability to simulate innovative manufacturing processes. Simulations enable advances in a range of areas from molecular sciences to process management systems that embrace supply chain relationships within and between complex multi-site manufacturers.¹⁹ To bring about these advances, public sector agencies should expand the availability of high capacity computing infrastructure to small as well as large manufacturing enterprises. Small manufacturers have innovative, risk-taking capabilities that can be furthered through access to high capacity computing, testing equipment, and other innovation infrastructure.

More collaboration between industry and academia will be needed to capitalize on these government initiatives. University researchers should search for productive new links to local businesses to apply intellectual investigation to design and production needs. The Working Group also advocates increased exchanges and creation of bridging positions between academia and industry to take greater advantage of university research collaborations and federally funded centers.²⁰

¹⁶ Manufacturing in America: A Comprehensive Strategy to Address the Challenges to U.S. Manufacturers. Washington, D.C.: U.S. Department of Commerce, January 2004, pp. 13-31.

¹⁷ J. Brighton, J. Bordogna, R. Colwell, “Ensuring Manufacturing Strength through Bold Vision” Arlington, VA: National Science Foundation, December 24, 2003.

¹⁸ P. Shapira, J. Youtie, A. Urmanbetova, “Advanced Technology and the Future of U.S. Manufacturing.” Sponsored by the Manufacturing Extension Partnership. Atlanta: Georgia, May 2004, pp. iv-ix.

¹⁹ Ibid.

²⁰ NII Innovation Frontiers Working Group C – Research Funding, op cit.

4) Provide translational mechanisms and funds for commercialization of university-led innovations. Models include the Small Business Innovation Research Program (SBIR) and the Small Business Technology Transfer Program (STTR).

With industry focusing R&D resources on near-term development, the growing role of academia in fundamental research has created an accumulation of early stage technologies on campuses across the country. Concerted effort is needed to ensure that the value of these technologies is sufficiently leveraged into next generation products, goods, and services or into solutions that address particular government needs.

In the decades following World War II, commercialization of innovations was achieved through a “push” of technology into private sector firms or government agencies. In the 1980s and ‘90s, new commercialization approaches arose in response to industry demand, such as establishing intellectual property policies and setting up incubators and technology parks.²¹

Challenges

Today, universities face hurdles to translating research into commercial products. Basic discoveries are generally not developed to the point that they have an application for a product, process, or public agency problem, and research concepts are often suspended before licensing or spin-off company possibilities can be defined. In addition, early stage financing is now less available as venture capitalists have moved toward later stage technologies with nearer term payoffs.

Two Small Business Administration programs -- the SBIR program for small business R&D and the STTR program for small business-university research partnerships -- have augmented resources to bridge the gap between research grants and development investments for small businesses. However, there is no parallel program targeting technologies that have not yet migrated into spin-off companies, particularly concepts and ideas discovered via grant funding from universities and research institutes.

We recommend that capabilities for moving university-generated ideas toward commercial products be enhanced. One option is to set up a fund, perhaps through the SBIR / STTR structure, to provide a translational mechanism for medium-sized and large companies to commercialize innovations within universities. The fund could fill in the gap between grant research and later stage capital for a selected portfolio of appropriate technologies. We also note the need for better sharing of best practices and more experimentation with fresh technology transfer methods, particularly those targeted in regional clusters that develop around universities and research institutes.

5) The U.S. must secure its leading position as a magnet for global talent. To encourage more Americans from a diversity of backgrounds to become scientists and engineers, new incentives must be put in place, such as portable fellowships and

²¹ J.D. Roessner, “Federal policies for technology transfer and commercialization” http://www.cherry.gatech.edu/sim/module/roessner_fr.htm, 1996.

“innovation scholarships.” To attract international talent, the federal government should institute proactive immigration policies in support of innovation goals.

Developing America’s Future Innovators

Since World War II, the United States has built and maintained the world’s pre-eminent research enterprise.²² The U.S. has also helped strengthen foreign scientific research by training many foreign scientists, hosting foreign visiting scientists, and engaging them in ongoing scientific discussion at conferences. In turn, we have benefited from the contributions of individuals from other nations who came here to study and often stayed after earning their degrees. Foreign scientists and engineers have been the source of many important American innovations. The general openness of the U.S. system has helped American scientists stay on top of developments occurring around the world.

Now, at the beginning of the 21st century, America’s leadership position is at risk. Many of our most talented scientists and engineers are approaching retirement; the portion of U.S. college students studying science and engineering is declining; and the post-9/11 security environment is limiting the number of foreign students coming to our campuses.

The National Education Defense Act (NEDA), enacted 1958 in response to the Soviet launch of Sputnik, stimulated a generation of scientists and engineers to enter technical fields. From the late 1950s through 1986, the number of U.S. students receiving bachelors degrees in engineering, mathematics, computer science, and the natural sciences rose steadily. The past two decades, however, have seen a decline in the number of Americans graduating in these fields, while the number of non-technical bachelor’s degrees earned has continue to rise.²³

Also concerning is that much of the future growth in America’s college-age population is expected to come from minorities, but science and engineering may not be able to attract its share of this growth. By 2020, more than 40 percent of college-age students will be nonwhite (primarily African-American and Hispanic-American), compared to 30 percent in 2000.²⁴ However, African-Americans account for only 7 percent of science and engineering bachelor’s degrees and Hispanic-Americans only 6 percent.²⁵

To boost domestic interest in science and technology, we recommend that federal government agencies involved in research allocate an increasing percentage of their undergraduate and graduate fellowships to portable science and engineering grants. These fellowships would be attached to the students for use at the academic institutions that best meet their interests. The objective of this recommendation is to create a revival

²² D. Hicks, National Innovation Initiative: Innovation Frontiers, Focus Group D: Relations with International Research Systems, White Paper, May 10, 2004.

²³ *Science and Engineering Indicators 2004* (Washington, D.C.: National Science Board, National Science Foundation, 1998), 2-23.

²⁴ *Ibid*, 2-4.

²⁵ *Ibid*, 2-23.

of interest in entering scientific and engineering fields, especially at graduate levels, along the lines of what occurred in the aftermath of the National Defense Education Act.

The Working Group recognizes and supports other efforts to increase the number and diversity of students entering scientific and technical fields, such as national fellowships for graduate studies have been recommended by the President's Council of Advisors on Science and Technology and the United States Commission on National Security/21st Century.²⁶ A reinvigorated scientific and technical workforce that reflects the rich diversity of America will satisfy the demands of the high tech sector and provide enhanced capabilities for scientific progress as today's generation of American scholars begins to retire.

We further recommend that industry partner with the public sector to create a prestigious program for "innovation scholars" of the Rhodes ... to encourage and reward students going into fields that would support scientific and technological innovation.

Tapping Skills from Beyond our Borders

Foreign scientific talent is and will remain a critical resource for the United States. In 2001, foreign students accounted for nearly half of all graduate students in engineering and computer science.²⁷ Thirty-five percent of engineering faculty and 39 percent of computer science faculty were foreign-born.²⁸

U.S. immigration policies are now limiting our access to foreign talent. The post-9/11 visa regime has reduced the number of foreign scientific visitors on our campuses and is effectively aiding our international competitors.²⁹ In science, insularity can undermine quality and competitiveness and thus the long-term innovative potential of our research community. Delays and difficulties in obtaining visas are contributing to a declining inflow of scientific talent according to recent reports by the National Science Foundation and also a survey of American universities. Other countries can and do take advantage of these circumstances. Foreign research institutions are offering attractive substitutes for U.S. conferences, degrees, and visiting scholar positions.

The Working Group believes U.S. immigration policy as it applies to prospective students, faculty, and researchers must be reassessed, even as we provide fresh incentives for encouraging more Americans to become research scientists and engineers.³⁰

²⁶ "Assessing the U.S. R&D Investment," President's Council of Advisors on Science and Technology, October 16, 2002; G. Hart and W. Rudman, "Road Map for National Security: Imperative for Change." The United States Commission on National Security/21st Century" February 15, 2001, pp. 38-63.

²⁷ Ibid, 2-21.

²⁸ Ibid, 5-25.

²⁹ See for example A. Gast, "Security Policies and Restrictions in Research," presentation at 29th Annual AAAS Forum on Science and Technology Policy, Washington DC, 23 April, 2004; and "Short-sighted", *The Economist*, May 8, 2004, p. 13,

³⁰ D. Hicks, op cit.

We offer one specific recommendation related to foreign-born students in the U.S. who wish to stay on and work for an American company. The federal government should provide automatic work permits (i.e. H1B visas) with appropriate screening and control to give permanent resident status to those who graduate from a U.S. university if they have a job offer from an American employer. We as citizens invest in the education of foreign scientific and technical talent, but current rules make it difficult for us to benefit from the contributions of knowledge, skill, and creativity that these new graduates might make to the nation's innovation enterprise.