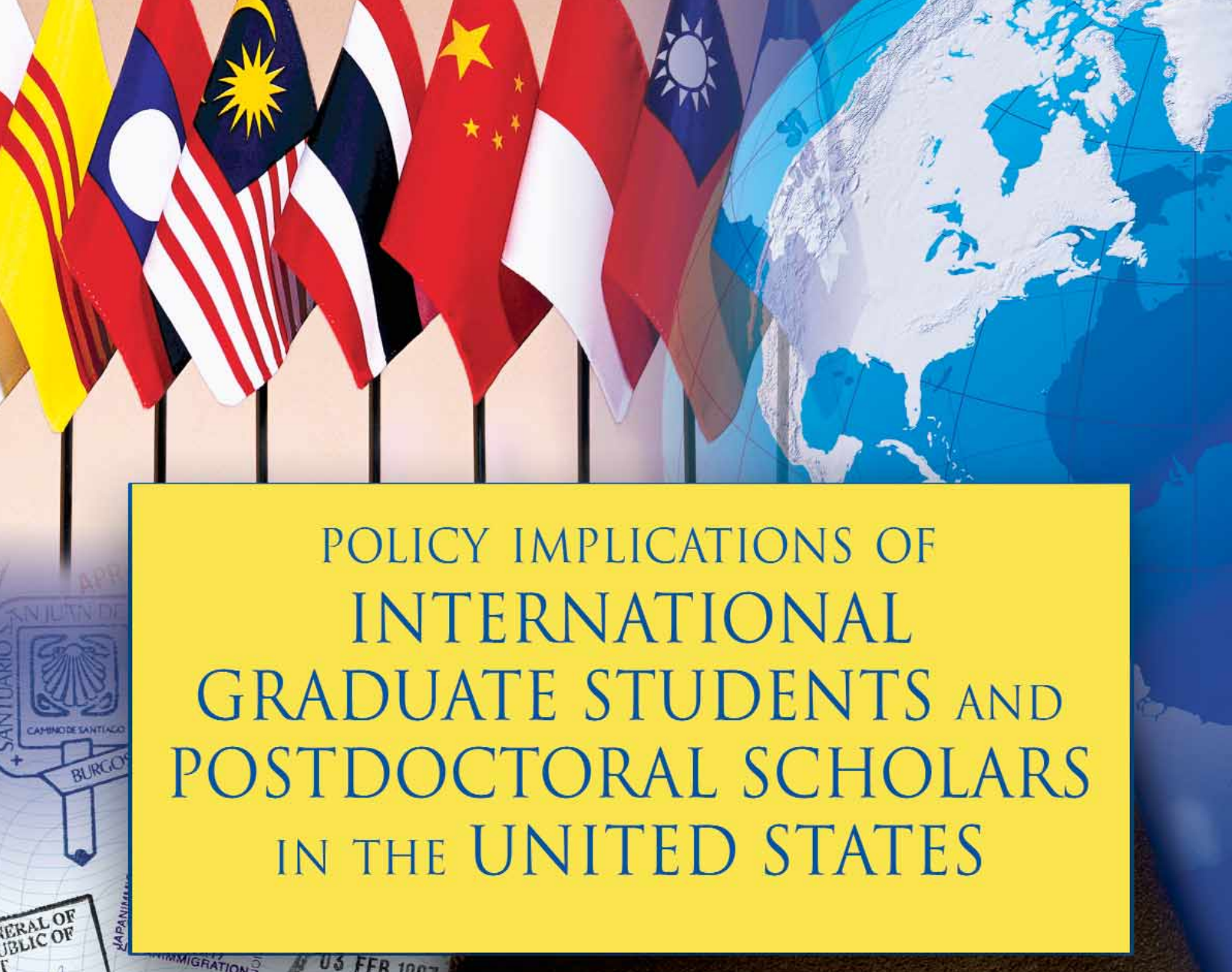

POLICY IMPLICATIONS OF INTERNATIONAL GRADUATE STUDENTS AND POSTDOCTORAL SCHOLARS IN THE UNITED STATES

THE NATIONAL ACADEMIES

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FOR MORE INFORMATION

This report was developed under the aegis of the National Academies Committee on Science, Engineering, and Public Policy (COSEPUP) and the Board on Higher Education and Workforce (BHEW). BHEW monitors critical national issues in the education and training of, and labor market for, the nation's science and engineering workforce. Ronald Ehrenberg, Irving M. Ives Professor of Industrial and Labor Relations and Economics at Cornell University is the chair of BHEW. COSEPUP is the only joint committee of the three honorific academies—The National Academy of Sciences, National Academy of Engineering, and Institute of Medicine. Its overall charge is to address cross-cutting issues in science and technology policy that affect the health of the national research enterprise. Maxine Singer, president emerita of the Carnegie Institute of Washington, is the chair of COSEPUP.

More information, including the full report, is available at **www7.nationalacademies.org/internationalstudents/**.

PREFACE

This report reflects the continuing interest of COSEPUP in the education and training of scientists and engineers in the United States. COSEPUP's 1993 report *Science, Technology, and the Federal Government: National Goals for a New Era* emphasized the importance of human resources to the research enterprise. A second report, *Reshaping the Graduate Education of Scientists and Engineers* (1995), urged institutions to offer graduate students expanded educational experiences and to equip them better to choose from among the broad range of S&E careers. That concern was extended to postdoctoral scholars in 2000 with *Enhancing the Postdoctoral Experience for Scientists and Engineers.*

Increasing the attractiveness of science and engineering (S&E) careers gained importance in the late 1990s as fewer US citizens pursued advanced training in S&E. The trend was accompanied by a substantial rise in the proportion of international graduate students and postdoctoral scholars in US institutions. Finally, from the advanced industrial societies of Europe and Japan to the newly emergent world powers of China and India, nations have launched efforts to compete for the most talented scientists and engineers worldwide.

In an effort to address the complex conditions affecting the relative standing of US S&E, the National Academies charged COSEPUP to address the following questions:

1. What is known about the impact of international graduate students and postdoctoral scholars on the advancement of US science, US undergraduate and graduate educational institutions, the US and other national economies, and US national security and international relations?

2. What is the impact of the US academic system on international graduate students' and postdoctoral scholars' intellectual development, careers, and perceptions of the United States? How does it differ if they stay in the United States or return to their home countries?

3. What is known about the impact of international student enrollment on the recruitment of domestic science and engineering talent in the United States? What is the status of working conditions for international graduate students and postdoctoral scholars compared with their domestic counterparts?

4. What are the impacts of various policies that reshape or reduce the flow of international students and postdoctoral scholars (for example, visas, immigration rules, and working conditions)?

5. What findings and conclusions can be drawn from the answers to the preceding questions? What principles should guide national policy regarding international graduate students and postdoctoral scholars?

To carry out the study, COSEPUP selected an ad hoc committee made up of people with special expertise in the demographic and personnel aspects of the S&E workforce and with wide research and educational experience in public and private universities, the private sector, professional societies, and government service. The committee heard from numerous experts and participants in diverse educational and research fields, from government agencies, and from persons who provided data on the recruitment, career paths, and motivations of international students. It also discussed in depth the recent effects of post-9/11 federal policy changes on the flow of foreign-born scientists and engineers and on the traditional perception of the United States as a welcoming destination for international students and scholars.

The overall thrust of the committee's findings and recommendations is to provide a basis for clarifying priorities and, where necessary, reshaping the policies that govern the movement and activities of international scientists and engineers, particularly with respect to visa and immigration policy. Such measures are essential to ensure the continued high quality of the US S&E enterprise in the years to come. Implementation will be possible only with mutual understanding and cooperation between those who set national security policies and those who educate and employ scientists and engineers.

Phillip A. Griffiths, *Chair*

FINDINGS AND RECOMMENDATIONS

In general terms, the committee believes that it is essential for the national interest of the United States that it maintain its excellence and overall leadership in science and engineering (S&E) research and education so that it can maintain its advantage in global knowledge production. Talented people constitute a critical input in such a knowledge-driven economy. The strategy of the United States has been and is to draw substantially from international human resources. However, as other nations build up their own S&E infrastructures, there is increasing competition for these talented people.

In such a world, what policies might best serve the interests of the United States and of S&E research in general? What actions can the US government and research universities take immediately to create or implement such policies?

The Impact of International Graduate Students and Postdoctoral Scholars on the United States

The total number of S&E graduate students in US institutions has grown consistently over the last several decades. The share of international graduate students has risen from 23.4 percent in 1982 to 34.5 percent in 2002 (see Figure 1-1). The share of temporary-resident postdoctoral scholars has increased from 37.4 percent in 1982 to 58.8 percent in 2002 (see Figure 1-2). In some fields, temporary residents make up more than half the populations of graduate students and postdoctoral scholars.

Despite the growing presence of international S&E graduate students and postdoctoral scholars on US university campuses, the data gathered by different sources on their numbers and activities are difficult to compare and yield only an approximate picture of their career status and contributions. The high level of participation of international scientists and engineers in US laboratories and classrooms warrants increased efforts to understand this phenomenon and to ensure that policies regarding their movement and activities are flexible to allow for rapid changes in research and technology.

Students and scholars contribute at many levels—as technicians, teachers, and researchers and in other occupations in which technical training is desirable. They have also been shown to generate economic gains by adding to the processes of industrial or business innovation.[1] And there is evidence that they have made a disproportionate number of exceptional[2] contributions to the S&E enterprise of the United States. For example, from 1990-2003 more than a third of US Noble laureates were foreign-born.

The S&E enterprise is increasingly multidisciplinary, interdisciplinary, and global. Historically, science has served as a bridge between nations and a means of communication that can transcend political barriers. The exchange of students among countries is considered an element of international relations and even foreign policy.[3] International students who remain in the United States after their studies often become part of networks that support knowledge transfer and economic development in the United States and the sending country. The networks are an important "pull" factor for students considering the United States as a destination for graduate and postdoctoral training. Those who return home after their studies or after some period of employment may go to work for US-owned multinational firms, continue research that adds to global knowledge, and form collaborations with US partners. Returnees who assume leadership positions at home may become strong foreign-policy and national-security assets for the United States.[4]

Finding 1-1: International students and scholars have advanced US S&E, as evidenced by numbers of patents, publications, Nobel prizes, and other quantitative data.

Finding 1-2: International graduate students and postdoctoral scholars are integral to the US S&E enterprise. If the flow of these students and scholars were sharply reduced, research and academic work would suffer until an alternative source of talent could be found. There would be a fairly immediate effect in university graduate departments and laboratories and a later cumulative effect on hiring in universities, industry, and government. There is no evidence that modest, gradual changes in the flow would have an adverse effect.

Finding 1-3: Innovation is crucial to the success of the US economy. To maintain excellence in S&E research, which fuels technological innovation, the United States must be able to recruit talented people. A substantial proportion of those people—students, postdoctoral scholars, and researchers—come from other countries.

Recommendation 1-1: The United States must maintain or enhance its current quality and effectiveness in S&E. A principal objective should be to attract the best graduate students and postdoctoral scholars regardless of national origin. The United States should make every effort to encourage domestic student interest in S&E programs and careers. A study should be undertaken to examine the best policies and programs to achieve that end.

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[1] G. Chelleraj, K. E. Maskus, and A. Mattoo. 2004. *The Contribution of Skilled Immigration and International Graduate Students to US Innovation* (Working Paper 04-10). Boulder, CO: University of Colorado. The authors conclude, "Our results strongly favor the view that foreign graduate students and immigrants under technical visas are significant inputs into developing new technologies in the American economy." Also see P. Chander and S. Thangavelu. 2004. "Technology adoption, education and immigration policy." *Journal of Development Economics* 75(1):79-94.

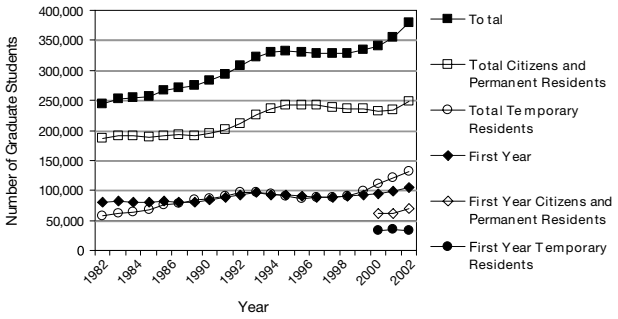
[2] P. E. Stephan and S. G. Levin. 2005. "Foreign scholars in U.S. science: Contributions and costs." In: *Science and the University*, eds. R. Ehrenberg and P. Stephan. Madison, WI: University of Wisconsin Press (forthcoming). The authors use six criteria to indicate "exceptional" contributions in S&E: persons elected to the US National Academy of Science or National Academy of Engineering, authors of citation classics, authors of hot papers, the 250 most-cited authors, authors of highly cited patents, and scientists who have played a key role in launching biotechnology firms.

[3] The US Departments of State and Education host an annual International Education Week. At the 2001 event, President Bush stated, "The relationships that are formed between individuals from different countries, as part of international education programs and exchanges, can also foster goodwill that develops into vibrant, mutually beneficial partnerships among nations."
The full statement is available at http://exchanges.state.gov/iew2001/message.htm.

[4] "Foreign students yesterday, world leaders today." Bureau of Educational and Cultural Affairs, US Department of State.
http://exchanges.state.gov/education/educationusa/leaders.htm.

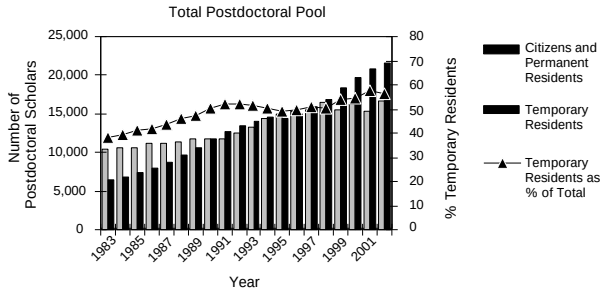
Recommendation 1-2: The overarching goal for universities and other research institutions should be to provide the highest-quality training and career development to both domestic and international graduate students and postdoctoral scholars of truly outstanding potential. Graduate admissions are directed toward fulfilling a variety of objectives, among which the education of the next generation of researchers should have the highest priority. This educational process will include research and sometimes a teaching experience. Admissions committees should keep in mind career and employment opportunities, in academe and elsewhere, when making admissions decisions. Moreover, data concerning employment outcomes should be readily available to both students and faculty.

FIGURE 1-1 Total full-time and first-year S&E graduate enrollments, 1982-2002.



SOURCE: National Science Foundation. 2004. Survey of Graduate Students and Postdoctorates in Science and Engineering 2002. Arlington, VA: National Science Foundation. Enrollment numbers include medical fields.

FIGURE 1-2 Academic postodoctoral-scholar appointments in S&E, 1983-2002.



SOURCE: National Science Foundation. 2004. Ibid. Medical fields are included, but postdoctoral scholars with medical degrees (presumably acting as physicians) are excluded from the analysis.

THE IMPACT OF THE US ACADEMIC SYSTEM ON INTERNATIONAL GRADUATE STUDENTS AND POSTDOCTORAL SCHOLARS

International graduate students and postdoctoral scholars who have trained in the United States have an opportunity to achieve careers as scientists or engineers in United States universities, industries, and national laboratories.[5] A decision to stay in the United States and become a citizen can be interpreted as a measure of career success, at least in relation to opportunities available in home countries. The stay rate of international doctorate scientists and engineers has increased steadily and substantially in the last decade.[6] Plans to stay vary by year of doctoral-degree award, field, and country of origin. The proportion of foreign-born doctorates remaining in the United States for at least 2 years after receiving their degrees increased from 49 percent for the 1989 cohort to 71 percent for the 2001 cohort.[7] Stay rates are highest among engineering, computer-science, and physical-sciences graduates. Stay rates varied dramatically among graduate students from the top source countries: China (96 percent), India (86 percent), Taiwan (40 percent), and Korea (21 percent). Decisions to stay in the United States appear to be strongly affected by the ability to do research in the students' home countries, which is tied to such factors as unemployment rate and per capita GDP.

Decisions to establish United States citizenship similarly show time and field specificity. In most fields, the percentage of graduate students who were temporary residents at the time of their degrees and obtained US citizenship was relatively constant from 1995 to 2001; in engineering, the percentages of students obtaining citizenship show marked time sensitivity.

There is less quantitative information about the career paths and experiences of either domestic or international postdoctoral appointees than of graduate students. Postdoctoral work has become the norm in the physical and life sciences and is becoming more common in other fields. Most postdoctoral scholars work in academe; about 10-14 percent work in other sectors, chiefly industry and national laboratories. Stay rates have not been quantified; but among postdoctoral scholars who trained in the United States, the United States was the most attractive place to settle regardless of nationality or where the PhD was earned.[8]

Other, more direct measures indicate that United States-trained international graduate students and postdoctoral scholars gain skills that make them competitive in the US job market. For US S&E occupations, 38 percent of doctorate-level employees in 2000 were foreign-born (see Table 2-1). Foreign-born faculty who earned their doctoral degrees at US universities increased from 11.7 percent in 1973 to 20.4 percent in 1999. In engineering

[5]N. Aslanbeigui and V. Montecinos. 1998. "Foreign students in US doctoral programs." *Journal of Economic Perspectives* 12:171-82.

[6]*International student* is usually taken to mean a student on a temporary visa, but figures sometimes include students on both temporary and permanent visas to compensate for the large number of Chinese students in the 1990s who became permanent residents by special legal provisions following the Tiananmen Square uprising. This issue is discussed in greater detail by Finn (see next footnote), who finds the stay rates of those on temporary and permanent visas almost the same.

[7]M. G. Finn. 2003. *Stay Rates of Foreign Doctorate Recipients from US Universities, 2001*. Oak Ridge, TN: ORISE. Although the stay rate cited in this study was defined as remaining in the United States for at least 2 years after receipt of the doctorate, Finn estimates that these rates do not fall appreciably during the first 5 years after graduation. About half the increase between the 1989 and 2001 cohorts is due to an increase in the number of PhDs awarded; the rest is from an increase in the number of new doctorate recipients deciding to stay.

[8]2004 Sigma Xi Postdoctoral Survey, available at http://postdoc.sigmaxi.org.

fields, they increased from 18.6 percent to 34.7 percent in the same period.[9] According to one of the few available studies,[10] 32 percent all new PhDs with definite plans to work in US industry were temporary residents at the time of graduation. That is about the same as the proportion of temporary residents in the total population of new PhDs. The proportion of new PhDs going into industry who are temporary residents is highest in mathematics (43 percent), civil engineering (42 percent), electrical engineering (41 percent), mechanical engineering (40 percent), and computer science (38 percent).

Finding 2-1: The education and training provided by US institutions afford international students the opportunity to do high-quality, frontier research and to gain the experience needed to compete for employment in S&E occupations in the United States and abroad.

Finding 2-2: Many international students and scholars who come to the United States desire to and do stay after their studies and training are completed. Those who return home often maintain collaboration with scientists and engineers in the United States and take with them a better understanding of the US culture, research, and political system.

Recommendation 2-1: Universities should continue to encourage the enrollment of international students by offering fellowships and assistantships. Universities that have large international student and scholar populations should conduct surveys to evaluate existing services provided by the institutions. Universities that do not already do so should offer orientation days for international students, train teaching assistants, update Web services, and provide professional development training for administrators staffing international student and scholar offices.

TABLE 2-1
Number of Foreign-Born in US S&E Occupations, 2000

	All S&E	Engineering	Life Sciences	Math and Computer Sciences	Physical Sciences	Social Sciences
All college-educated	816,000	265,000	52,000	370,000	92,000	37,000
Bachelor's degree	365,000	132,000	6,000	197,000	21,000	9,000
Master's degree	291,000	100,000	10,000	146,000	21,000	14,000
Doctoral degree	135,000	28,000	28,000	21,000	46,000	12,000

SOURCE: 2000 US Census 5-percent Public Use Microdata Samples. Includes all S&E occupations other than postsecondary teachers since field of instruction was not included in occupation coding for 2000 Census.

Recommendation 2-2: International postdoctoral scholars make up a large and growing proportion of the US S&E workforce, but there are no systematic data on this population. A high priority should be placed on collecting and disseminating data on the demographics, working conditions, and career outcomes of scholars who earned their doctoral degrees outside the United States. When combined with current data collected by the National Science Foundation (NSF) and professional societies, this should make possible a more complete picture of the US S&E workforce. Funds should be allocated for this purpose by Congress to the NSF or by nonprofit foundations to other organizations.

The Impact of International Student Enrollment on the Recruitment of US S&E Talent

Several researchers have suggested that large numbers of international graduate students and postdoctoral scholars may have at least a mild adverse effect on domestic enrollments. As the numbers of S&E baccalaureate degrees awarded to members of underrepresented minority groups has increased, there has not been a concomitant increase in graduate-school enrollments.[11] However, it is not clear whether women or underrepresented-minority students are being displaced or are choosing other career paths. An empirical study of admissions to graduate schools showed in the aggregate a substantially higher rate of acceptance of US citizens over foreign applicants, a modestly higher rate of acceptance of women than of men in three of the fields studied, and a substantially higher rate of acceptance of members of underrepresented minority groups over other US citizens in all five fields studied.[12]

More recent studies also find no evidence of displacement of women and members of underrepresented minority groups in the graduate admissions process. For example, one study found no evidence of displacement but marked effects on educational outcomes. The most elite institutions saw the largest increases in temporary-resident enrollment and the steepest drops in enrollment of US citizens.[13] Those effects were statistically significant for white males, but not for women or members of underrepresented minority groups. It is not clear whether white males were deterred from enrolling by international students or chose other career paths for different reasons. For example, some may have been drawn to careers in business during the dot.com and financial-services boom or to other high-paying professions throughout the 1990s, many of which did not require graduate training.

Other evidence suggests that there is no displacement of US citizens from graduate programs by temporary residents. The number of PhDs granted to undergraduates from US institutions changed little while the number of non-US bachelor's degree recipients obtaining US doctorates rose sharply. Thus, a sub-

[9]National Science Board. 2004. *Science and Engineering Indicators 2004* (NSB 04-2), Arlington, VA: National Science Foundation, Appendix Table 5-24.

[10]G. Black and P. Stephan. "The importance of foreign PhDs to US science." In: *Science and the University*, eds. R. Ehrenberg and P. Stephan. Madison, WI: University of Wisconsin Press (forthcoming).

[11]D. R. Burgess. 1998. "Where will the next generation of minority biomedical scientists come from?" *Cancer* (Supplement) 83(8): 1717-19.

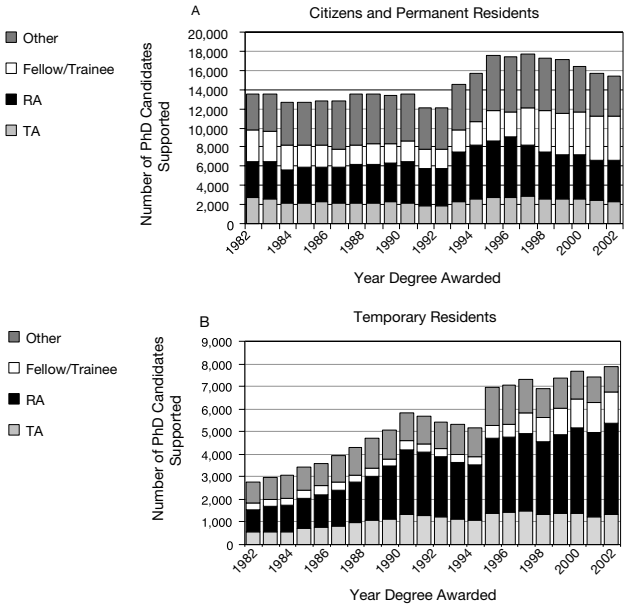
[12]G. Attiyeh and R. Attiyeh. 1997. "Testing for bias in graduate school admissions." *Journal of Human Resources* 32 (3): 524-48. The authors examined biochemistry, economics, English, mathematics, and mechanical engineering admissions at 48 leading graduate schools.

[13]G. J. Borjas. 2004. *Do Foreign Students Crowd Out Native Students from Graduate Programs?* (Working Paper 10349). Cambridge, MA: National Bureau of Economic Research.

stantial change in proportion was observed, but it was caused mostly by the expansion of PhD programs; a majority of the new slots were taken by students who had earned their first university degrees outside the United States.[14] Another study calculated that an increase of one full-time international student in an S&E graduate department is not associated with displacement of US citizens, including members of underrepresented minorities.[15]

A study examining possible displacement of domestic scientists and engineers from S&E describes the importance of several other factors. First, the displacement of native-born scientists and engineers occurs mostly from "temporary," not "permanent," jobs in academe. Thus, the US-born are losing academic positions that are less valued rather than highly valued. Second, that result, with the finding that displacement is largest for those in mathematics and computer science, suggests that US citizens may have been pulled and not pushed from the academic sector, at least in some fields. Those US-born scientists and engineers appear to be seeking better opportunities and higher-paying positions elsewhere in the economy.[16]

FIGURE 3-1 Primary mechanisms of support for doctoral candidates, 1982-2003.



SOURCE: National Science Foundation. 2004. Survey of Earned Doctorates 2003. Arlington, VA: National Science Foundation. *Other:* support from student's institution of higher education, state and local government, foreign sources, nonprofit institutions, or private industry; *traineeships:* educational awards given to students selected by the institution or by a federal agency; *research assistantships:* federal support for students whose assigned duties are primarily in research; *teaching assistantships:* state support for students primarily teaching.

[14]R. B. Freeman, E. Jin, and C. Y. Shen. 2004. *Where Do New US-Trained Science-Engineering PhDs Come From?* (Working Paper 10605). Cambridge, MA: National Bureau of Economic Research.

[15]M. Regets. 2001. *Research and Policy Issues in High-Skilled International Migration,* Bonn: IZA.

[16]S. G. Levin, G. C. Black, A. E. Winkler, and P. E. Stephan. 2004. *Differential Employment Patterns for Citizens and Non-Citizens in Science and Engineering in the United States: Minting and Competitive Effects* (Working Paper). St. Louis, MO: University of Missouri.

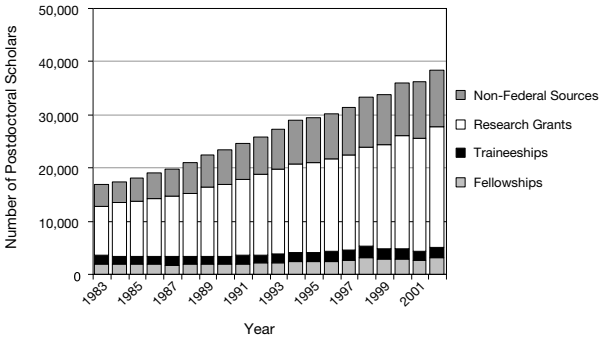
Postdoctoral work has become the norm in the physical and life sciences and is becoming more common in other fields. Little is known about the educational background, motivations, or career paths of either domestic or foreign-born postdoctoral scholars. Citizenship status does not seem to affect level of satisfaction with training experience. There is a tendency for more temporary residents than US citizens to feel that their postdoctoral positions were preparing them for independent research positions.

Another measure of working conditions is compensation. In 2002, 50.2 percent of international graduate students were supported by research assistantships (RAs); 18.3 percent were fellows or trainees, whose positions usually carry a higher stipend than RAs; and 27.7 percent of domestic graduate students were RAs and 29.7 percent were fellows or trainees. Similar proportions of domestic and international students were supported by teaching assistantships (see Figure 3-1).

Data on support mechanisms for postdoctoral scholars, while not available by citizenship, show similar trends (see Figure 3-2). There is a significant difference in annual postdoctoral stipends. That temporary residents earned less than citizens may be attributable largely to the different funding opportunities for temporary residents, in that most federal training grants and fellowships are citizenship-restricted.

Finding 3-1: Recruiting domestic S&E talent depends heavily on students' perceptions of the S&E careers that await them. Those perceptions can be solidified early in the educational process, before students graduate from high school. The desirability of a career in S&E is determined largely by the prospect of attractive employment opportunities in the field and, to a lesser extent by potential remuneration. Some aspects of the graduate education and training process can also influence students'

FIGURE 3-2 Mechanisms of support for postdoctoral scholars by field, 1998-2002.



SOURCE: National Science Foundation. 2004. Survey of Earned Doctorates 2002. Arlington, VA: National Science Foundation. *Non-Federal Sources:* support from the institution of higher education, state and local government, foreign sources, nonprofit institutions, or private industry; *research grants:* support from federal agencies to a principal investigator, under whom postdoctoral scholars work; *traineeships:* educational awards given to scholars selected by the institution or by a federal agency; *fellowships:* competitive awards given directly to scholars for financial support of their graduate or postdoctoral studies.

decisions to enter S&E fields. The "pull factors" include time to degree; availability of fellowships, research assistantships, or teaching assistantship funding; and whether a long postdoctoral appointment is required after completion of the PhD. The evidence that large international graduate-student enrollment may reduce enrollment of domestic students is sparse and contradictory but suggests that direct displacement effects are small compared with pull factors.

Finding 3-2: There are substantial differences among S&E fields in training and career patterns. For example, in engineering, a bachelor's or master's degree is sufficient to begin a professional career; in the life sciences, doctorates customarily spend over 4 years as postdoctoral scholars before entering the workforce. In the physical sciences[17] and engineering, most students obtain careers in industry; in the life sciences, most work toward positions in academe. Such field-specific variations are not reflected in aggregate data.

Finding 3-3: International and domestic academic postdoctoral scholars express similar satisfaction with their training experience. But access to funding sources and employment opportunities is limited by residence status. There are variable discrepancies in stipends that favor domestic postdoctoral scholars in all fields.

Finding 3-4: Multinational corporations (MNCs) hire international PhDs in proportions similar to the output of university graduate and postdoctoral programs for their US research laboratories and often hire US-trained PhDs for their nondomestic laboratories. The proportion of international researchers in several large MNCs is around 30-50 percent. MNCs appreciate international diversity in their research staff and pay foreign-born and domestic researchers the same salaries, which are based on degree, school, and benchmarks in the industry.

Recommendation 3-1: So that students can make informed decisions about advanced training in S&E, career outcomes of recent graduates should be communicated to prospective students by university departments and faculty advisers. In addition to intensive focused research work, graduate education should encompass career preparation and the development of varied skills for successful careers in S&E. Universities should develop graduate education and postdoctoral programs that prepare S&E students and scholars for the diversity of jobs they will encounter. When it is appropriate, funding agencies should provide career-transition grants for early-career researchers. The committee encourages discussion among universities, industry, and funding agencies to explore how to expand graduate fellowships and encourage women and members of underrepresented minorities to consider education and training in S&E.

The Impact of Policies That Reshape or Reduce the International Flow of Students and Scholars

There is increasing international competition to recruit the best S&E students and scholars. With the increasing competition, there is keen interest in why students choose to study abroad and how students choose destinations and institutions.[18] The decision of graduate students and postdoctoral scholars to go abroad for study is a combination of "push" and "pull" factors.[19] Under conditions of increasing capacity among traditional sending countries, the ability of the United States to continue to attract the best students will increasingly depend on its pull factors, including quality, job opportunities, convenience, and perception of being a welcoming place.

Layered on top of the globalization of competition for students is the decline in international students taking the Test of English as a Foreign Language (TOEFL) and the Graduate Record Examination (GRE) graduate-school entrance examinations. One interpretation of the decline is that fewer international students want to study in the United States. However, the decline in TOEFL volumes is more likely to have been influenced by increasing competition from the International English Language Testing System (IELTS).[20] GRE volumes started to decrease in Asia after antifraud measures were taken in 2000. The number of students taking the GRE multiple times has decreased, and it is likely that some less-qualified students are now discouraged from taking the examination.[21] In addition, Australia, Canada, and other countries competing with the United States for graduate students do not require applicants to take the GRE.

On top of that are the recent increases in security screening by US immigration officials. The United States, like other nations, must struggle to balance the need to secure technical information with the need to maintain the openness of scholarship on which its culture, economy, and security depend. The free flow of knowledge and people sometimes conflicts with the national interests of states. Repercussions that followed the terror attacks of September 11, 2001, included security-related changes in federal visa and immigration policy. The changes were intended to restrict the illegal movements of an extremely small population, but they have had a substantial effect on large numbers of foreign-born graduate students and postdoctoral scholars already in the United States or contemplating a period of study here. Pre-existing immigration-related policies relevant to international student flows are international reciprocity agreements, deemed-export policies, and specific acts that grant special or immigrant status to groups of students or high-skill workers, for example, the Chinese Student Protection Act of 1992 and the policies enacted shortly after the end of the

[17]The physical sciences include physics, chemistry, earth sciences, mathematics, and computer science. In each of those subfields, there can be divergent career interests among graduates; but taken as a whole, a position in the industrial sector is the predominant career destination among recent graduates, whether or not it was the desired career at PhD inception or completion.

[18]A. Bohm and D. P. Chaudhri. 2000. *Securing Australia's Future: An Analysis of the International Education Markets in India*. Sydney: IDP Education Australia Limited. This study reports that although the United States is "an established brand, providing an excellent education across a wide array of characteristics, it performs poorly in affordability and provision of a tolerant and safe environment."

[19]T. Mazzarol and G. N. Soutar. 2001. *Push-pull Factors in Influencing International Student Destination Choice* (Discussion Paper 0105). Crawley, WA: Centre for Entrepreneurial Management and Innovation, University of Western Australia; T. Davis. 2003. *Atlas of Student Mobility*. New York: Institute for International Education; and J. Enders and A. M. Mugabushaka. 2004. *Wissenshaft und Karriere: Ehrfahrungen und Werdegange ehemahleiger Stipendiaten der DFG*. Bonn: Deutsche Forschungsgemeinshaft.

[20]The IELTS is owned, developed, and delivered through the partnership of the British Council, IDP Education Australia, ILTS Australia, and the University of Cambridge.

[21]D. L. Wheeler. 2002. "Testing services says GRE scores from China, South Korea, and Taiwan are suspect." *The Chronicle of Higher Education* (August 16).

Cold War to allow scientists and engineers of the former Soviet Union to enter the United States.

Together, increased competition, decreased test-taking, increased security screening, and a soft economy have had a dramatic impact on graduate-student applications, particularly from 2001 to 2004. Declines in admissions and first-time enrollments were less substantial (see Table 4-1). What is the meaning of the declining enrollment numbers? Several interpretations seem plausible. First, the decline began from an enrollment peak that followed the atypical economic conditions of the late 1990s, including the dot.com boom and the doubling of the National Institutes of Health (NIH) budget.[22] The current decline could be interpreted as a return from an unsustainable peak to a point on a long-term curve that had been rising steadily for many years. A second possible interpretation is that a 3-year decline is more accurately seen as a trend rather than a statistical blip. In either case, there is no evidence that the quality of graduate students or the staffing level of laboratories has suffered. S&E populations have always fluctuated, and in ways that are seldom predicted.

TABLE 4-1. Change in Applications, Admissions and Enrollments for International Graduate Students, 2003-2004

	Total	Engineering	Life Sciences	Physical Sciences
Applications	-28% (-5%)	-36% (-7%)	-24% (-1%)	-26% (-3%)
Admissions	-18%	-24%	-19%	17%
Enrollments	-6%	-8%-	10%	+6%

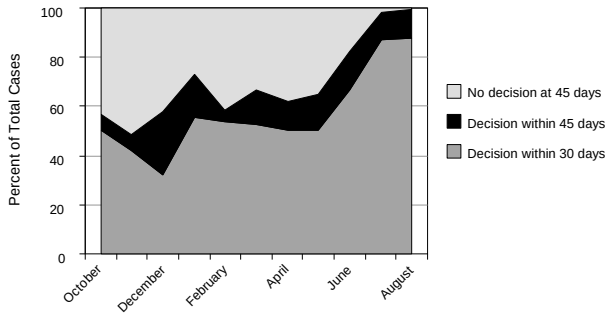
SOURCE: H. Brown. 2004. Council of Graduate Schools Finds Decline in New International Graduate Student Enrollment for the Third Consecutive Year. Washington, DC: Council of Graduate Schools (November 4). 2004-05 data are listed in parentheses, and are from H. Brown and M. Doulis. 2005. Findings from the 2005 CGS International Graduate Survey I. Washington, DC: Council of Graduate Schools.

Throughout its history, the United States has used immigration policy to manage the flow of visitors. Since the F and J visa classes were established in 1952, it has been possible to measure the impact of policies on students and exchange scholars. However, because those visa classes include students from primary to graduate school, as well as postdoctoral scholars and many other non-university exchange visitors, and because graduate students and postdoctoral scholars can enter the United States with other visa classes, including the H-1b, it is not practical to try to use immigration statistics to determine anything useful about any particular level of student or trainee. That is evident in comparing enrollment patterns and visa issuance rates: if one looks only at issuance rates, the primary sending countries for postdoctoral scholars appear to be European; but enrollment numbers indicate that Asian countries send more scholars by far. There are also policy implications: restrictions applied to particular visa classes may be having unintended effects because a class includes a heterogeneous group of people.

Improvement of data on immigration and emigration has been championed for at least 20 years.[23] Coupling data inadequacies for immigration with those for the US workforce, particularly for postdoctoral scholars, and our understanding of the composition of the S&E workforce is even more limited. Moreover, there is a lack of analysis of trends and relationships among student flows, enrollments, economic cycles, and other factors. Congress and administrative agencies need better data and more analysis to craft better policies.

Finding 4-1: The flow of international graduate students and postdoctoral scholars is affected by national policies. Among them, changes in visa and immigration policies since 9/11 have adversely affected every stage of the visa-application process for graduate students and postdoctoral scholars in S&E. Interagency cooperation and a willingness to work with members of the S&E community have helped to reduce some bottlenecks and improve procedures, but unfavorable perceptions remain and additional steps need to be taken. Some policies contribute to anxieties among international students and scholars and a perception that the United States does not welcome them. International sentiment regarding the US visa and immigration processes is a lingering problem for the recruitment of international students and scholars. Those environmental factors discourage international students and scholars from applying to US colleges and universities and discourage colleagues who would otherwise send their students to the United States. Recent improvements in processing time and duration of Visas Mantis clearances are a positive step (see Figure 4-1), but extending visa validity periods and Mantis clearances commensurate with a period of study has not been uniform across nationalities.

FIGURE 4-1. Visas Mantis Security Advisory Opinion (SAO) Workload, FY 2004



SOURCE: U.S. Department of State.

[22]One review of the NIH budget concluded that its dramatic growth did not result in an increase in new US doctorates or in the number of US citizens in postdoctoral appointments even while the number of international postdoctoral scholars was rising. H. H. Garrison, S. A. Gerbi, and P. W. Kincade. 2003. "In an era of scientific opportunity, are there opportunities for biomedical scientists?" *FASEB Journal* 17:2169-2173.

[23]NRC. 1985. *Immigration Statistics: A Story of Neglect.* Washington, DC: National Academy Press; NRC. 1996. *Statistics on U.S. Immigration: An Assessment of Data Needs for Future Research.* Washington, DC: National Academy Press; NRC. 1999. *Measuring the Science and Engineering Enterprise: Priorities for the Division of Science Resources Studies.* Washington, DC: National Academy Press. The latter study focused on the Science Resource Statistics division of the NSF and urged sufficient funding to "continue and expand significantly its data collection and analysis."

Finding 4-2: Large drops in international applications in the 3 years after 9/11 caused considerable concern in the university community, but their effects on numbers of first-time enrollments of international S&E graduate students were modest.

Finding 4-3: The flow of international graduate students and postdoctoral scholars is affected by institutional policies. Universities have been responsive to the needs of international students. Many have offices dedicated to international students, and several offer orientation sessions before the start of the school year and teaching-assistant training and English-language courses. Steps taken by educational and exchange institutions have mitigated some of the adverse effects of visa and immigration policies by creating resources for international applicants and establishing earlier acceptance notifications to allow more time for visa processing. Some universities have begun to reimburse admitted graduate students the $100 Student and Exchange Visitor Information System (SEVIS) fee.

Finding 4-4: Exogenous factors, many of which predate 9/11, affect the flows of international graduate students and postdoctoral scholars. Other countries are expanding their technological and educational capacities and creating more opportunities for participation by international students. The natural expansion of education in the rest of the world increases the potential supply of talent for the United States and at the same time increases competition for the best graduate students and postdoctoral scholars. Economic conditions—including availability of university-sponsored financial support and employment opportunities—can affect student mobility, as can geopolitical events, such as war and political instability.

Finding 4-5: The inadequacy of data on international graduate students and postdoctoral scholars limits our understanding of the composition of the S&E workforce and of how it might respond to economic or political changes. Moreover, the lack of timeliness and coverage of data on US-trained and internationally trained scientists and engineers hinders our examination of trends and relationships among student flows, enrollments, economic cycles, and other factors. Congress and administrative agencies need better data and more analysis to craft better policies.

Recommendation 4-1: The United States needs a new system of data collection to track student and postdoctoral flows so that it can understand the dynamics and effects of shifting sources of talent. Funds should be provided to the NSF or other institutions to collaborate internationally to create a data system similar to a balance-of-trade account to track degree production, student and postdoctoral movement between countries, push-pull factors affecting student choice at all degree levels, and employment outcomes.

Recommendation 4-2: If the United States is to maintain overall leadership in S&E, visa and immigration policies should provide clear procedures that do not unnecessarily hinder the flow of international graduate students and postdoctoral scholars. New regulations should be carefully considered in light of national-security considerations and potential unintended consequences. Research institutions and the Departments of State (DOS) and Homeland Security (DHS) should continue their discussion on these matters.

a. *Visa Duration:* Recent policies to extend the duration of Visas Mantis clearances for some students and scholars is a positive step. We strongly encourage DOS and DHS to continue working toward applying those provisions to students and scholars from all countries.

b. *Travel for Scientific Meetings:* Means should be found to allow international graduate students and postdoctoral scholars who are attending or appointed at US institutions to attend scientific meetings that are outside the United States without being seriously delayed in re-entering the United States to complete their studies and training.

c. *Technology Alert List:* This list, which is used to manage the Visas Mantis program, should be reviewed regularly by scientists and engineers outside government. Scientifically trained personnel should be involved in the security-review process.

d. *Visa Categories:* New nonimmigrant-visa categories should be created for doctoral-level graduate students and postdoctoral scholars, whether they are coming to the United States for formal educational or training programs or for short-term research collaborations or scientific meetings. The categories should be exempted from the 214b provision whereby applicants must show that they have a residence in a foreign country that they have no intention of abandoning. In addition to providing a better mechanism for embassy and consular officials to track student and scholar visa applicants, the categories would provide a means for collecting clear data on numbers and trends of graduate-student and postdoctoral-scholar visa applications.

e. *Reciprocity Agreements:* Multiple-entry and multiple-year student visas should have high priority in reciprocity negotiations.

f. *Change of Status:* If the United States wants to retain the best students, procedures for change of status should be clarified and streamlined.

CONCLUSION

Maintaining and strengthening the S&E enterprise of the United States, particularly by attracting the best domestic and international graduate students and postdoctoral scholars, will require the cooperation of the government, universities, and industry to agree on an appropriate balance between openness, mobility, and economic and national security. Making the choices will not be easy, but the recommendations provided here define priorities, data, and analyses needed to determine effective policy strategies and substantive steps that will advance the vitality of US research and attract the talented people necessary to perform it.

FACTS AND FIGURES ABOUT INTERNATIONAL S&E GRADUATE STUDENTS AND POSTDOCTORAL SCHOLARS

(1) How many international S&E graduate students are enrolled in US academic institutions? In 2002, there were 125,000 full-time international S&E graduate students enrolled in US institutions. Temporary visa holders comprised 49 percent of the graduate students in engineering (58,300 students), 48 percent in computer sciences (26,800 students), 40 percent physical sciences (13,000 students), and 39 percent in mathematical sciences (7,000 students).

(2) Are enrollments of international graduate students increasing or decreasing? The total number of S&E graduate students in US institutions has grown consistently over the last several decades. The share of international graduate students has risen from 23.4 percent in 1982 to 34.5 percent (125,000 of 325,000 total) in 2002. First-time enrollment of temporary residents declined 6 percent (by 2,100 students to 32,000) in 2002. Preliminary figures indicate first-time enrollments may decline through 2005.

(3) Are enrollments of US graduate students increasing or decreasing? The 20-year trend for US citizens and permanent residents shows less growth and more years of decline than does the trend for temporary visa holders. Enrollment of US students increased more slowly during the 1980s and declined from 1994-2000, and in 2002 was 6 percent below the peak year of 1993 (when, after the Tiananmen Square uprising, a number of Chinese students became US permanent residents). Even so, in 2002, US student S&E graduate enrollment increased by 15,500 students, the second largest numerical gain in the last 20 years. The proportion of women and minority students enrolled in S&E graduate programs has grown steadily over the past decade; the mid-1990s decline in US citizen graduate enrollment is attributable to reduced white male enrollment.

(4) How many graduate degrees are awarded each year to international students? The number and proportion of S&E PhDs awarded to temporary residents has been increasing steadily since 1966, when 1627 PhDs were awarded to temporary residents, 14.3 percent of the total. In 2003, 8276 (32.9 percent) S&E PhDs were awarded to temporary residents. In 2002, temporary residents received 19.5 percent (1400) of all PhDs awarded in the social sciences, 18.0 percent (1480) in the life sciences, 35.4 percent (2020) in the physical sciences, and 58.7 percent (3000) in engineering.

(5) How many international postdoctoral appointees are there at US educational institutions? The numbers of postdoctoral scholars with temporary-residence visas has risen from 6,472 in 1983 to 21,601 in 2002; the number of US citizens and permanent residents in postdoctoral positions rose more slowly, from 10,432 in 1983 to 16,715 in 2002. The growth in postdoctoral positions was largest in the life sciences, where total numbers increased from 9,494 in 1983 to 26,262 in 2002, 68.5 percent of the total postdoctoral population.

(6) What proportion of international postdoctoral scholars in the United States have a US PhD? Of the 60 percent of academic postdoctoral scholars who hold temporary visas, about four-fifths have non-US doctorates. This means that half of all US academic postdoctoral scholars have non-US PhDs. Most were awarded in China (25 percent), followed by India (11 percent), Germany (7 percent), South Korea (5 percent), Canada (5 percent), Japan (5 percent), the UK (4 percent), France (4 percent), Spain and Italy (2 percent).

(7) What are the stay rates for international graduate students and postdoctoral scholars? The proportion of international doctorates remaining in the United States for at least 2 years after receiving their degrees increased from 49 percent for the 1989 cohort to 71 percent for the 2001 cohort. Stay rates were highest among engineering, computer-science, and physical-sciences graduates and varied dramatically among graduate students from the top source countries: China (96 percent), India (86 percent), Taiwan (40 percent), and South Korea (21 percent). Stay rates are not monitored for postdoctoral scholars, but a 2004 survey indicates that a majority wish to remain in the US after their training is completed.

(8) How are full-time international graduate students and postdoctoral scholars supported financially? Overall, graduate students are receiving more financial support than they are paying in tuition. In 2000, the average support (stipend, tuition remission, health coverage, fees) provided per graduate student across all fields was $37,000. Multiplying by the number of graduate students enrolled in 2000 (341,000) yields a total investment of about $13 billion. This investment is spread across federal, state, university, and private sectors, and depends on citizenship status. For the 2000 cohort, 48.9 percent of international students (3800 students) were supported on federal research assistantships, and about 17 percent (1300 students) each for state-supported teaching assistantships, federal fellowships or traineeships, and other forms of support (self-support, private fellowship, industry, foreign government). There are no specific numbers on funding for international postdoctoral scholars. In total, postdoctoral scholars are primarily supported by federal research grants (in 2002, 59.2 percent, or 22,670 scholars). Further, 27.7 percent (10,620) were supported by non-federal sources and 13 percent (5030) by federal traineeships or fellowships.

(9) What are the primary sending countries for S&E graduate students and postdoctoral scholars? Since the 1960s, India, Taiwan, South Korea, and China have been the primary sending countries, as measured by the total number of US S&E PhDs awarded. In 1966, Indian students earned 3 percent (338) of US S&E PhDs, in 2003 3.2 percent (801). In 1966, Chinese Students earned 0.7 percent (84) of US S&E PhDs, in 2003 10.2 percent (2559). South Korea: 1966, 0.6 percent (73), 2003, 3.9 percent (972); and Taiwan: 1966 1.5 percent (168), 2003, 1.9 percent (478).

(10) What visas are used by international graduate students and postdoctoral scholars? Graduate students usually use either an F or J visa to study in the US. To apply for a US visa they must supply proof of acceptance at a US institution and also must prove that they do not intend to immigrate. As of 2003, all student and exchange visitors are monitored by SEVIS and verification of acceptance is now possible electronically. Postdoctoral scholars use a variety of visas to train in the US. The majority enter using a J visa, and are entered into the SEVIS database. A substantial proportion enter on H-1b visas; several other visa classes are also utilized including O, TN, EA, F, B, G, WB, A, L, and PR.

(11) What proportion of the US S&E workforce is foreign-born? Foreign-born scientists and engineers were 22.7 percent of the US S&E labor force in 2000, an increase from 12.7 percent in 1980. Representation of foreign-born scientists and engineers in US S&E occupations varies by field and degree level. Foreign-born doctorates were 37.3 percent of the US S&E labor force in 2000, an increase from 23.9 percent in 1990. In 2001, 57 percent of those who were foreign-born S&E doctorate holders were US citizens.

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