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Report of the NSB Committee on Foreign Involvement in U.S. Universities

NATIONAL SCIENCE BOARD

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I. EXECUTIVE SUMMARY

CONCLUSIONS AND RECOMMENDATIONS

Foreign-born assistant professors, postdoctorates, and graduate students now comprise a high fraction at U.S. universities in engineering, mathematics, physics, and computer science. In those disciplines they play a major role and are essential to the continuation of educational and research programs.

Recommendation 1: NSF should give high priority to its efforts to increase the pool of U.S. candidates for academic careers in engineering, mathematics, physics, and computer science.

Recommendation 2: NSF should give high priority to those programs which attract more U.S. students to careers in science and engineering.

Recommendation 3: Present NSF policy to leave to the discretion of principal investigators the selection of research assistants, including their nationality, has served science and the scientific community well. No change in the current policy is recommended.

Universities, and to some extent, industry would experience severe problems if the influx of foreign students would diminish abruptly and significantly. Present immigration policies and regulations encumber significantly efforts of American industry to employ foreign scientists and engineers as well as foreign-born U.S. graduate students.

Recommendation 4: NSF should encourage the U.S. Government to review its policy on visa conversion and immigration with the view of facilitating entrance of foreign scientists and engineers to the U.S. labor force.

Generally, foreign graduate students perform academically as well as U.S. graduate students. Difficulties have sometimes arisen in assignments, such as teaching assistantships, in which knowledge of the English language and/or the U.S. system of cultural values are important performance factors.

Recommendation 5: Universities should incorporate classes on American culture and values in their English language programs for foreign graduate students.

NSF sponsored University-Industry and Engineering Research Centers perform their research and educational programs in diverse programmatic and industrial settings. These circumstances call for flexibility at the local level.

Recommendation 6: The decision to accept foreign companies as industrial sponsors should continue to be left at the Center level. No general NSF policy is warranted. NSF should continue to monitor the foreign participation in the NSF supported ERCs and IUCs. Centers should be encouraged to ensure reciprocity of information transfer and access to sponsoring foreign laboratories by U.S. scientists and students before allowing foreign companies to become industrial sponsors.

Foreign involvement in U.S. universities shows an increasing tendency. Overall, these involvements have a positive impact.

Recommendation 7: NSF should monitor the inflows and retention of foreign students, postdoctorates, and faculty. In addition, NSF should explore the availability of information to monitor other foreign involvement in U.S. university programs, such as financial support for research, facilities' construction, and acquisition of expensive equipment. The conditions attached to such support should be noted.

MAJOR FINDINGS

Total Foreign Enrollment in U.S. Universities

- Over 1 million students study worldwide in foreign countries; 36 percent of these are enrolled in U.S. universities.
- Although the U.S. has the largest number of foreign students, it ranks only 14th in its proportion of foreign students to total student population.
- After a period of rapid growth—rising from 155,000 in 1974 to 337,000 in 1982—the rate of increase in the number of foreign students slowed considerably in the mid-eighties, reaching 356,000 by 1987. Earlier predictions of 1 million foreign students in U.S. academic institutions by 1990 are unlikely to be fulfilled.
- The growth in foreign enrollment has been accompanied by a shift in the regions from which these students come. In 1954, more than one-half of foreign students came from Europe, North America, and Latin America. By 1986, students from these regions made up only 27 percent of the total, while almost 50 percent came from South and East Asia. Students from the Middle East made up about 12 to 13 percent, both in 1954 and 1986 with an interim peak of 30 percent during 1979/80.
- The rise in foreign enrollment has occurred in the context of overall growth. The foreign proportion of total enrollment has remained relatively steady at between 2 percent and 3 percent during the last decade.

Foreign Graduate Enrollment in Science and Engineering

- In 1987, foreigners comprised 45 percent of all graduate students in engineering, 43 percent in mathematics, and 41 percent in computer science of U.S. doctorate-granting institutions.
- The number of foreign students enrolled in graduate science and engineering (S/E) programs in U.S. doctorate-granting institutions has risen from 33,100 in 1975 to 76,200 in 1987, an average annual increase of 7.0 percent. During the same period, the number of U.S. citizens enrolled in these programs grew from 177,200 to 188,700—a 0.5 percent average annual increase.
- In general, foreign graduate students performed academically as well as U.S. students.
- In disciplines with a high percentage of foreign graduate students, chairpersons and faculty would like to see the proportion of foreign students somewhat lower if there were an abundant supply of well qualified U.S. students.
- Between 40 percent and 60 percent of foreign students graduating in the U.S. stay on to join the U.S. labor force.

Foreign-Born Faculty and Postdoctorates

- Foreigners comprised between 60 percent and 70 percent of the engineering postdoctorates (depending on subfield) employed since 1979. No consistent trend can be observed, possibly because of the small numbers involved—fewer than 1,000 each year. In the sciences, foreign postdoctorate employment increased from 31 percent to 41 percent between 1979 and 1987. This increase was particularly pronounced in the physical sciences, where 56 percent of the postdoctorates were held by foreigners in 1987.
- The number of foreign postdoctorates increased from 6,100 in 1979 to 10,800 in 1987, a 7 percent average annual growth rate. Over the same period, the number of U.S. postdoctorates rose from 12,000 to 14,500, an annual increase of 2 percent.
- In a 1986 sample of U.S. institutions with doctorate programs, 10 percent of the faculty members and doctorate-holders in non-faculty positions were foreign. Of these, 6.5 percent were foreign citizens on permanent visas and 3.5 percent were on temporary visas.
- Computer science departments had the highest proportion of foreign faculty and doctorate-holders in non-faculty positions in 1986 (18 percent), followed by engineering departments (an average of 14 percent).

Faculty with Foreign Baccalaureates

- In 1986, 16 percent of full-time faculty had received their baccalaureates at foreign institutions. This proportion was higher in certain subfields: for example, approximately one-quarter of the full-time faculty in mechanical and civil engineering as well as computer sciences had foreign bachelor's degrees.
- The proportion of faculty holding foreign bachelor's degrees is greater at the assistant professor level than at higher levels. The most dramatic illustration of this was in electrical engineering, where in 1986, 39 percent of the assistant professors held foreign baccalaureates, as compared to 20 percent at the associate professor level and 18 percent of full professors.

Foreign Participation in U.S. University Programs

- Research and development sponsored by foreign sources is only a small portion of all university R&D; it is also only a small part of all industry-sponsored university R&D.
- Foreign-financed R&D is concentrated in a few universities and is spread over several research fields.
- The top 5 universities receiving foreign funds account for 51 percent of all foreign investment in U.S. university research; the top 20 account for 70 percent. The top five universities are: Texas A&M University (primarily due to the Deep Sea Drilling Program), Harvard University, Massachusetts Institute of Technology, Oregon State University, and University of Wisconsin.
- Japan is the biggest sponsor of R&D at U.S. universities ($9.5 million), followed by the United Kingdom ($7.0 million) and West Germany ($5.6 million).
- U.S. university policies generally do not distinguish between U.S. and foreign sponsors.

Foreign Scientists and Engineers in Federal Laboratories

- In 50 Federal laboratories surveyed by the General Accounting Office in 1988, 5,700 foreign researchers—together with 57,000 U.S. researchers—worked at the laboratories as guest and visiting researchers or as participants in educational programs.
- Most of the foreign researchers conducted R&D either at the National Institutes of Health (34 percent) or Department of Energy research laboratories (32 percent).
- More than 80 percent of the foreign researchers were affiliated with foreign universities and other nonprofit organizations.

- The largest proportion of foreign researchers came from Japan (13 percent), followed by the United Kingdom and People's Republic of China (8 percent each).

Supply and Demand of Scientists and Engineers

- Between 1976 and 1986, the Nation's S&E work force has nearly doubled.
- Currently, there appears to be a rough balance between supply and demand for S&E personnel. This balance has been accomplished through substantial occupational mobility and increasing reliance on foreign-origin personnel. In light of demographic trends for the U.S. population, the reliance on foreign-origin personnel is likely to increase during the next decade.
- Between 1972 and 1983, foreign-born scientists and engineers increased from 10 percent to 17 percent of the S&E labor force. In the electronics industry, approximately 30 percent of the S&E labor force consisted of naturalized and foreign citizens in 1985.
- Present immigration policies and regulations encumber significantly efforts of American industry to employ foreign scientists and engineers as well as foreign-born graduate students.

II. FOREIGN STUDENTS IN U.S. UNIVERSITIES

WORLDWIDE STUDENT MOBILITY

Since the end of World War II, the United States has hosted the largest number of foreign students—340,000 in 1983, out of a worldwide total of more than 1 million. Although strictly comparable data are not available, it is useful to examine this influx in the context of other major host countries.

Around the world, foreign student enrollment has increased dramatically since 1970. (Table 1).

By 1983, this increase was 270 percent in the U.S., 278 percent in France, and 160 percent in West Germany. (A large increase was also reported for the U.S.S.R., although these data are only for the 1970–78 period.) The increase in the United Kingdom was significantly smaller—72 percent; this was due to the 1979 introduction of full-cost tuition for foreign students.

Table 1. (Unesco)* Foreign Student Enrollment in Leading Host Countries, Selected Years, 1970–1984

Host Country	1970	1975	1980	1981	1982	1983	1984
United States[1]	144,708	179,350	311,882	326,299	336,985	338,894	342,113
France	34,500	93,750	110,763	129,047	134,566	130,244	128,350
Germany, F.R.	27,769	53,560	61,841	67,216	71,393	72,267	76,918
U.S.S.R.	27,918	43,287	62,942[2]	—	—	—	—
United Kingdom	24,606	49,032	56,003	50,684	46,000	42,267	—
Canada	22,263	22,700	28,443	32,303	35,556	35,365	—
Lebanon	22,184	—	31,028	26,343	29,480	—	—
Italy	14,357	18,921	29,447	30,652	29,221	28,068	27,548
Egypt	13,387	—	21,751	16,297	17,062	—	—
Saudi Arabia	1,404	4,026	14,296	16,469	17,275	16,529	—
Switzerland	9,469	10,113	14,716	15,515	15,657	16,277	16,830
Romania	1,786	4,971	15,888	16,962	16,251	14,808	13,068
India	7,804	8,880	14,710[3]	—	—	—	—
Austria	8,573	10,320	—	12,885	13,515	13,943	14,858
Sweden	—	—	13,182	—	—	—	—
Belgium	8,611	9,748	12,875	12,260	11,871	12,528	21,188
Spain	10,575	8,909	10,997	—	—	—	—
Brazil	—	—	12,800	11,680	10,829	—	—
Australia	7,525	8,356	8,777	10,921	12,104	10,797	12,028
Argentina	—	—	7,882[3]	—	—	10,049	—
Japan	4,447	5,541	6,543	7,182	8,117	9,523	10,692
Vatican City	8,128	5,740	9,104	7,417	8,239	9,211	9,656
German D.R.	—	5,386	7,106	7,411	7,987	8,472	9,143
Yugoslavia	—	2,358	4,426	5,022	5,610	6,664	7,962
Greece	5,796	1,049	7,673	—	—	—	—
Turkey	6,125	5,907	—	6,378	6,030	5,524	6,732

*Source: Unesco Statistical Yearbook 1986, Table 3.15 "Education at the third level: number of foreign students enrolled", pp. III 418–421.
[1]Source: Open Doors, 1984/85.
[2]Figures are for 1978.
[3]Figures are for 1979.

HISTORICAL DATA AND TRENDS

Foreign Student Enrollment

Concurrent with the increase in foreign students in the U.S. was a similarly explosive growth in domestic enrollment. This resulted in only a modest increase in the proportion of foreign students to the overall student population, i.e., from 1.4 percent to 2.7 percent during the 1970–1984 period. Thus, in 1983, although the U.S. had the largest number of foreign students, it ranked only 14th in percentage of foreign students to total student population (Table 2). France (11.4 percent), the United Kingdom (4.7 percent) West Germany (4.9 percent) and Switzerland (17.4 percent)—among other Western countries—all had larger percentages. Near the other end of the spectrum was Japan, with less than 0.5 percent of students from other countries.

The rate of increase in the number of foreign students coming to the U.S. slowed considerably in the mid-eighties. Earlier predictions of 1 million foreign students in U.S. academic institutions by 1990 seem increasingly unlikely to be fulfilled.

Table 2. (Unesco)* Foreign Student and Total Enrollment in Leading Host Countries, 1983

Host Country	Foreign Enrollment	Total Enrollment	% of Total Enrollment
United States[1]	338,894	12,393,700	2.7
France	130,244	1,144,080	11.4
Germany, F.R.	72,267	1,471,964	4.9
U.S.S.R.[2]	62,942	5,301,300	1.2
United Kingdom	42,267	897,000	4.7
Canada	35,365	1,192,925	3.0
Lebanon[3]	29,408	73,052	40.3
Italy	28,068	1,120,342	2.5
Egypt[3]	17,062	873,565	2.0
Saudi Arabia	16,529	87,821	18.8
Switzerland	16,277	95,661	17.0
Romania	14,808	174,042	8.5
India[3]	14,710	5,345,580	0.3
Austria	13,943	154,126	9.0
Sweden[2]	13,182	223,295	5.9
Belgium	12,528	245,762	5.1
Spain	10,997	787,864	1.4
Brazil[3]	10,829	1,479,397	0.7
Australia	10,792	349,243	3.1
Japan	9,523	2,409,983	0.4
Vatican City	9,211	9,211	100.0
German, D.R.	8,472	434,326	2.0
Argentina[4]	7,882	580,626	1.4
Yugoslavia	6,694	375,393	1.8
Greece[3]	6,623	124,694	5.3
Turkey	5,524	335,090	1.6

*Source: Unesco Statistical Yearbook 1986, Table 3.15 "Education at the third level: number of foreign students enrolled", pp. III 418–421.
[1]Source: Open Doors, 1983/84.
[2]Figure is for 1978.
[3]Figure is for 1982.
[4]Figure is for 1979.

Preferences for Countries of Destination

Preferences for countries of destination vary in different world regions and countries. In 1984, almost 60 percent of students who relocated from South and East Asia came to the United States whereas 40 percent of African students went to France and just 18 percent came to the U.S. (Table 3).

By country, the U.S. was selected by 87 percent Canadian, 79 percent Japanese, 75 percent Korean, 67 percent Nigerian, and 51 percent Chinese outbound students. Other trends can be observed in students from Algeria and Morocco (79 and 78 percent went to France) and Turkey (65 percent went to the Federal Republic of Germany).

These patterns of student mobility suggest that linguistic competency, geographic proximity, and cultural or ideological affinity strongly influence the choice of target country.

The shifts in the representation of various countries may be traced to a combination of factors. First, at the end of World War II, many European universities were in need of rebuilding; as these institutions were restored to their positions, the proportion of students from these countries seeking education abroad declined.

Second, economic factors play a significant role; the growth in the number of students from OPEC nations—which reached 35 percent of the total in 1979—reflects the increasing purchasing power of these countries during the oil shortage of the early seventies.

Finally, political changes have resulted in dramatic changes in the number of students coming to the U.S. from certain countries. The overthrow of the Imperial Government in Iran led to a sharp decline in the number of Iranian students enrolled in U.S. institutions: these dropped from 51,000 in 1979 to 12,000 in 1986. Conversely, the opening up of relations with the People's Republic of China has resulted in an increasing number of Mainland Chinese students in the United States; these have risen from less than 1,000 in 1974 to 20,000 in 1986.

Graduate Enrollment

Since 1975, foreign student enrollment in graduate S/E programs has grown more rapidly than has U.S. enrollment during the same period. The enrollment of foreign students increased by over 125 percent between 1975 and 1986; in contrast, graduate enrollment of U.S. students increased by just under 15 percent. Because foreign students' enrollment growth has exceeded that of U.S. students, their proportion as a share of all graduate S/E students has increased, rising from 16 percent in 1975 to 28 percent in 1986 (CHART 1).

Enrollments for both foreign students and U.S. students have increased considerably within certain fields. For example, graduate enrollment in computer science nearly tripled for U.S. students between 1975 and 1986; during

Table 3. (Unesco)* Distribution of Foreign Students by World Region of Origin in Leading Host Countries[1]

Region of Origin	Host Country[2] U.S.	France	Germany, F.R.	U.S.S.R.	U.K.	5 Leading Countries	Next 45[3] Countries	Total 50 Countries
Africa	18.4	40.5	2.4	7.2	5.6	74.1	25.9	183,109
Europe	17.7	13.7	18.7	10.8	2.1	55.1	44.9	159,931
Middle East	30.9	7.6	12.9	—	4.3	56.6	43.4	156,450
North America	46.3	15.2	6.8	—	5.6	81.1	18.9	73,016
Oceania	48.4	2.0	2.4	—	4.1	65.9	34.1	7,310
Latin America	63.1	0.0	7.0	11.3	2.4	75.1	24.9	33,855
South and East Asia	58.9	0.4	4.5	12.0	7.5	79.8	20.2	208,353
U.S.S.R.	17.1	0.0	7.5	—	0.6	25.7	74.3	1,146
% of World Total	36.9	14.2	7.8	6.9	4.6	70.4	29.6	918,350

*Source: Unesco Statistical Yearbook 1986, Table 3.16 "Education at the third level: number of foreign students enrolled", pp. III 425–449.
[1]Percentages are based on student numbers for each region of origin.
[2]Figures for the United States are from 1984; for France, the Federal Republic of Germany and the United Kingdom from, for U.S.S.R. from 1978.
[3]Figures are for 1984 for most countries.

the same period, foreign student enrollment in this field increased five-fold. Foreign student enrollments also increased noticeably in the mathematical sciences; between 1977 and 1987, the foreign student share of enrollment increased from just under 25 percent to 40 percent of total graduate enrollment. In contrast, however, foreign students in 1987 made up less than 5 percent of the total in psychology and only 12 percent in the health sciences.

Overall, foreign students were more likely to be enrolled in engineering graduate programs than in science studies; despite enrollment growth in both science and engineering, these preferences remained apparent. Between 1975 and 1987, foreign students increased their representation among all engineering graduate students from 32 percent to 45 percent; among science students, they increased their representation from 12 percent to 24 percent. (Charts 1 and 2)

The proportion of foreign citizens among doctorate recipients remains higher in engineering than in the sciences. Across broad science fields, proportions are highest in computer sciences, lowest in biological sciences and psychology.

Post-graduation plans of foreign doctorate recipients vary considerably by field. Overall, nearly 80 percent of the holders of permanent visas and over 50 percent of the holders of temporary visas planned to stay in the U.S. Foreign physical science Ph.D.'s were more likely to cite postdoctoral study as their reason for staying, regardless of visa status. Engineering doctorate-holders with permanent visas indicated more often industrial employment as their reason for staying, those on temporary visas, postdoctoral studies and academic employment.

EDUCATIONAL COST

The costs of higher education in the U.S. are rising rapidly and therefore estimates for educational costs also change rapidly, thus introducing considerable uncertainty into the numerical values obtained. To estimate the subsidies to resident foreign S/E students from U.S. sources, data were obtained by the NSF Division of Policy Research and Analysis (PRA) from published sources, consultations with university planners, and in-house statistical analyses.

Costs of training science and engineering students were estimated to be on the order of $6,000 to $7,500 for undergraduate students and $16,000 to $19,000 for graduate students during the 1985–1986 academic year.

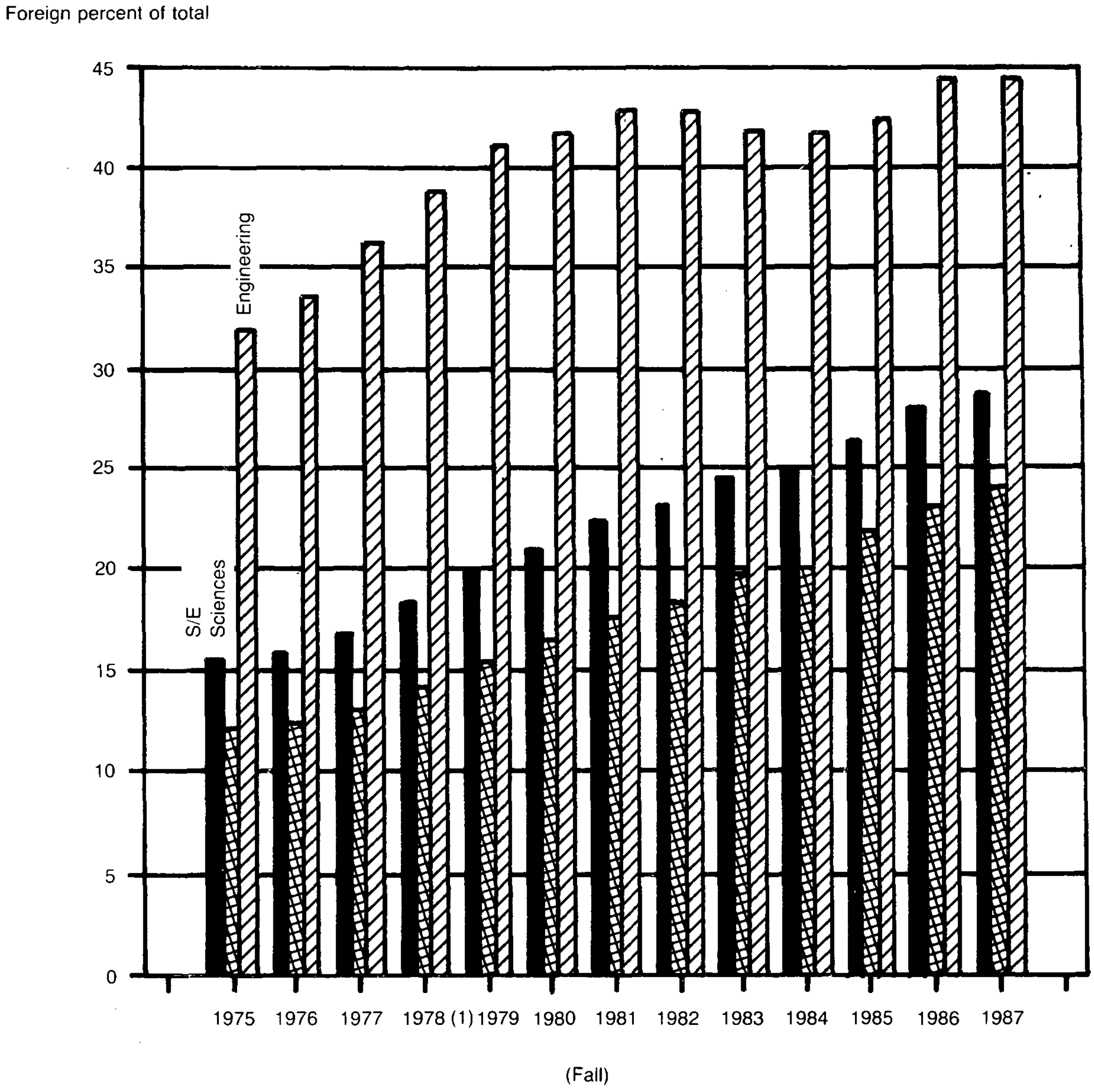
In the absence of financial assistance, expenses for an individual for an academic year are the sum of tuition and fees and living expenses; these vary depending on whether the university or college is public or private. For the 1985/86 academic year, tuition and fees for an out-of-state resident at a public institution were estimated at $3,500 and $8,400 at a private institution. Typical living expenses for the academic year were estimated at $6,300.

Based on data from the International Institute for Education and the National Academy of Sciences, it was estimated that U.S. sources covered—on average—about 10 percent of the living and tuition expenses over the population of foreign S/E undergraduates and about 25 of the living and tuition expenses over the population of graduate students.

In the 1985/86 academic year, about 135,000 nonresident foreigners were enrolled in S/E training at U.S. colleges and universities. About 60 percent of these were enrolled in undergraduate training, about 75 percent attended public universities and colleges, and over 90 percent were enrolled full time.

Thus, of the approximately $2.4 billion total spent in training nonresident foreign students during the 1985/86 academic year, $1.1 billion were covered by U.S. sources and $1.3 billion were paid for by the individuals or foreign institutions. Sixty percent of the expenditures by U.S. sources represented the excess of training costs over tuition charges at public universities and colleges. In

Chart 1. Foreign Percent of Total Graduate Science/Engineering Enrollment in Doctorate-Granting Institutions



Source: National Science Foundation. SRS

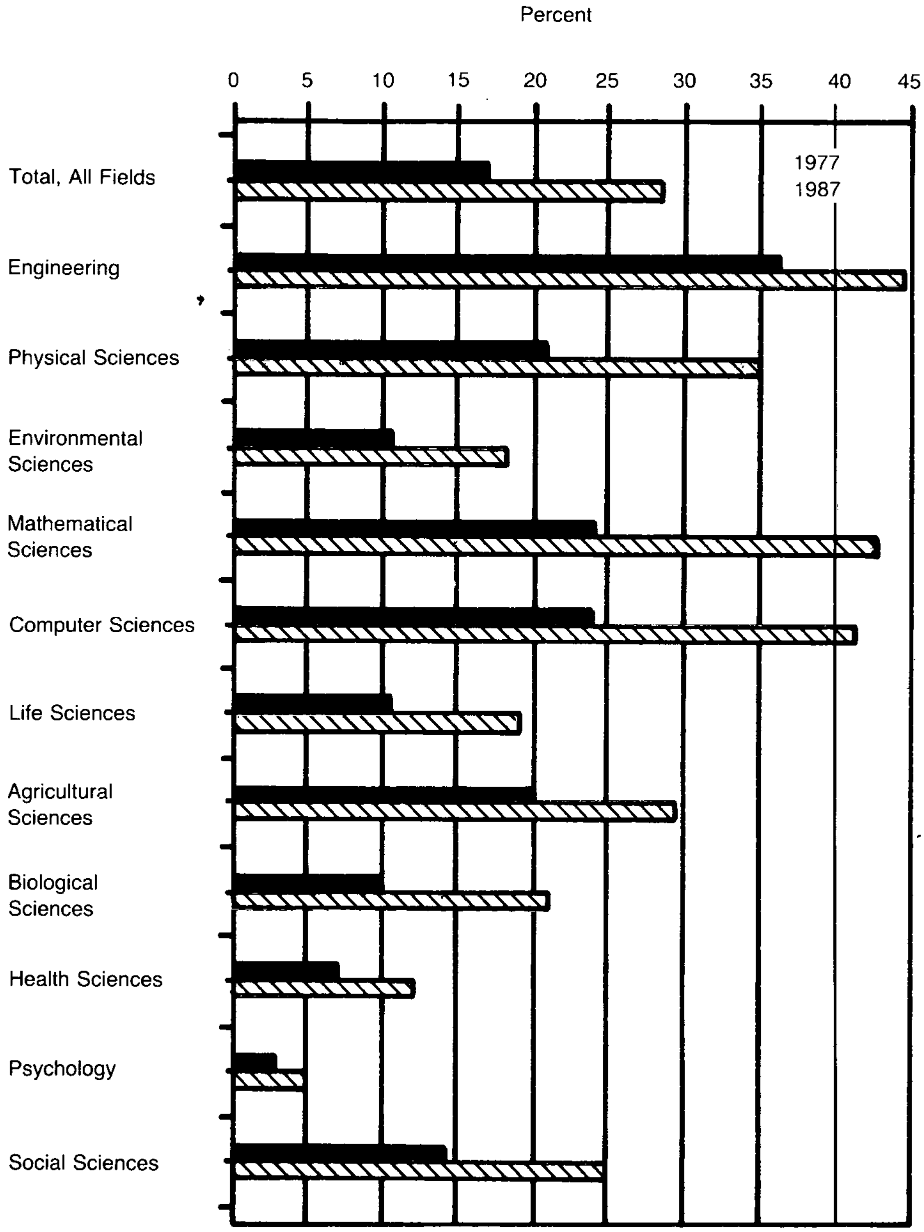
other words, most of the subsidies to foreigners represented transfer payments from State Governments. In turn, 80 percent of these funds went to graduate students. Overall, out of the $1.1 billion training cost of nonresident foreign students which is covered by U.S. sources, about $468 million went to the training of foreign graduate students or about $42,500 per student for a two-year master's program.

Using a similar procedure, the cost of precollege education (i.e., from kindergarten to high school) in the U.S. can be estimated. Assuming that a person attends elementary school and high school for 13 years, the cost of precollege education equals the sum of average per-pupil total expenditures during the 13-year schooling period. If a person received a Ph.D. in June 1984, the cost of precollege education in 1988 dollars is $32,000. Education to the baccalaureate adds $28,000 and to the master's level another $35,000; this assumes a four-year undergraduate period and a two-year period for the master's program. Thus, if a foreign student enters a U.S. university with a bachelor's degree from his home institution, such an education would have cost $60,000 in the United States.

QUALITY IMPACTS

That foreign graduate students approach numerical parity with U.S. students in several disciplines has in-

Chart 2. Foreign Full-Time Graduate Science/Engineering Enrollment in Doctorate-Granting Institutions by Field



Source: National Science Foundation, SRS

creasingly attracted attention in the last decade. A recent study by E. G. Barber and R. P. Morgan provided data and analyses of this phenomenon at U.S. engineering schools through a survey of departmental chairpersons and faculty in engineering programs (IIE Research Report Series Number 15: "Boon or Bane, Foreign Graduate Students in U.S. Engineering Programs, 1988").

The authors conclude that "... high proportions of foreign graduate students are, at the present time, essential to the operation of U.S. engineering programs, but they also render these programs vulnerable." Both industry and engineering schools would experience severe problems if engineering schools should severely restrict the training of foreign students or if the influx of foreign students would diminish abruptly and significantly. Industry is affected because a significant proportion of foreign graduate students ultimately obtain employment in the United States. At universities, the supply of U.S. born students alone would be insufficient to keep engineering educational as well as research programs at their present level.

According to the study, foreign graduate students are generally considered academically as qualified as U.S. students, although they are perceived as showing some significant differences. On the positive side, they are generally thought of being more diligent in their work and having a higher level of theoretical sophistication. However, because of difficulties in communication, they are perceived as being less effective in some respects, especially in positions as teaching assistants. Other problems sometimes mentioned which relate to their performance include their lack of familiarity with U.S. undergraduate culture and academic norms (E. G. Barber and R. P. Morgan: "The Impact of Foreign Students on Engineering Education in the United States," *Science*, Vol. 236, 1987). With respect to the U.S. system of cultural values, B. M. Vetter observed recently that "Most of these foreign teachers are men who come from cultures that do not view women as colleagues. The result can be what American women see as sexual harassment and as refusal to take them seriously as students." (B. M. Vetter: "Demographics of the Engineering Pipeline," *Engineering Education*, May 1988, 735–740). In a recent study on teaching assistants, R. M. Diamond and P. Gray recommended "That in addition to the general program for all new teaching assistants, special orientation programs be established for international teaching assistants and that these programs include:

- information about the organization and administration of American universities;
- information on the cultural differences they can anticipate;
- a clarification of the role of student and teacher in American universities;"

(R. M. Diamond and P. Gray: "National Study of Teaching Assistants;" Center for Instructional Development, Syracuse University, January 1987).

Overall, if there were an abundant supply of well qualified U.S. graduate students, both chairpersons and faculty would like to see the proportion of foreign students somewhat lower.

To ascertain the validity of the findings in other fields of science, a recent survey questioned a sample of Ph.D.-granting graduate departments in four fields of science (chemistry, physics, mathematics, and computer science) concerning the impact of foreign students on their programs. The survey revealed substantial dependence upon the supply of foreign applicants in order to maintain the quality of graduate programs. Prevailing responses in all four fields indicated a shortage in the supply of high quality U.S. applicants, accompanied by a surplus of high quality applicants from abroad. The survey indicated very strong competition for the limited pool of high quality U.S. students. Although few departments have a formal policy limiting the percentage of foreign applicants admitted to their programs, many suggested that in the absence of constraints on funding, legislative limitations, or informal efforts to maintain a balanced enrollment, the proportion of foreign students would be higher than it is, even to the degree of being able to fill their program's entire enrollment with high quality foreign students. There was consensus that this situation was unlikely to change greatly in the near future.

The impact of the foreign enrollment on the quality of programs was generally viewed as positive. The preparation and diligence of foreign students was generally seen as better than that of U.S. students upon entry to graduate school, although most respondents seemed to believe that the differences evened out over the course of the education of those attaining a Ph.D. degree. While foreign students often lacked experience in research prior to entering graduate school, many respondents noted a need to improve U.S. undergraduate programs in this respect as well. Nearly all programs have measures in place to ensure that the English language skills of foreign students do not have a detrimental effect on the quality of educational programs. In addition to the professional competence of foreign students, many noted that the cultural diversity represented an additional enhancement of their programs.

NSF SUPPORT FOR FOREIGN STUDENTS

In the above-mentioned survey of graduate departments in chemistry, physics, mathematics, and computer science, respondents were asked to rank the sources of funding for entering students (usually teaching assistants) and for research assistants. NSF funding was generally ranked as less important for entering students, with in-house university funds being the primary source of teaching assistantships. Where NSF funding was mentioned as a source for entering students, it usually ranked second or third for U.S. students, and was less likely to figure in the support of foreign students.

NSF support was usually ranked as the primary or secondary source of funding for research assistants, usually in tandem with "Other U.S. Government Funds." For most departments, the rankings for U.S. and foreign students were the same. This suggests that little distinction has been made in the evaluation of U.S. and foreign students for support involving U.S. government funds, whether from NSF or other agencies, which was consistent with responses indicating that there was little difference in the assignments given to U.S. and foreign research assistants unless a department had a particular involvement with a laboratory doing defense-related research.

III. FOREIGN-BORN FACULTY IN U.S. UNIVERSITIES

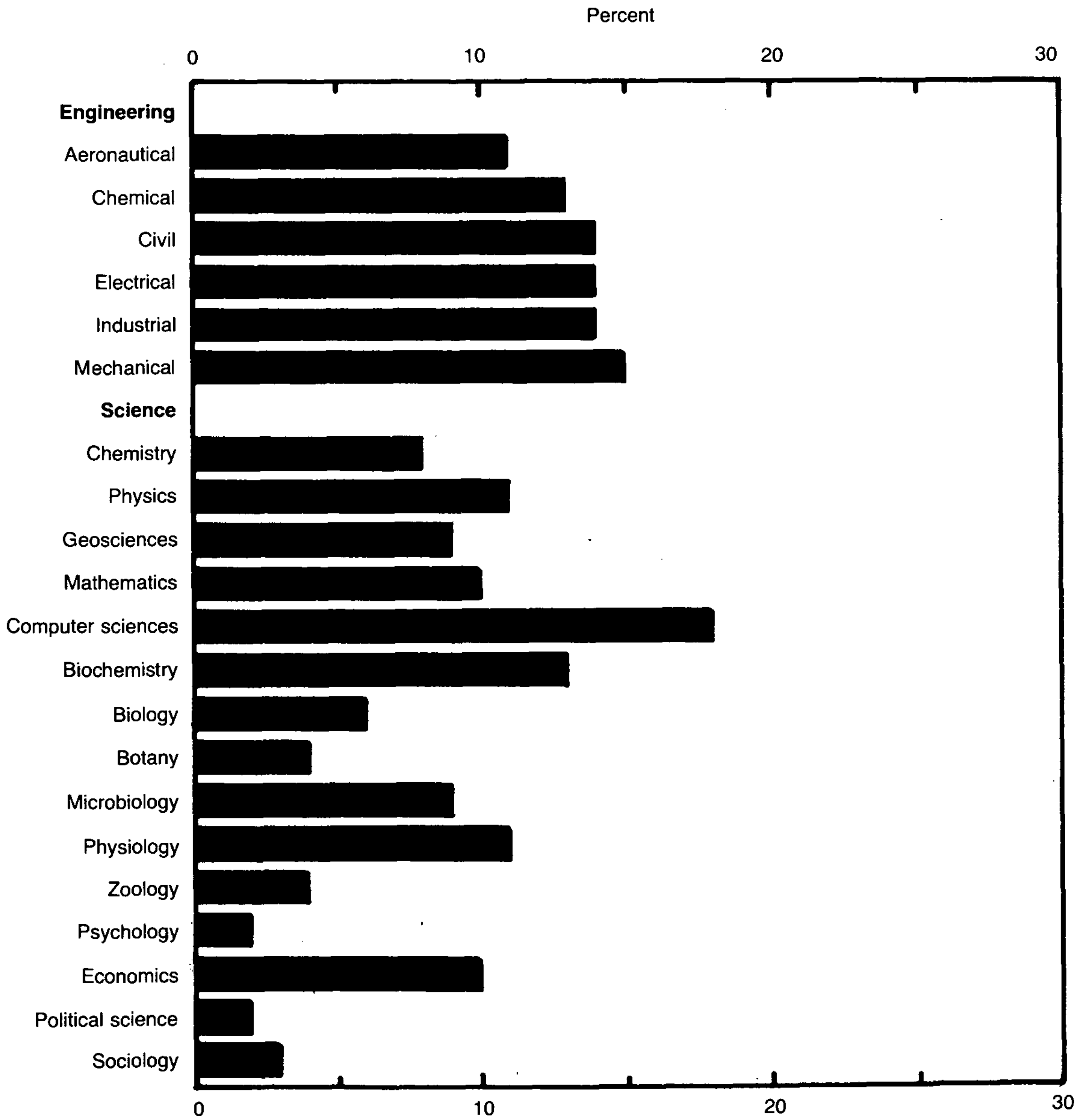
HISTORICAL DATA AND TRENDS

In 1986, NSF surveyed department heads in 21 selected science and engineering fields. Two of the questions contained on the survey targeted foreign faculty members. The first dealt with citizenship status, and asked for the numbers of non-resident alien faculty members who were on temporary or permanent visas. The second asked for the number and academic rank of foreign faculty members who did not receive their baccalaureate in the U.S.

The survey population was 2,074 doctorate-granting departments in the 156 institutions that had S/E doctoral programs in the fall of 1984 and which received at least $2.15 million in Federal R&D funding in FY 1983. Responses were received from 1,664 (80 percent) of the departments located in 154 institutions. Responses to the relevant questions are summarized below.

Chart 3. Foreign Participation in Academic Departments: 1986

(Full-time faculty and doctorates in non-faculty positions)



Source: National Science Foundation, SRS

Distribution in Institutions/Departments

In 1986, 10 percent of the 40,393 full-time faculty members and doctorate-holders in non-faculty positions at the universities surveyed were foreign. Of these, 6 percent (2,575) were foreign citizens on permanent visas and 3 percent (1,310) were on temporary visas. Computer science departments had the highest proportion of foreign faculty at 18 percent, followed by an average of 14 percent for engineering (CHARTS 3 and 4).

In all, over one-half of the departments surveyed employed foreign faculty members and foreign doctorate-holders in nonfaculty positions. Of these, 51.0 percent employed between one and five foreigners, and 7.9 percent employed five or more. Approximately 35 percent of the departments surveyed had no foreign faculty members.

By department, the average number of foreign faculty members was 2.3. The highest average numbers of foreign faculty members were in electrical engineering and mathematics departments; these averaged 4.6 and 4.0, respectively. The average for faculty on permanent visas was 1.5; less than 1.0 person per department was on a temporary visa. Foreign faculty in the life sciences, physical sciences, and engineering tended to be on temporary visas more often than were faculty members in the social sciences, mathematics, psychology, computer science, and environmental science.

Faculty with Foreign Baccalaureates

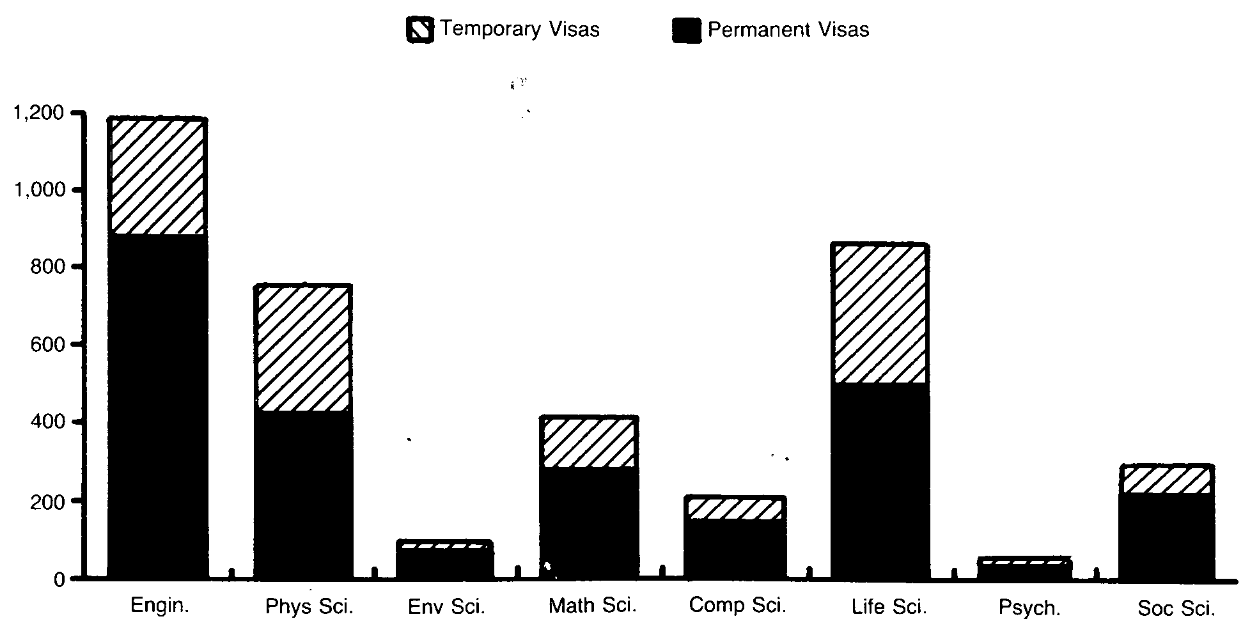
In 1986, sixteen percent of full-time faculty had received their baccalaureates at foreign institutions. This proportion was higher for faculty in engineering fields. For example, one-quarter of the full-time faculty in mechanical and civil engineering and one-fifth of those in chemical engineering had foreign bachelor's degrees. Figures for foreign involvement in U.S. faculties would be significantly higher if foreign born faculty with U.S. baccalaureates were included (Charles E. Falk, "Foreign Engineers and Engineering Students in the United States" in *Foreign and Foreign-born Engineers in the United States*, National Academy Press, 1989).

In addition, 46 departments reported that 50 percent or more of their faculty had foreign bachelor's degrees. Fifty-two percent of these were science departments, 44 percent engineering departments, and 4 percent a combination of science and engineering. The number of total faculty in these departments ranged from 3 to 75 with an average of 18.

In the departments surveyed, there were—on average—4.0 full-time faculty members with baccalaureates from foreign institutions. Reflecting the greater proportion of engineering faculty with foreign bachelor's degrees, these averages were 5.9 and 3.5 for engineering and science departments, respectively.

Responses to the ranking question revealed that the proportion of faculty members with foreign baccalaureates generally was greater at the assistant professor level than at higher levels (e.g., associate professor and full professor levels). This was not the case, however, within the geosciences, physiology, and zoology. In these fields, the proportion of full professors holding foreign baccalaureates exceeded those at the assistant and associate professor levels (Table 4).

Chart 4. Foreign Faculty by Visas Type: 1986



Source: National Science Foundation, SRS

Table 4. Faculty with Foreign Baccalaureates by Department and Rank, 1986

Department	Total		Professor		Assoc. Professor		Asst. Professor	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Engineering								
Aeronautical	114	22	52	18	29	27	33	30
Chemical	242	20	96	14	67	27	79	30
Civil	501	26	227	23	130	24	144	35
Electrical	683	23	287	18	145	20	253	39
Industrial	106	21	31	13	25	19	50	33
Mechanical	560	25	237	20	130	24	193	38
Sciences								
Chemistry	432	12	285	13	56	8	91	16
Physics	770	20	531	20	117	17	122	26
Geoscience	197	16	125	19	44	14	28	10
Computer Science	335	26	93	20	64	19	178	36
Mathematics	881	19	457	18	211	17	213	24
Biochemistry	319	16	161	15	82	15	76	17
Biology	356	12	219	14	70	8	67	11
Botany	52	8	29	8	12	6	11	8
Microbiology	210	13	107	14	55	11	48	13
Physiology	251	15	123	16	70	13	58	14
Zoology	45	5	25	6	14	5	6	4
Psychology	104	3	61	3	18	2	25	4
Economics	371	15	158	13	76	13	137	19
Political Science	128	7	75	8	26	5	27	7
Sociology	93	5	45	5	24	4	24	7

Source: Faculty Survey, National Science Foundation, SRS

IV. FOREIGN PARTICIPATION IN U.S. UNIVERSITY PROGRAMS

NSF-SPONSORED CENTERS

Foundation guidelines to NSF-sponsored University-Industry and Engineering Research Centers place the decision to include foreign firms with individual Centers. In the case of University-Industry Centers, for example, Center Directors have the authority to decide on foreign participation; in practice, they consult usually informally with their industrial members prior to the decision. In addition, NSF encourages Centers to be alert to opportunities for participation by foreign firms that are likely to result in knowledge gains and to assure reciprocity in information exchange between U.S. and foreign participating firms. In all cases, foreign firms must adhere to guidelines for U.S. firms and provide information as well as financial support to Centers.

Centers, in general, distinguish between the U.S. and foreign firm participation primarily on the basis of competitiveness concerns, and on the likelihood that U.S. companies may discontinue participation if foreign companies join. Major foreign companies have sometimes been excluded from participation on this basis. These trends may be changing. Increasingly, foreign firms are encouraging U.S. access to their laboratories through offering long term visits to U.S. scientists and seminars on foreign firm research activities. Centers are becoming more interested in seeking out pockets of excellence abroad, access to foreign laboratories, and knowledge contributions by foreign firms to Center activities. The participation of foreign students in Center activities follows, in general, the same patterns as their participation in university departments. Table 5 and Chart 5 illustrate the degree of foreign student involvement.

OTHER PARTICIPATION

A recent General Accounting Office study (GAO: "Foreign Sponsorship of U.S. University Research," 1988) was aimed at providing information on foreign firms' and governments' sponsorship of R&D at U.S. universities. Study results—which were obtained through a survey mailed to the 150 universities with the largest R&D expenditures in FY 1985—showed that foreign funds (as distinct from funding received from international sources such as the World Bank) accounted for $74.3 million, or about 1 percent of the $6.8 billion in total FY 1986 R&D expenditures by the 107 universities reporting foreign funds.

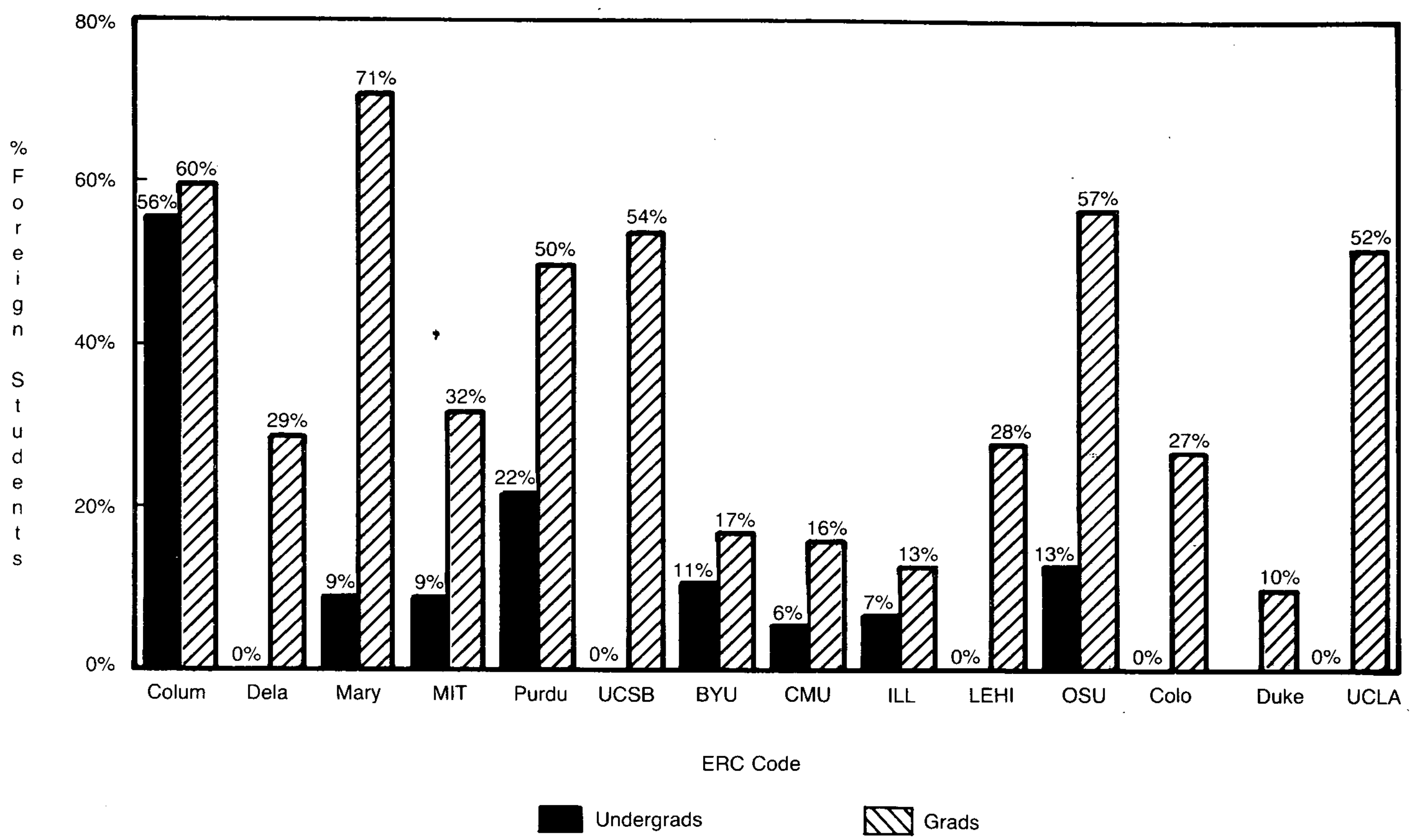
Table 5. Foreign Student Participation in IUCs: Data from 35 IUCs by Region

University	IUC	Total Undergr	Foreign Undergr	Percent Foreign	Total Grad	Foreign Grad	Percent Foreign
Northwest							
Colorado Sch of Mines	ASPPRC	2	0	0%	14	1	7%
Washington, Univ of	PACC	1	0	0%	20	2	10%
Wyoming, Univ of	CMM	2	0	0%	22	11	50%
Subtotal		5	0	0%	56	14	25%
Southwest							
Arizona, Univ of	OCC	0	0	0%	85	22	26%
Arizona, Univ of	CMC	1	0	0%	10	5	50%
Calif, Univ of @ Berkeley	CSA	4	1	25%	23	4	17%
New Mexico Tech	RCEM	4	0	0%	3	1	33%
Oklahoma State Univ	WHRC	4	0	0%	20	11	55%
Southern Calif, Univ of	CMA	0	0	0%	8	8	100%
Texas A&M Univ	CESHR	0	0	0%	14	0	0%
Texas, Univ of @ Arlington	CAEDS	14	2	14%	17	13	76%
Texas, Univ of @ San Antonio	UICRC	4	1	25%	9	2	22%
Subtotal		31	4	13%	189	66	35%
Midwest							
Case Western Reserve Univ	CAPR	8	4	50%	9	7	78%
Illinois Inst of Technology	CIITS	0	0	0%	10	7	70%
Iowa State Univ	CNDE	3	0	0%	14	6	43%
Iowa, Univ of	CSDO	7	0	0%	37	32	86%
Northwestern Univ	CET	0	0	0%	14	5	36%
Ohio State Univ	CWR	0	0	0%	22	16	73%
Subtotal		18	4	22%	106	73	69%
Northeast							
Alfred Univ	OGR	4	0	0%	12	9	75%
Carnegie-Mellon Univ	CISR	3	0	0%	8	4	50%
Lehigh Univ	PMC	3	1	33%	15	10	67%
Lehigh Univ	CIMS	0	0	0%	9	0	0%
Massachusetts, Univ of	IRP	4	0	0%	26	16	62%
MIT	CPPP	4	1	25%	6	2	33%
Northeastern Univ	CER	7	0	0%	19	14	74%
Rensselear Poly Inst	CICG	10	2	20%	25	9	36%
New Jersey Inst of Technology	HTWMC	5	1	20%	57	23	40%
Rutgers Univ	ROC	100	0	0%	35	13	37%
Rutgers Univ	CPR	8	2	25%	14	7	50%
Subtotal		148	7	5%	226	107	47%
Southeast							
Florida Univ/Purdue Univ	CSE	0	0	0%	6	2	33%
Georgia Inst of Technology	MHRC	4	0	0%	36	10	28%
North Carolina State Univ	CCSP	1	0	0%	35	12	34%
North Carolina State Univ	CAPPS	2	0	0%	2	1	50%
North Carolina, Univ/Duke	LTC	1	0	0%	9	0	0%
Tennessee, Univ of	MCEC	6	0	0%	19	8	42%
Subtotal		14	0	0%	107	33	31%
Grand total		216	15	7%	684	293	43%

Source: National Science Foundation, ECD

Overall, foreign businesses supported very little U.S. university research. Universities reported that $27.6 million (37 percent) of their foreign funds were from business sources; $46.8 million (63 percent) came from nonbusiness sources, including governments and nonprofit organizations. Foreign businesses thus accounted for about one-third of 1 percent of the R&D expenditures of the 107 universities. By contrast, U.S. businesses accounted for $512.5 million, or 8 percent of these universities' total R&D expenditures.

Chart 5. Foreign Student Participation in ERCs



Most of the universities surveyed have not and do not plan to establish foreign offices, although one university reported having a permanent office in a foreign country to solicit funding, and two others planned to establish such offices in the next two years. Only five universities had a foreign business or other organization under contract to solicit funding and/or negotiate licenses for university-developed technologies; six more plan to do this within the next two years.

Top University Recipients of Foreign Funds

Foreign funds are highly concentrated in a few universities. While 107 of the universities responding to the GAO survey reported receipt of some foreign funds for R&D, five of these schools—Texas A&M University, Harvard University, Massachusetts Institute of Technology (MIT), Oregon State University, and the University of Wisconsin—accounted for 51 percent of these funds (Table 6). Conversely, 74 of the universities each received less than $500,000 in FY 1986 from all foreign sources. For all five of the top foreign-funded universities, such funding made up only a small portion (between 1 percent and 9 percent) of their total R&D expenditures.

Except for the research sponsored at MIT, most of the foreign-funded R&D at the top five universities is not in "emerging technologies"—i.e., technologies which will lead to new products or processes and which are ex-

Table 6. Universities' R&D expenditures from foreign and all sources: FY 1986 (dollars in millions)

Recipients	Total from foreign sources	Percentage of foreign sources	Total from all sources	Percentage of all sources
All universities*	$74.3	100	$6,808.2	100
Top 20*	58.4	79	2,190.0	32
Top 5*	37.7	51	918.2	13

*Of the 107 universities reporting foreign funds. Ranking of universities is in terms of reported R&D expenditures from foreign sources.

SOURCE: GAO, "Foreign Sponsorship of U.S. University Research," 1988 pected to play a significant role in the economic growth of the U.S. by the year 2000. Aside from this point, however, there was very little similarity among the five universities in terms of either their sponsoring countries or research fields. The following delineates the source and use of foreign funding for R&D at the top five universities.

Texas A&M University. Texas A&M received $15.2 million in foreign funding; this represented 9 percent of its total R&D funding. Almost all (99 percent) of the foreign funding was from non-business sources, and was provided in support of the ongoing international ocean-drilling program, sponsored by NSF. Canada, France, Japan, the United Kingdom, West Germany, and the European Science Foundation each contributed about $2.5 million to the program in 1986.

Harvard University. Of Harvard's total R&D expenditures, $10.8 million (six percent) were provided by foreign funding. Non-business sources accounted for 95 percent of these funds, while four countries—Korea, Indonesia, Bangladesh, and Kenya—provided 90 percent of the funding. Almost all of the research (92 percent) was focused on trade, finance, and banking: through the Harvard Institute for International Development, the funding supported development of a trade ministry, strengthening the analytic capability of the ministry of finance, and reviewing the capital incentive structure.

Massachusetts Institute of Technology. MIT's foreign R&D expenditures totaled $5.3 million, representing 2 percent of its total R&D funding. Businesses provided almost all (98 percent) of the funding. Japan accounted for 42 percent of the funds, the United Kingdom for 15 percent, and other West European countries for an additional 28 percent. About three-quarters of foreign-funded research was distributed among eight engineering fields.

Oregon State University. Of Oregon State University's total R&D expenditures, $4.1 million (five percent) were received from foreign sources. Just under 80 percent of this funding was provided by non-business sources. Half was from Mexico, Poland, the U.S.S.R., the United Nations, and Tunisia. Other Middle East countries and multinational businesses accounted for another 43 percent of these funds. Almost all (97 percent) of the foreign funds were designated for developing agricultural colleges, increasing capacity for agricultural extension, and agricultural management capacity.

University of Wisconsin. At the University of Wisconsin, $2.4 million in foreign funds were received; this represented 1 percent of the university's total R&D expenditures. Almost 90 percent was from business sources; over 10 countries provided the funding. Approximately one-half of the funds was for research in weather monitoring, and 10 percent for agriculture; the remainder was dispersed over more than eight research fields.

Sources of Foreign Funds

According to the GAO sample, numerous countries support R&D in U.S. universities. Although Japan sponsored more R&D than did any other country in FY 1986, no single country predominated in providing R&D funds for U.S. universities: the United Kingdom and West Germany were also major contributors. As a region, Western Europe accounted for $28.9 million, or 39 percent, of the foreign funds reported (Table 7).

University Policies on Foreign Funds

According to the GAO survey, university policies and practices in accepting or administering research funds generally do not distinguish between U.S. and foreign sponsors. Where there are differences, universities tend to place greater restrictions on foreign—rather than U.S.—sponsors. Differences cited by universities primarily involved the financial and legal provisions of funding research, and included the following:

- Imposing payment provisions, such as requiring advance payment of the full amount in U.S. dollars;
- Subjecting funding to greater overall scrutiny and/or to approval through different review channels than for domestic funding; and
- Ensuring that research agreements comply with U.S. export control regulations and other laws.

Industrial Liaison Programs

Many universities have established industrial liaison programs to increase industrial access (both U.S. and for-

Table 7. Foreign funds by country and region: FY 1986 (dollars in millions)

Country/Region	Dollars
Western Europe	$28.9
United Kingdom	7.0
West Germany	5.6
Other Western Europe	16.3
Far East	18.3
Japan	9.5
Other Far East	8.8
Middle East	7.9
Israel	0.7
Other Middle East	7.2
Other	17.5
Canada	5.7
Multinational	1.5
Other*	10.3

*For the top five universities receiving foreign funds, "other" included Columbia, Brazil, Mexico, Poland, the USSR, and Tunisia.

SOURCE: GAO, "Foreign Sponsorship of U.S. University Research," 1988 eign) to university research information. Liaison program membership benefits may include seminars, publications, interactions/consultations with faculty or graduate students, access to university facilities, access to student resumes, visits by faculty to corporate facilities, ability to help select research projects, and continuing education and industrial scholar programs. In return for these benefits, universities may charge a fee or request a contribution.

Thirty-eight percent (41) of the universities which reported receipt of foreign funding described three of their major industrial liaison programs. Of these, 70 percent (71) had been created since 1980; they had 2,848 U.S. member companies (85 percent) and 496 foreign member companies (15 percent). Information on the amount of money contributed by foreign sources to these liaison programs could not be determined.

Three universities—Texas A&M, MIT, and the University of California at Berkeley—accounted for 76 percent of the foreign membership reported. Their programs were all university-wide and were in the areas of thermodynamics, oceanography, chemistry, transportation studies, materials processing, and engineering. The relevant Texas A&M liaison program did not charge an annual fee. MIT identified 116 foreign members in its university-wide liaison program; fees for this are based on company size and range from $25,000 to $100,000. A second MIT liaison program has 30 foreign members who pay an unspecified annual fee. The University of California at Berkeley reported 42 foreign members in an industrial liaison program; most of these had been granted membership by sponsoring research projects. Fees to join the liaison program at Berkeley begin at $5,000.

Foreign Endowments and Gifts

Of the 134 responding universities, 20 reported having received over $500,000 in accumulated gifts or endowments for R&D programs, facilities, and/or equipment from any single foreign source since the beginning of FY 1984. The gifts and endowments identified totaled $27.3 million. Japan accounted for the largest number of these—12—followed by Canada with three. Switzerland, Spain, Italy, Israel, Peru, and Somalia also provided gifts or endowments. The Japanese gifts and endowments were for imaging in the arts and media; equipment purchase or facilities construction; support of a faculty chair and of a center of Japanese business and economics; research on fisheries, legal restrictions in the Pacific Community, construction technology, and radiology; and fellowships.

V. FOREIGN SCIENTISTS AND ENGINEERS IN U.S. BEYOND UNIVERSITIES

FEDERAL LABORATORIES

Federal laboratories represent a vital R&D resource, performing research in a broad range of fields to meet national objectives and priorities. In 1986, the Federal Government obligated $18 billion for R&D to these laboratories. To determine the extent of foreign participation at these laboratories, the GAO surveyed 52 laboratories in 7 Federal agencies (GAO: "U.S. and Foreign Participation in R&D in Federal Laboratories," 1988). These agencies—the Departments of Agriculture (AG), Commerce (DOC), Defense (DOD), Energy (DOE), Health and Human Services (HHS), and Interior (DOI), and the National Aeronautics and Space Administration (NASA)—together accounted for about 95 percent of the funds obligated for Federal laboratory R&D. The individual laboratories selected for inclusion in the sample were among each agency's largest and were more likely to conduct R&D in fields with commercial potential.

Fifty Federal laboratories responded to the survey. These employed 43,902 researchers, had a combined R&D operating budget of $14.1 billion in FY 1986, and included the major Federal laboratories involved in R&D with commercial potential.

Federal laboratories offer a variety of programs through which foreign (as well as U.S.) governments, businesses, universities, and other nonprofit organizations can collaborate on or fund R&D. The principal mechanisms for such interaction are (1) guest and visiting researcher programs, which enable senior researchers from outside organizations to collaborate on a project with a colleague at the laboratory, and (2) educational programs, which bring postdoctoral fellows, faculty, and students to the laboratories to gain experience and/or training in a research field. About 19,000 outside researchers participate per year through these programs. The benefits of these programs are mutual; in fact, several laboratories rely on outside researchers (both U.S. and foreign) to supplement their permanent staff. For example, one-half of the foreign researchers participating in R&D at the National Institutes of Health (NIH) were postdoctoral fellows who received training for careers in medical research. Only about 10 percent of the fellows receive full-time positions at NIH.

Through these programs, 5,677 foreign researchers—representing 30 percent of all outside researchers—conducted R&D at the surveyed Federal laboratories in FY 1986.

Distribution of Foreign Researchers

The majority of the foreign researchers conducted R&D at either NIH (34 percent) or the nine DOE energy research laboratories (32 percent). The next largest proportions worked at DOE's defense programs laboratories (9 percent) and NASA laboratories (8 percent). The fewest number of foreign researchers were involved in work at Air Force and DHHS laboratories (1 percent each).

Of all laboratories surveyed, only NIH and the U.S. Geological Survey had more foreign than U.S. outside researchers at their laboratories (52 percent and 65 percent, respectively). The majority of U.S. outside researchers were concentrated in DOE energy research laboratories.

Country of Origin

The largest number of foreign researchers came from Japan (758, or 13 percent of all foreign researchers). Of these, over one-half (394) worked at NIH; an additional one-quarter (191) worked at DOE's energy research laboratories. Similar priorities were reflected by the 448 researchers from the United Kingdom; most (33 percent) worked at NIH, while just over one-quarter were at DOE's energy research laboratories.

The next largest proportion of foreign researchers (8 percent) came from the People's Republic of China. Of these, 41 percent conducted research at DOE's energy research laboratories, 30 percent worked at NIH, and 15 percent were at the National Institute of Standards and Technology (NIST).

Priorities among the remaining groups of foreign nationals shifted between energy and medical research. West German researchers were concentrated at DOE's energy research laboratories (42 percent), with just under one-quarter more at NIH, and 11 percent at NASA's laboratories. Indian researchers, on the other hand, focused on NIH research (42 percent), with an additional 27 percent at DOE's energy research laboratories, and 12 percent at NASA laboratories. Researchers from the Soviet Union and other Eastern European countries were concentrated at both DOE energy research laboratories (39 percent) and NIH (34 percent).

Institutional Affiliation

Of the 2,953 foreign guest and visiting researchers, 57 percent were affiliated with universities and other nonprofit organizations. Twenty-five percent were government-affiliated; another 118 (4 percent) were affiliated with businesses; these were generally guest researchers. Parent companies or sponsoring professional organizations or trade associations paid researchers' salaries, housing, and other costs.

In addition to collaborating with researchers who conducted R&D through guest and visiting researcher programs, employees at Federal laboratories frequently work with their agencies' contractors. Forty laboratories reported that 508 foreign researchers employed by a Federal contractor conducted R&D at the laboratories to fulfill contract terms. NASA laboratories reported that 334 foreign researchers worked as contractor personnel in FY 1986.

Foreign Participation by Program Type

Japanese nationals were the most heavily represented in both guest and visiting researcher programs (13 percent) and educational programs (15 percent). Among Japanese guest and visiting researchers, 33 percent worked at NIH, and 36 percent worked at DOE's energy research laboratories.

Nine percent of the foreign participants in guest and visiting researcher programs came from the United Kingdom, 8 percent were from West Germany, and 25 percent came from other Western European countries. Overall, 403 Western European researchers worked at NIH, 489 worked at DOE's energy research laboratories, 263 worked at DOE's defense programs laboratories, 145 worked at NASA, and 224 worked at other surveyed laboratories.

Among program participants from the People's Republic of China, 131 worked at DOE's energy research laboratories, 56 worked at NIST, and 48 worked at NIH.

Among educational program participants, Japan had, as stated, the highest proportion with 10 percent; India had the second highest. Regarding participants in educational programs overall, 10 percent of the university and high school faculty members and of the graduate, undergraduate, and high school students who worked at Federal laboratories in FY 1986 were foreign nationals. Similarly, 41 percent of all postdoctoral fellows conducting research at Federal laboratories under educational programs were foreign nationals; of these, 73 percent worked at NIH.

The likelihood that foreign researchers participating in educational programs will seek U.S. citizenship apparently varies by nationality. Japanese researchers typically will return to Japan; a higher percentage of researchers from India (for example) will seek U.S. citizenship.

U.S. INDUSTRY

Current S/E Work Force

In 1986, there were more than 1.6 million employed scientists and 2.2 million employed engineers in the U.S.; together, these represented about 3.6 percent of the national work force. Between 1976 and 1986, the Nation's S/E work force nearly doubled, increasing four times as rapidly as total U.S. employment.

Overall, the S/E work force grew at an average annual rate of 6.3 percent per year since 1976; there was, however, substantial variation across fields. Employment of scientists increased at a faster rate than that of engineers: 7.1 percent per year versus 5.8 percent. Almost 20 percent of the increases among scientists were due to growth in the employment of computer specialists; if computer specialists are excluded, employment growth for scientists averaged only 5.5 percent per year. Among engineering subfields, the largest relative employment growth was in electrical and astronautical/aeronautical engineering.

S/E Employment by Sector

Industry. In 1986, industry was the major employment sector for both scientists and engineers, employing 66 percent (almost 2.6 million) of the S/E work force. Engineers were more likely than scientists to work in industry—80 percent of engineers, versus 48 percent of scientists, were so employed. Between 1976 and 1986, total industrial S/E employment increased an average of 7 percent per year, rising from 1.3 million in 1976 to almost 2.6 million in 1986.

Increases in industry's share of the S/E work force become more pronounced at the doctoral level. Although educational institutions remained the primary employer of doctoral scientists and engineers in 1985, the proportion employed in this sector had declined steadily since the early 1970's, while the industry share increased. In 1973, 59 percent of all S/E doctorate-holders were in educational institutions and 24 percent were in industry; in 1985, these proportions were 53 percent and 31 percent, respectively.

Another trend in industry sector S/E employment was a gradual shift from the manufacturing to the non-manufacturing sector, with the proportion of scientists and engineers in manufacturing industries declining from over 57 percent in 1977 to about 55 percent in 1986. By 1986, about 45 percent of all industrial scientists and engineers were employed in non-manufacturing industries.

Much of the increase in S/E employment in the non-manufacturing sector can be attributed to the rapidly expanding work force of the service industries. Changes within manufacturing, however, are almost entirely explained by structural change. While manufacturing experienced little or no growth in total employment levels between 1977 and 1986, science and engineering employment increased by an average of 4.9 percent per year—primarily because of the increased dominance of engineers, computer specialists, and mathematical scientists. The labor-intensive production of the seventies shifted to the more high-tech and knowledge-intensive environment of the eighties.

Academia. With just under 15 percent (almost 573,000) of the S/E work force, academia ranked a distant second to industry as an employer of scientists: 29 percent of all scientists were in the education sector, but only 4 percent of all engineers. Of the scientists and engineers employed by academia, almost 84 percent were in scientific fields; one-half of these were either life scientists or social scientists. Of the 91,000 engineers in the sector, 25,000 (27 percent) were electrical/electronics engineers and 17,000 (19 percent) were mechanical engineers.

Over the 1976–86 decade, academia's share of the S/E work force increased from 13 percent to almost 15 percent. The ratio of scientists to engineers remained constant at about six to one. In general, academia experienced the same increasing demand for scientists and engineers as did industry; this demand was especially pronounced for those with engineering or computer science degrees. Moreover, because some universities in the early 1980's were unable to compete with salaries offered by private industry, they lost faculty members in certain high demand engineering positions.

Federal Government. The Federal Government ranked as the third largest employer of scientists and engineers in 1986, accounting for about 9 percent of S/E employment. Over 54 percent of the 334,200 Federal S/E work force were in engineering occupations; almost one-half were in either electrical/electronics or civil engineering. Among Federally employed scientists, 26 percent (40,200) were in the life sciences and 21 percent (32,100) were computer specialists. Almost one-half of the Federal scientists and engineers were employed by DOD; AG had the second highest share with 12 percent.

Other Sectors. Of the remaining 10 percent of the employed S/E work force (423,700), almost one-half worked for State and local governments, 34 percent were employed by nonprofit institutions, and 16 percent were in the military or other organizations in 1986.

Demand for Scientists and Engineers

As of 1986, there appeared to be a rough balance between the supply and demand for science and engineering personnel: employment indicators suggested generally sufficient demand to accommodate the S/E work force. This is demonstrated by both a high labor force participation (94.5 percent) and a low unemployment rate (1.5 percent) for scientists. Furthermore, in a 1985 survey, industrial employers reported low levels of shortages; this also indicates that the Nation's science and engineering labor force is, in general, sufficient to meet the economy's current demands.

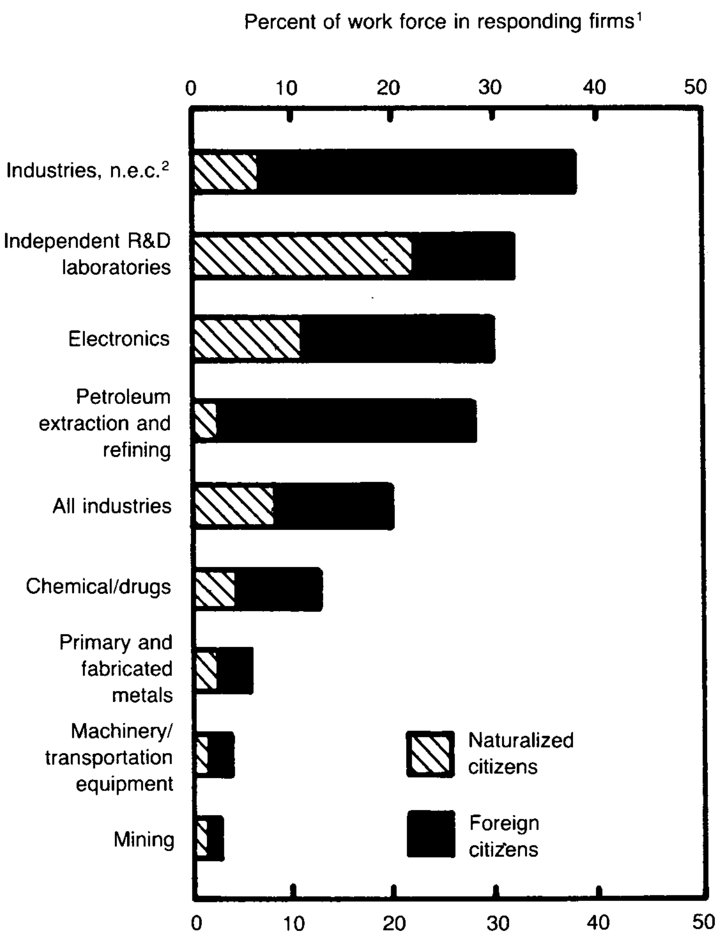
One exception to this supply/demand equilibrium is the demand for engineering Ph.D.'s. In 1986, engineering schools reported shortages of faculty in that discipline, with almost 9 percent of authorized full-time engineering faculty positions unfilled. Industry employers reported shortages in electronics engineering, nuclear engineering, and electrical engineering.

Academic shortages for several other fields are reported in a 1988 National Council of Education survey. About six in ten colleges and universities reported shortages of faculty in computer sciences. Although every type of institution was affected, shortages of computer scientists were especially severe among doctoral institutions, where 86 percent reported inability to fill vacant faculty positions. This survey also indicated that one-third of all institutions were unable to fill vacant positions in mathematics, with public institutions more likely than independent institutions to report such difficulties.

Lacking graduate candidates to fill these academic positions, educational institutions have increasingly relied on foreign scientists and engineers to maintain their staffing levels. U.S. industry also reports reliance on foreign scientists and engineers. A 1985 survey of 300 U.S. firms showed the dependence of U.S. industry on foreign scientists and engineers. In firms employing foreign citizens, these personnel made up an average of 9 percent of the firms' S/E work force. An additional 11 percent was of naturalized U.S. citizens (see Chart 6).

To assess the quality impacts of foreign engineers in U.S. industry, a survey was carried out of 20 members of

Chart 6. Foreign and Naturalized U.S. Citizens as Percent of Science/Engineering Work Force in Selected Firms by Industry: 1985



[1]Data refer only to responding firms employing foreign citizens (chart 1).
[2]Not elsewhere classified. Includes aerospace, construction, engineering and architectural services, and utilities.
Source: National Science Foundation

the Industrial Research Institute (IRI) and discussions were held with top-level managers in the industrial R&D community (Peter Cannon: "Foreign Engineers In U.S. Industry," in *An Exploratory Assessment; Foreign And Foreign-Born Engineers In The United States*, National Academy Press, 1988). Results confirmed that foreigners comprise a significant segment of the engineering work force in U.S. industry.

In comparing foreign engineers to their U.S. counterparts, preparation, skills, and professionalism were found to be about equal, with poor communication skills noted as the major drawback of foreign engineers.

The author recommended that the artificial barriers to entry into the United States of foreign engineers must be lowered. U.S. demographic and market needs make it urgent to simplify current immigration regulations so as to make it easier for American industry to employ foreign-born graduate students.

Encouraging more Americans to enter science and engineering careers through major reform and strengthening of the U.S. educational system was also recommended. Monitoring the propensity of foreigners to remain in the United States was suggested so as to anticipate the problem that would arise should significantly more foreigners choose to return to their countries.

To supplement these 1988 results, in January 1989, several of the highest R&D funding companies in the United States were asked about the nationality of newly hired and already employed scientists and engineers over the last few years. Responses indicate an average of about 10 percent of newly hired scientists and engineers were foreign citizens, and approximately 8 percent of the research work force.

As the above illustrates, the balance between supply and demand for S/E personnel is being accomplished through means other than production of new science and engineering graduates. Educational institutions have increasingly relied on foreign scientists and engineers to maintain their staffing levels. This is also true of U.S. research-intensive industry, although to a far lesser extent. Overall, between 1972 and 1982, native-born U.S. citizens declined from 90 percent of the S/E labor force to 83 percent; this also reflects an increasing reliance on foreign personnel to maintain the supply-demand equilibrium in the S/E labor market.

The balance between supply and demand for S/E personnel has also been accomplished through other means than employment of foreign scientists and engineers. One major source of supply is occupational mobility. For example, in the late 1970's, individuals with degrees in closely related fields (e.g., chemistry, physics, mathematics) filled the gap between job openings and new degrees in engineering and computer science. One consequence of this was that between 1972 and 1982, the portion of the engineering work force with degrees in non-engineering fields rose from roughly 15 percent to approximately 20 percent.

Also, during this period, a large amount of reciprocal flow between engineering and computer specialists took place. Almost one-half of the inflow to computer specialties from other occupations came from engineering and about one-tenth of the inflow to engineering came from computer specialties. Concern has sometimes been expressed about this type of mobility in that many computer specialties include practitioners who may not be fully trained engineers.

Another source of supply for scientists and engineers, particularly in industrial non-R&D activities, is the pool of non-degree technicians who are promoted on the basis of their experience. However, data are not available to indicate the proportion of the U.S. science and engineering work force that consists of such non-degreed individuals.

Overall, the U.S. research system shows a dependence on foreign scientists and engineers and this dependence is expected to continue.

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