DOCUMENT RESUME

ED 108 942 SE 019 230

TITLE The Human Resources of Science and Engineering - Today and Tomorrow.
INSTITUTION Scientific Manpower Commission, Washington, D.C.
PUB DATE Feb 75
NOTE 106p.; A symposium at the annual meeting of the American Association for the Advancement of Science (January 1975)

EDRS PRICE MF-$0.76 HC-$5.70 PLUS POSTAGE
DESCRIPTORS *Engineering; Engineering Education; Human Resources; *Manpower Development; *Manpower Utilization; Physical Sciences; Science Education; *Scientific Manpower

ABSTRACT

This publication is a collection of 15 illustrated papers presented at a symposium at the annual meeting of the American Association for the Advancement of Science, 1975. Manpower specialists examined the present utilization of manpower in each of several science and engineering fields. Past projections of supply and demand were compared with what really happened. The nature and quality of career guidance in science and engineering included a special look at guidance for girls and minority youths. Field by field enrollment information shows some trends that will change the relative supply of new graduates in science and engineering over the next few years. Policies and practice learning toward future balances in the supply of and demand for scientists and engineers are encouraged. (Author/EB)

The Human Resources of Science and Engineering

Today & Tomorrow

SMC

SCIENTIFIC
MANPOWER
COMMISSION

A participating organization of
AMERICAN ASSOCIATION for the
ADVANCEMENT OF SCIENCE
1776 Massachusetts Avenue, N.W.
Washington, D. C. 20036

February 1975

The Scientific Manpower Commission is a nonprofit corporation made up of Commissioners representing its eleven member scientific societies.

The Commission is charged with the collection, analysis and dissemination of reliable information pertaining to the manpower resources of the United States in the fields of science, engineering and technology; promotion of the best possible programs of education and training of potential scientists, engineers and technicians; and development of policies of utilization of scientific, engineering and technological manpower by educational institutions, industry and governmnt for optimum benefit to the nation.

THE HUMAN RESOURCES OF SCIENCE AND ENGINEERING - TODAY AND TOMORROW

A Symposium

at the 1975 Annual Meeting of the

American Association for the Advancement of Science

January 27, 1975

SMC Staff: Betty M. Vetter - Executive Director

Eleanor L. Babco - Administrative Assistant

Dave Carter - Secretary

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TODAY AND TOMORROW

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The Authors

John D. Alden is Director of Manpower Activities of Engineers Joint Council, and Executive Secretary of the Engineering Manpower Commission of E.J.C. in New York City.

Donald R. Beem heads both the Membership Department and Special Science Programs at the American Institute of Biological Sciences in Arlington, Virginia.

C. Alan Boneau is the Director of Programs and Planning for the American Psychological Association in Washington, D. C.

Truman A. Botts directs the activities of the Conference Board of The Mathematical Sciences in Washington, D.C., and was the Secretary of the Mathematics Section of the American Association for the Advancement of Science in 1974.

David W. Breneman, a Senior Fellow of the Brookings Institution, is Staff Director of the National Board on Graduate Education in Washington, D.C.

Janet W. Brown directs the Office of Opportunities in Science of the American Association for the Advancement of Science, Washington, D. C.

Bonnie Henderson is the Assistant Director of Education and Manpower of the American Geological Institute in Falls Church, Virginia.

Robert E. Henze is Director of the Membership Division, American Chemical Society, Washington, D. C.

Charles V. Kidd serves the Association of American Universities in Washington D. C. as its Executive Secretary.

David R. Reyes-Guerra is the Executive Director of the Engineers Council for Professional Development in New York City.

Paul H. Robbins is Executive Director of the National Society for Professional Engineers in Washington D.C, and was the 1974 Secretary of the AAAS Section for Engineering.

Raymond W. Sears directs the Manpower Division of the American Institute of Physics in New York City.

Robert L. Stern is in Advanced Technology Services at Xerox Corporation in Stamford, Connecticut, and was the 1974 Secretary of the AAAS Section for Industrial Science.

James W. Symington, U.S. House of Representatives, is Chairman of the Subcommittee on Science, Research and Technology in the Committee on Science and Technology.

Betty M. Vetter is Executive Director of the Scientific Manpower Commission in Washington, D.C.

INTRODUCTION

On January 27, 1975, a group of specialists in a variety of areas came together in a symposium at the 1975 annual meeting of the American Association for the Advancement of Science to discuss the human resources of science and engineering, both presently and in the future. The session was sponsored jointly by the Scientific Manpower Commission and the AAAS Sections in Industrial Science, Engineering and Mathematics; and was arranged by Betty Vetter and Robert Stern.

Manpower specialists in each of several fields of science and engineering outlined the size and present utilization of the professionals in their fields.

Dr. David Breneman examined some past projections of supply and demand, discriminating between those errors in past models that can be avoided in the future and those that are not yet capable of accurate prediction.

Dr. David Reyes Guerra talked about the nature and quality of career guidance in science and engineering while Dr. Janet Brown looked at the specialized area of guidance for girls and minority youth in these fields where women and minorities are minimumly represented.

Looking toward the future, field by field enrollment information showed some of the changing enrollment trends that will change the relative supply of new graduates in science and engineering over the next few years.

Members of the symposium were not all agreed as to whether imbalances between supply and demand presently exist, or probably will exist in the future. However, there was agreement that data presently available are incomplete, inconsistent and sometimes used in unreal ways to project the future.

Four speakers representing academia, the professional societies, industry and government assessed the implications for action in these sectors to encourage policies and practices leading toward future balances in the supply of and demand for scientists and engineers.

The fifteen papers presented in this symposium together with their accompanying charts and tables, are published without editing, both at the request of several persons who attended the symposium, and for the benefit of those who were not present but will find the information both interesting and provocative.

Betty Vetter

PHYSICS MANPOWER AND ITS UTILIZATION

by

Raymond W. Sears
American Institute of Physics

The Physics Community

The American Institute of Physics has for many years collected information on the physics community including the surveys covering enrollments and degrees, the physics portion of the National Register of Scientific Personnel from its inception in 1954 to its demise in 1970 and the AIP-APS Register of Physicists and Related Scientists in 1973. The physics community is best described by the data from the 1973 Register, our own most recent overall survey. The data are bounded bv our continued use of the NSF definition of a physicist to assure continuity with previous National Registers. Briefly, a physicist is an individual with a doctorate or master's degree in physics or an individual with a bachelor's degree in physics plus two years of additional training or employment in physics or the equivalent. Individuals with degrees in related fields (mostly advanced degrees) and working in a subfield of physics were included on the basis of a combination of self identification with physics and the extent of their experience in physics. Lower degree holders previously classified as physicists who have moved to work clearly outside of physics for a substantial period of time (about five years) were no longer classified as physicists.

In the 1973 Register there were about 20,000 PhD physicist respondents and 15,000 lower degree level physicist respondents. The response rate for PhDs was estimated at 81%. Accordingly, there were about 24,000 physicists at the doctoral level in 1973. The lower degree level response was somewhat less and estimated at 75%. There were about 20,000 physicists with master and bachelor degrees in 1973. The total population of physicists in the U.S. was about 44,000.

The proportion of women physicists at the PhD level has remained at about 2.0% for some time but jumped to 2.7% in 1973. The proportion of women physicists at the master and bachelor levels is substantially larger and has been increasing at a rather steady rate for the past decade.

Women Physicists 1964-73

	PhD's	Master's & Bachelor's
Year	Percent	Percent
1964	2.1	4.0
1968	2.0	4.8
1970	2.1	5.1
1973	2.7	6.4

Overall, women are about 4.0% of the total community. This is substantially lower than in other sciences.

The production of physicists during the 1960's fell short of the demand in the U.S.A. and the deficiency was filled by immigration from abroad. As a consequence, the U.S. physicist work force has a sizeable proportion of non U.S. citizens.

Non U.S. Citizen Physicists 1964-73

	PhD's	Master's & Bachelor's
Year	Percent	Percent
1964	9.7	3.1
1968	11.0	4.2
1970	11.5	6.3
1973	9.0	6.5

Note that the PhD percentage fell from 11.5% in 1970 to 9.0% in 1973. There has been a lowered rate of immigration of PhD's since 1970 and many earlier immigrants have become naturalized or returned to their native country. All of these factors have contributed to the lower proportion of non-citizens in 1973.

The APS-AIP Register was the first survey in physics where data was obtained on minority and ethnic classifications of physicists. The data is shown in the next table which lists the percentage of the total community who identify with various races and ethnic groups.

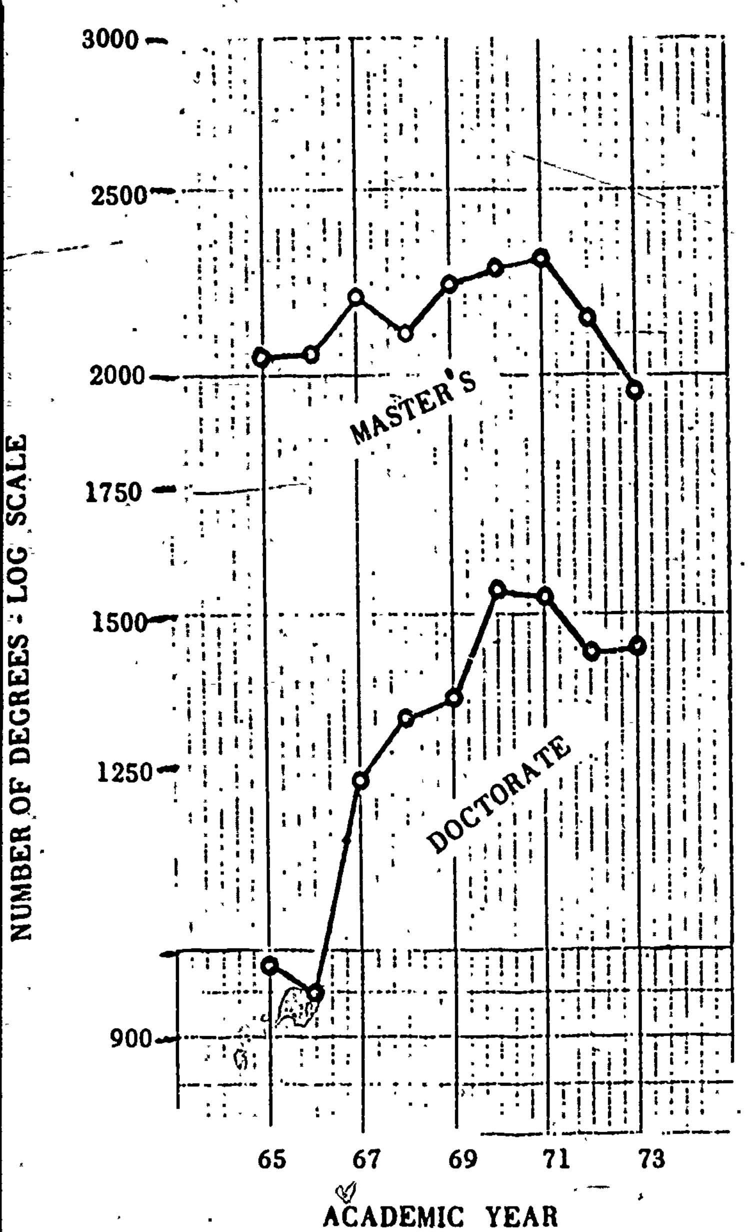
Race and Ethnic Groups in U.S. Physics 1973

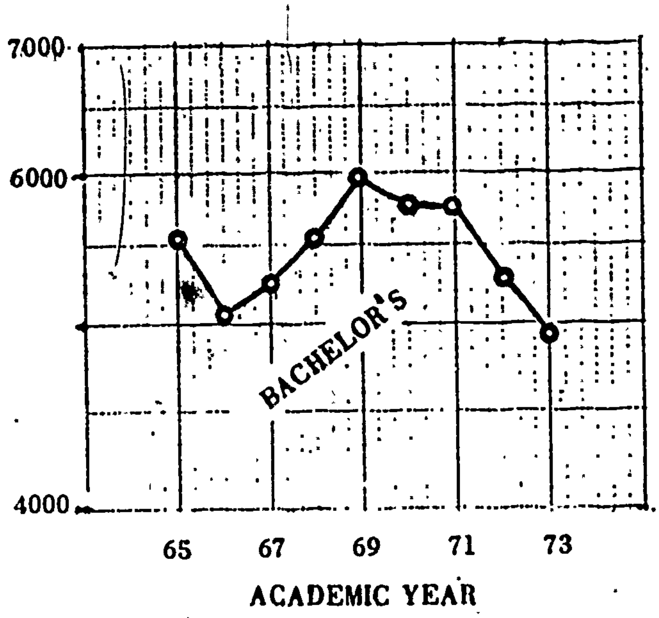
	Total Percent	PhD's Percent	Master's Percent	Bachelor's Percent
White	90.7	90.2	90.9	92.4
Black	0.6	0.4	0.9	0.8
Oriental	4.4	4.9	3.8	3.4
Other Asian	1.2	1.3	1.5	0.4
American Indian	0.3	0.2	0.4	0.4
Mexican American	0.2	0.2	0.2	0.1
Puerto Rican	0.1	0.1	0.3	0.1
Other Spanish-Speaking	0.3	0.3	0.5	0.3
Other	0.1	1.2	1.3	1.4
No Response	1.8	2.2	1.4	1.4

The identifications are classified by level of background training. Note that this is not an exact proportion of individuals since multiple responses were permitted. Only 4.4% of the lacks, and 0.8% of the Whites made multiple responses while 75% of American Indians, 30% of the Mexican Americans, 28% of the Puerto Ricans and 57% of the other Spanish speaking individuals gave multiple identifications.

The number of physics degrees granted from 1965 through 1973 is shown on the next page. The number of bachelor and masters degrees peaked in 1969

Physics Degrees Awarded by Academic Year





and 1971 respectively and have since been declining. The number of bachelor degrees fell below 5,000 for the first time since 1959 but Susanne Ellis our expert in such matters does not expect it to decrease much further.

The production of physics doctorates reached a maximum in 1970 and has been declining since that time. The number of doctorates will continue to decline for several years to around 1,000 based on current enrollments in graduate schools.

Utilization

Physicists are employed mainly in academic, industrial and governmental institutions with the rank order expressed as a percentage of physicists.

Employers of Physicists

Institutions	PhD's	Master's & Bachelor's*
Colleges and Universities	51.0%	12.4%
Industry	22.5	36.3
F.F.R. & D. Centers	11.8	5.5
Government	10.6	19.8
Non Profit Organizations	2.5	3.0
Junior Colleges & Secondary Schools	1.4	22.9
Other	0.2	0.1
	100.0%	100.0%

* *Excluding Graduate Students*

Considering first doctorate physicists, one-half are employed in academic institutions. Here 44% of the total effort involves teaching, 42% research, and 9% administration with 5.0% other. Almost one-quarter of the PhD's are employed in industry, involving 40% research and 60% development, engineering and administration. The remaining quarter employed in governmental institutions and federally funded research and development centers where 61% of their work is in basic and applied research.

Only 12% of physicists with lower degrees are employed in colleges and universities. Note however, that a sizeable percentage (22.9%) are employed in junior colleges and secondary schools (mostly high schools) which brings the total to about a third of the physics work force with less than a doctorate degree. A larger proportion are employed by industry and government than is the case for PhD's.

Some physicists are unemployed. Unemployment rose to a high value in 1971-72, but was improved considerably by 1973 for physicists, chemists and engineers alike.

Unemployment of Physicists, Chemists and Engineers

		1968	1970	1971 (percent)	1972	1973
Physicists	PhD/DSc	0.5	1.3	1.8		1.2
	MA/MS	1.4	3.0	5.8		2.1
	BA/BS	1.3	2.7	6.0		2.0
	Total	1.0	2.1	3.9		1.5
Chemists	PhD/DSc		1.1	2.1	2.5	1.5
	MA/MS		1.8	3.1	3.5	2.2
	BA/BS		1.5	3.2	3.4	1.7
	Total		1.4	2.7	3.0	1.7
Engineers	Total	0.9	2.2	3.2	2.0	1.2

By 1973 some physicists had moved to areas outside of physics, others found work abroad, some non-citizens returned to their native land and other physicists found employment in applied physics. The unemployment level has continued to improve slightly in the early part of last year, but recently has started to turn around. What is ahead as a result of our current economic situation is a puzzle.

The proportion of new physicists entering into the various physics subfields since 1970 varies considerably with the subfields. Areas with higher than the average percentage growth of new physicists include:

1. Medical Physics
2. Astronomy
3. Geophysics
4. Plasma Physics
5. Acoustics
6. Biophysics
7. Elementary Particle Physics
8. Atomic & Molecular Physics
9. Chemical Physics
10. Optics

listed in rank order.

Physics subfields with the lowest percentages of growth include:

1. Electronics
2. Thermal Physics
3. Theoretical Physics
4. Mechanics
5. Metrology
6. Nuclear Physics
7. General Physics
8. Solid State Physics
9. Physics of Fluids
10. Electromagnetism

with rank order as is indicated.

Noting that around half the number of physicists are employed by academic institutions prompts a brief look at this employment situation. Data on the number of physics faculty members engaged in teaching and research is shown on the next page as determined by our annual faculty survey. Note that the ordinate scale is logarithmic. Postdocs are not included in these figures. Separate curves are shown for physics doctorate granting institutions, for colleges and universities granting master and bachelor

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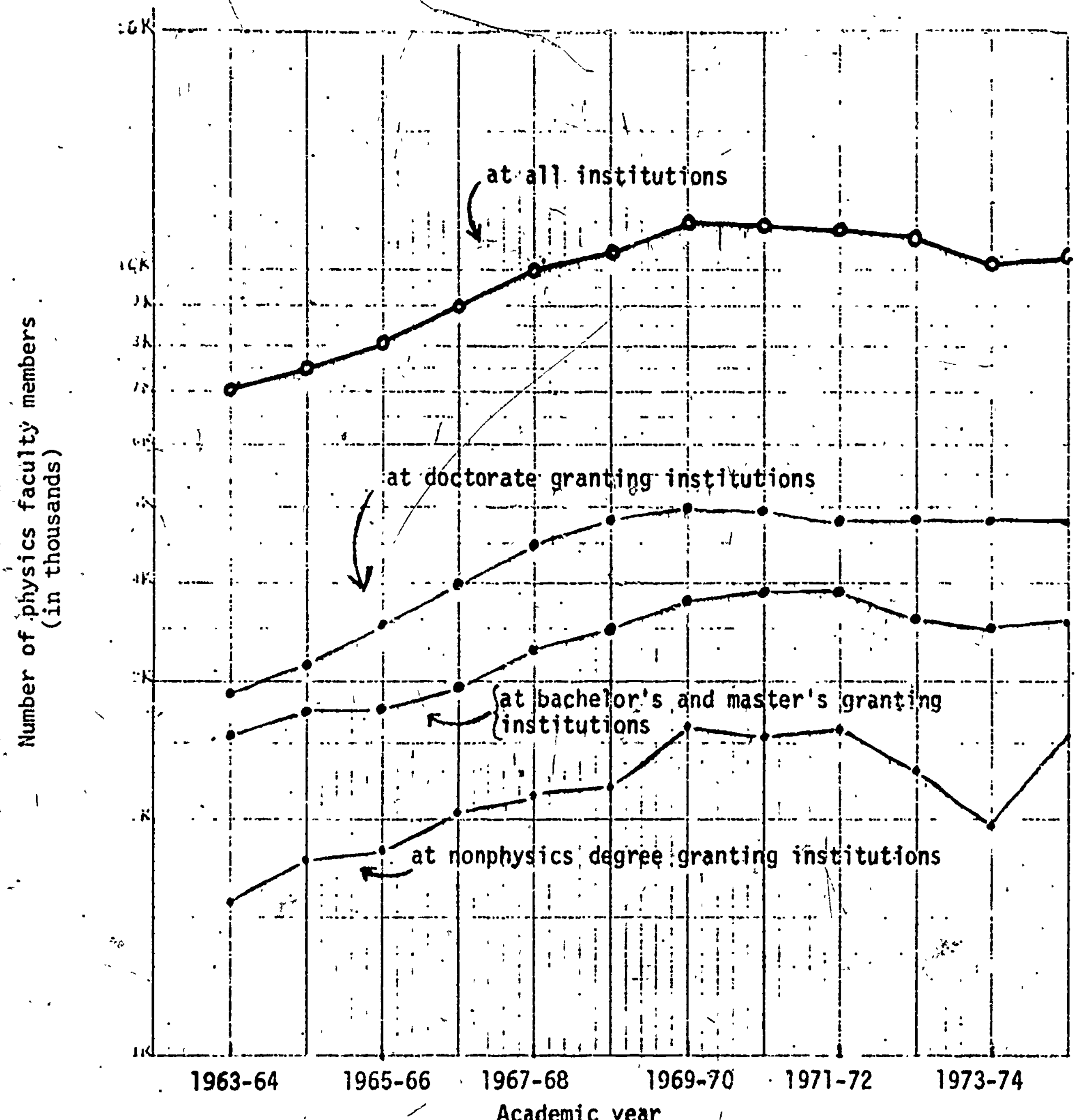
Physics Faculty at Institutions Offering Physics Courses



degrees in physics and for colleges teaching physics courses without a major in physics. Secondary schools are excluded. The top curve sums over all academic institutions. We note overall a substantial drop of almost 1,200 or 10% from the peak in the 1969-70 academic year. There has been little change in the total number of faculty members in doctoral granting institutions from 1972-1974, but new data show a 1.2% drop for 1975. The faculty at bachelor's and master's granting institutions has been decreasing since 1971 but new data indicate an increaseof 1.5% for the 1974-75 academic year. Unpublished data for 1975 indicate a substantial growth in physics faculty members for two year institutions.

The physicists employed in industry amounting to slightly over 25% of the physics community are employed over a broad spectrum of more than 1,000 companies. There is a high concentration in a very few industrial laboratories so that over one-half of the industrial physicists are employed by 25 firms. Each of over eight-hundred industrial companies has less than five physicists.

In 1970 and earlier registers, information was obtained concerning each physicists primary and secondary activity. Since physicists in most institutions divide their time between various types of activity, our 1973 Register was designed to ascertain such data in greater detail. For the first time we can obtain the total proportion of the effort physicists expend on various types of activity.

Work Activity of Physicists in U.S.A. -1973

(students excluded)

Activity	Doctorates	Lower Degree Physicists
Research	44.8%	25.7%
Teaching	24.4	23.0
Administration	13.7	13.0
Development	8.0	14.5
Design & Engineering	4.5	15.9
Consulting	2.8	4.2
Other	1.8	4.7

This "full time equivalent" data and the percentages there from are, of course, related but not directly coupled numerically to the earlier data on physicists "principle activity". Comparing "principle activities" with earlier data shows that the proportion of basic research in both industrial and governmental labs decreased between 1970 and 1973 continuing earlier trends noted in the Bromley Report (Physics in Perspective - National Academy of Sciences, 1972). The decrease is most pronounced in industry where greater emphasis is placed on applied work. It is interesting to note that 12.5% of the overall effort of all physicists in the U.S.A. with a doctorate is in development, design and engineering.

Physicists with lower degrees working in development, design & engineering total almost 30%. I expect the percentages for both groups to increase for this type of work in the future.

What is ahead for physicists is just as clouded by the current economic picture as it is for most other professional fields. An increased emphasis ahead (R&D) on energy and related problems appears certain. This will involve physicists. A recent study by the National Planning Association for the

National Science Foundation has ascertained that in 1970, 8,000 physicists were employed in selected energy related sectors. Assuming maximum effort to develop domestic fuel sources, the study estimates that a total of 16,500 physicists will be employed in these same sectors by 1980. By 1985 the number is projected to 22,800. The growth of the energy related sector should, of course, be coupled to the other sectors of our economy so that growth in energy may not be quite as large as predicted in this study. Even though we are not sure of the rate, I am confident of a substantial utilization of greater numbers of physicists in energy related problems in the future. Broadly, I believe that the proportional effort of physicists will increase across the board in applied matters. Most opportunities for new physicists will likely be found in applied physics.

CHEMISTRY MANPOWER AND ITS PRESENT UTILIZATION

by

Robert E. Henze
American Chemical Society

In a comprehensive section on "the people of chemistry" in the American Chemical Society's study entitled CHEMISTRY IN THE ECONOMY, the size of chemistry's qualified manpower pool is estimated conservatively at 200,000. This number includes approximately 137,000 chemists and biochemists, and 53,000 chemical engineers employed in both the public and private sectors, and 10,000 chemically trained individuals currently employed in other areas than chemistry or outside the labor force. Estimates for the latter group are included in the total because these individuals could possibly be drawn into the chemical labor force if sufficient need for their services should arise in the future.

The development of firm estimates of the total number of professional practitioners in any field, chemistry included, is seriously hindered by a lack of uniformly accepted definitions among those who collect manpower data. Census counts contain self-defined professionals; employer survey counts contain employer-defined professionals, based on job classifications as well as training and experience. Professional societies, on the other hand, generally count professionals on the basis of specified academic attainment. Further complicating the problem are differences of opinion with respect to the academic equivalency of on-the-job training and work experience. These and other questions will need to be resolved before firmer estimates of total scientific and engineering personnel can be developed.

Over half of the nation's chemists and chemical engineers are employed in industry. BLS data for 1970 indicate 71% in industry and 19% in colleges and universities. (TABLE I) NSF Register data for 1970 include additional sectors and portray a slightly different distribution. (TABLE II) Data from ACS membership records--58% Industry, 22.8% Education, and 10.7% Government--compare more closely with the NSF Register findings than with the BLS findings because of the rather close similarities in the groups covered by ACS and NSF.

It should be emphasized here that the industry category is not limited to what is commonly thought of as the "chemical industry." Chemists and chemical engineers are employed across almost the entire spectrum of business and industry. Subgroup examples include foods, textiles, paper, chemicals, petroleum, rubber, pharmaceuticals, metals, plastics, building materials, electronics, transportation, and communications. It is difficult to name very many industries in which chemists and chemical engineers are not directly or indirectly involved. For a comprehensive picture of the contributions of chemistry and where chemists and chemical engineers work and what they do, I strongly recommend CHEMISTRY IN THE ECONOMY, the report of a major study conducted by the American Chemical Society with partial support from the National Science Foundation.

Contrary to the popular impression, not all chemists and chemical engineers are engaged in research and development. According to the 1970 NSF Register of Scientific and Technical Personnel, only about one-half of responding chemists were so engaged. (TABLE III) The 31,000 engaged in R&D plus the 11,500 engaged in the management of R&D constitute about 50.1% of

TABLE I. ESTIMATED EMPLOYMENT OF CHEMISTS - 1970

		Number	Percent
All Sectors		136,800	100.0
Private Industry		98,000	71.6
Manufacturing	80,200		
Non-Manufacturing	17,800		
Government		12,300	9.0
Universities & Colleges		26,200	19.2

Sources: BLS, and Chemistry in the Economy, 1973, ACS

TABLE II. NUMBER OF CHEMISTS BY TYPE OF EMPLOYER - 1970

	Number	Percent
Educational Institutions	19,800	22.8
Federal Government	5,000	5.7
Other Government	1,500	1.7
Non-Profit Organizations	2,200	2.5
Industry and Business	50,900	58.5
Self-Employed	1,000	1.2
Military	1,400	1.6
Other	800	1.0
Not Employed	3,500	4.1
No Report	700	0.8

Source: American Science Manpower - 1970, NSF 71-45

TABLE III. PRIMARY ACTIVITIES OF REGISTRANTS IN CHEMISTRY - 1970

		Number	Percent
Research and Development		31,200	35.8
Basic	12,700		
Applied	11,500		
Development	7,000		
Management or Administration		21,500	24.6
R & D	11,500		
Other	10,000		
Teaching		10,300	11.8
Production and Inspection		13,400	15.4
Consulting		1,400	1.6
Exploration, Forecasting, Reporting		800	0.9
Other		2,700	3.1
Not Employed		3,500	4.1
No Information		2,200	2.5

Source: American Science Manpower - 1970, NSF 71-45 the total. For chemical engineers the basic research component is generally lower and the development component higher. The 50% research/non-research ratio increases markedly if one considers only chemists and chemical engineers with doctorate degrees.

Buried within these major categories of activities, especially in the "other" category, are a host of less familiar areas of activities of chemists and chemical engineers; for example, forensic science, marketing and sales, science writing, patent law, information science, museums, and banking. The ACS is currently preparing and publishing a series of papers, under the title CAREERS NONTRADITIONAL, to demonstrate to students that the employment horizon for chemists has many dimensions.

Not all chemists and chemical engineers in the U.S. labor force hold the Ph.D. degree. In fact, less than one half do. (TABLE IV) Reports on degree distribution are not in agreement from source to source due mainly to self determination in joining the Society, in the case of the ACS; self determination in responding to survey questionnaires, in the case of the NSF Register; and self definitions, in the case of the Postcensal Survey. The number of No-Degree respondents in the Postcensal is exceedingly large --16.7%. Comparable degree figures for chemical engineers are BS 45.7%; MS 24.6%; Ph.D. 27.3% from ACS, and 58.2%, 20.9% and 5.7% respectively, from Postcensal Survey data.

For those that are interested in them, further demographic details of chemistry's current manpower base can be found in the several references cited in earlier text and tables.

TABLE IV. DISTRIBUTION OF CHEMISTS BY HIGHEST DEGREE

	(1 Am. Chem. Soc. 1974	(2 Postcensal 1972	(3 NSF-Register 1970
	%	%	%
Bachelor's	30.0	40.2	42.0
Master's	17.6	15.0	22.0
Ph.D	51.2	22.0	34.5
Other Degree, No Degree, No Response	1.2	22.9	1.5

Sources: 1) ACS Domestic Membership (58,066) Excluding, Students, Emeritus, Over 64.

2) Character of Persons in Engineering and Scientific Occupations 1972, Tech. Paper 33, Bureau of Census

3) American Science Manpower - 1970, NSF 71-45

TABLE V. REQUIREMENTS FOR CHEMISTS AND CHEMICAL ENGINEERS IN SELECTED ENERGY-RELATED SECTORS IN THE UNITED STATES, ASSUMING MAXIMUM EFFORT TO DEVELOP DOMESTIC FUEL SOURCES

	1970	1980	1985
Chemists	13,200	19,100	27,800
Chemical Engineers	33,600	42,300	51,500

Source: The Demand for Scientific and Technical Manpower in Selected Energy-Related Industries, 1970-1985, National Planning Association

TABLE VI. SUPPLY/DEMAND

New Graduates	Inexperienced
Currently Employed	Experienced
Underemployed	Degree Level
Unemployed	Primary Work Activity
Transfers	Specialists - Generalists
Immigrants	Interdisciplinary

TABLE VII. SUPPLY TIME-FRAME CONSIDERATIONS

New Graduates

4 Years BA/BS
5-6 Years MA/MS
6-7 Years Ph.D.

Currently Employed

0-3 Months Orientation

Underemployed-Unemployed-Transfers

3-12 Months On-the-Job Training
6 Mo.-2 Years College or University Review
1-2 Years Cross Disciplinary Education

Immigrants

Dependent Upon Quotas, Etc.

At this point I would like to present a few thoughts relative to manpower demand projections, particularly those associated with proposals for concerted attacks on major national problems such as energy, mass transit, housing, health care, and environmental improvement. An example at hand is the very detailed report prepared for NSF by the National Planning Association entitled "The Demand for Scientific and Technical Manpower in Selected Energy-Related Industries, 1970-85: A Methodology Applied to a Selected Scenario of Energy Output." Time does not permit me, nor am I qualified, to discuss the methodology employed in this study. Instead, I would like to explore briefly the implications of the projected requirements for additional scientists and engineers; for engineers--101,600 in 1970 to 224,600 in 1985; for scientists--39,800 in 1970 to 82,700 in 1985. For chemists, the report projects an annual additional requirement of about 590 chemists between 1970 and 1980; and 1,740 between 1980 and 1985. (TABLE V) For chemical engineers the report projects an annual additional requirement of 870 chemical engineers between 1970 and 1980; and 1,840 between 1980 and 1985.

Projections such as these raise questions. What is the supply source of these additional chemists and chemical engineers? What special training or work experience, if any, will they need to have? (TABLE VI) Equally important are supply time frame considerations. (TABLE VII) How long a lead time is needed to meet the required demand? Is the projected output of new graduates from our colleges and universities sufficient to meet the demand during the proposed time periods? Is this the best source of the people needed to meet the specific requirements of the demand?

Those of us who are concerned with the meaningful and continuous employment of scientists and engineers will, or I believe should, have questions concerning the nature of the demand itself, particularly if government funding is involved. We must ask: Does the projected demand mean "real" jobs for the numbers specified? Temporary or permanent? What are the sources of funding? Will the funds be taken from other efforts currently involving the services of scientists and engineers? These and many additional related questions will need to be considered if we are to meet the scientific and engineering manpower needs of the nation and at the same time maintain a reasonable balance between supply and demand over the long term.

GEOSCIENCE AND THE QUALITY OF LIFE

by

Bonnie Henderson
American Geological Insititute

I want to thank the President of the U.S. and the Secretary of the Interior for working so hard lately to make part of my speech, and for laying the groundwork for relating the fuel crisis and our economic distress to the presently accelerated need for geoscientists.

In the '50's and '60's we had an excess capacity for crude oil, but since we could get it cheaper abroad, that's what we did - about a third of our needs. The domestic job market for geologists was not so good.

But all this time our consumption of fuels was spiralling upward. We were not too worried and were protecting our domestic prices, and finding some oil off-shore. Coal was losing out, mining engineering courses were being dropped, and atomic energy plants were proliferating, at least on the drawing boards.

Then came the oil embargo in the Middle East, and when it was over, we found we were paying $11 a barrel for imported oil instead of $3. To add to our pain, there was a massive transfer of wealth and political power to the Persian Gulf.

Project Independence was born and now has a goal of 1985, by which time it is hoped we can largely be independent of imported oil. The National Petroleum Council says that by 1985 our overall demand for petroleum liquids will have increased to 23 million barrels a day. (In 1970, we were using 15 million b/d.)

But, they say, our need for oil imports will continue to grow until 1980, before we can start tapering off. By 1980, our domestic supply should be 17 million b/d of crude oil, and in addition we will then be using another 26.8 million b/d of other fuels in terms of oil equivalent.

The NPC estimates that we have still to find 47.5% of the oil in our nation. That is the reason that the demand for exploration geologists and geophysicists will continue to be so strong. Now they must go into deeper earth formations, deeper into water, farther into hostile environments to discover new locations of oil and gas.

Meanwhile alternate energy sources will be researched and developed by interdisciplinary teams of scientists and engineers, including geoscientists.

They will be working on geothermal problems, how to harness heat from the interior of the Earth; how to tap the sun for energy on a giant scale on earth; how to extract energy from the ocean's tides; how to make oil out of coal; how to get oil out of oil shales and tar sands; how to move from the nuclear-fission process for atomic energy, with its dependence on limited supplies of uranium, to thermonuclear fusion using hydrogen in sea water.

By geoscientists, we are talking primarily about geologists and geophysicists, but we also include geochemists, paleontologists, engineering geologists, oceanographers, environmental scientists and teachers of geoscience. Many of them are from interdisciplinary backgrounds; they are pure and applied scientists. Their work is concentrated heavily at all times on energy and environmental matters, not just now in our present crisis.

Energy applications are the most dramatic aspect of the present and future demand for geoscientists, but there is much more that geoscientists do to modify and preserve the environment and to improve the quality of human life.

The geologist studies our whole habitat, the physical system that is the Earth. He probes and interprets its billions of years of geologic history, drawing conclusions from limited evidence and making analogies from events happening around us now. His is a practical science applied to human problems such as

1. Predicting earthquakes and advising about the relocation of towns
2. Application of geology to land-use planning
3. Optimum sites for construction of dams
4. Stable locations for building houses in cities, and highways between cities
5. Where to find the minerals man needs, whether in the ground or on the sea floor
6. How to deal with subsidence of soil after the pumping of oil or water
7. How to prevent oil-well blowouts
8. How oil affects sea life
9. Where underwater faults are
10. How the health of people is affected by the geologic conditions where they live
11. Where to store safely the radioactive uranium mine wastes; what will be the environmental impact on the community of zoning changes and new projects.

There are about 38,000 now of all kinds of geoscientists, most of them men, because this has traditionally been a man's field. Under 5% are women, in the work force.

As for forecasting demand, we do not have any sophisticated methodology with which to do it. We have had to rely recently on interviews with all the major types of employers - industry, academic and governmental. There is not even a consensus among them as to when the peak in hiring needs will be reached. Their guesses range from 3 to 8 years.

Recruitment on the campuses is fierce now. Last spring, Department Chairmen reported that their students were getting four and five job offers each, except for those who planned to teach geology. The optimum degree level for most geoscientists is the master's degree (many employers say that a Ph.D is too specialized, too narrow in his interests, not flexible enough - except for the few they need for pure research in the laboratories). As in most other fields, there have not been many new college and university jobs opening up.

But industry is hiring bachelors now and causing a drop in graduate enrollment. Industry will finish their training in a crash program. Some oil companies and contractors want to double their geophysical staffs in the next five years. But the only way they can possibly do that is to rely on an influx of geophysicists, mathematicians and physicists, something that always happens anyway. The geologic community is not panicking about manpower - yet - and so far is unwilling to take the time and money for careful planning ahead.

Women are coming up faster than men in our pipeline. Last year they made up 19% of the undergraduates after increasing their numbers by nearly a third in one year. They increased in graduate schools, too, while men were lost from master's and doctoral programs.

Minority students are still very scarce in geoscience - with all ethnic minorities combined, in all subfields of geoscience combined, they made up only 3.2% of undergraduates, 2.3% of master's candidates, and only 1.2% of Ph.D candidates.

They made up a smaller proportion among earned degrees. Spanish-surnamed students earned twenty bachelors and four masters degrees in 1973; American Blacks only eleven bachelors and seven masters; American Indians one bachelors and two masters degrees. No Ph.D's to any of these groups were reported by department chairmen for 1973.

In about 180 departments, not a single minority student is enrolled, although there is often money there for financial assistance particularly for these groups. No minority students have applied for admission in those schools. It will take many years before there will be equitable numbers of minority graduates in geoscience for the same reasons that they are scarce in other physical science fields, but also because almost no geology is presently taught in colleges catering largely to ethnic populations.

The hypothetical person who could get the most job offers of anyone in our field would be a Black woman geophysicist!

The jobs are there for minorities, affirmative action officers are eager, but there are no people. Someone suggested that we have a solution looking for a problem.

The American Geological Institute surveyed women geoscientists in depth this past summer, as to their numbers and professional characteristics. Questionnaires were sent to all names identifiable as female from a composite list of members of our 18 constituent societies to 1150 names. Although we had an 83% response after one follow-up mailing, we ended up with data from only 646 full-time employed eligible women.

In the fall we sent an identical questionnaire to a randomly selected sample of 3000 men geoscientists, from whom we had a 79% response rate. Four and one half percent of the women were unemployed; zero point five per cent of the men were unemployed.

Comparing the characteristics of men and women geoscientists -

35% of both had bachelor's degrees
46% of women, 33% of men had masters
32% of men and 19% of women had Ph.D's

Industry employed 43% of men; 18% of women
Colleges and universities employed 25% of the women, 24% of the men
In secondary schools were 27% of the women, 5% of the men.
18% of the women worked for the Federal Government; 10% of the men.

19% of the men, but only 6% of the women were in management and administration, but
21% of the women were in R & D, compared to 11% of men.
11% of the men but only 4% of the women were in consulting.
44% of the women were engaged in teaching, compared to 25% of the men.
Exploration was the main activity of 24% of the men, but of only 6% of the women.
9% of women were in information services and editing.

The exact salary differentials have not yet been completed, but heavily favor men because of the distribution according to type of employer and work activity.

We are all more or less obsessed with the collection and interpretation of data. We wring our hands in private and apologize in public for not having better data now, and for having made unsound predictions in the past. Sudden events such as an oil embargo or the end of the military draft, or cancellation of sixty planned atomic energy plants can throw all our assumptions awry about manpower supply and demand.

Yet there seems to be a continuous circle of interdependence of the factors we seek to measure. You can start anywhere on the circle - from employers' needs for specialized scientific and technical manpower, to the students choice of major fields, to the universities' curriculum offerings, to the specialized faculty needed, to the distribution of the graduates into the workforce that exists, and back to the employers' needs, and on around again. The pivot point is perhaps our desired quality of life, which we must examine and reassess constantly as to purpose and priorities. Around and around we go, grabbing for the ring of balanced ratios.

THE CHANGING EMPLOYMENT PICTURE IN THE MATHEMATICAL SCIENCES

by

Truman Botts
Conference Board of the Mathematical Sciences

Toward understanding the present employment situation and prospects in the mathematical sciences it is helpful to go back a few years. Whatever else may be said of these uncertain times in which we live, they have constituted a truly golden age for the discovery and application of new mathematics, and as a field for employment and training the mathematical sciences have grown remarkably over the past quarter-century. Two major indicators reflecting this growth are: (1) the formation, diversity and increase in membership of professional societies associated with the mathematical sciences, and (2) the rapid increase during the period 1955-1970 in the number of bachelor's, master's and doctor's degrees in the mathematical sciences granted by U.S. colleges and universities. Today, however, the mathematical job market is shifting, and in particular, as we shall see, the academic job market for mathematical PhD's has become very tight and threatens to become even tighter in future years.

In the U.S. at present, the principal professional societies that identify themselves primarily or partly with the mathematical sciences are eleven in number and constitute the membership of the Conference Board of the Mathematical Sciences, the organization whose modest headquarters in Washington I direct (see the tabulation on the following page). The Conference Board has two kinds of member organizations: constituent and affiliate. In general the constituent organizations have primarily mathematical interests, while the affiliate ones (starred in the tabulation) have an identity that is only partly mathematical or is associated with some particular mathematical methodology or area of application. The most venerable of these professional societies is the American Statistical Association, founded in 1839. Numbering about 1,000 members by 1920, it has grown more than tenfold over the succeeding five decades. It represents professional interests not only in statistics per se but also in the many and increasingly diverse areas in which statistical methods are used. The American Mathematical Society is the primary research-oriented professional society in mathematics; founded in 1888 (at Columbia University by six persons, who initially called it the New York Mathematical Society) it has grown even more rapidly than the American Statistical Association over the period shown: from about 800 members in 1920 to over 14,000 by 1970. The Mathematical Association of America, founded in 1915 and representing collegiate-level interests and education in mathematics has grown from 1,100 to some 18,300 over the same period. Mathematics education at the school level is represented by the National Council of Teachers of Mathematics, founded in 1920 by about 100 persons. Its membership, over 45,000 in 1970, is now nearly 50,000, making it by far the largest of all the mathematical professional societies in the United States.

The Institute of Mathematical Statistics, concerned with the strongly mathematical and theoretical aspects of statistics, was founded in 1935 and has grown from 200 in 1940 to some 3,000 in 1970. The Association for Symbolic Logic, an international organization formed in 1936 and devoted to both the mathematical and philosophical aspect of symbolic logic, numbered around 200 in 1940 and around 1,800 by 1970. The most startlingly rapid growth is that of the Association for Computing Machinery, formed in 1947: from 700 in 1950 to nearly 27,000 by 1970.

Conference Board of the Mathematical Sciences

Constituent and Affiliate(*) Member Organizations

	Year Founded	Membership					
		1920	1930	1940	1950	1960	1970
American Statistical Association*	1839	1,000	2,300	2,700	4,200	7,500	10,100
American Mathematical Society	1888	800	1,900	2,300	4,500	6,700	14,200
Mathematical Association of America	1915	1,100	2,000	2,100	4,400	10,000	18,300
National Council of Teachers of Mathematics	1920	100	5,700	5,400	6,800	22,400	45,400
Institute of Mathematical Statistics	1935	---	---	200	1,200	2,000	3,000
Association for Symbolic Logic	1936	---	---	200	300	700	1,800
Association for Computing Machinery*	1947	---	---	---	700	7,000	26,900
Society of Actuaries*	1949	---	---	---	1,100	1,900	3,500
Operations Research Society of America*	1952	---	---	---	---	2,900	6,200
Society for Industrial and Applied Mathematics	1952	---	---	---	---	1,300	3,600
The Institute of Management Sciences*	1953	---	---	---	---	2,200	6,800

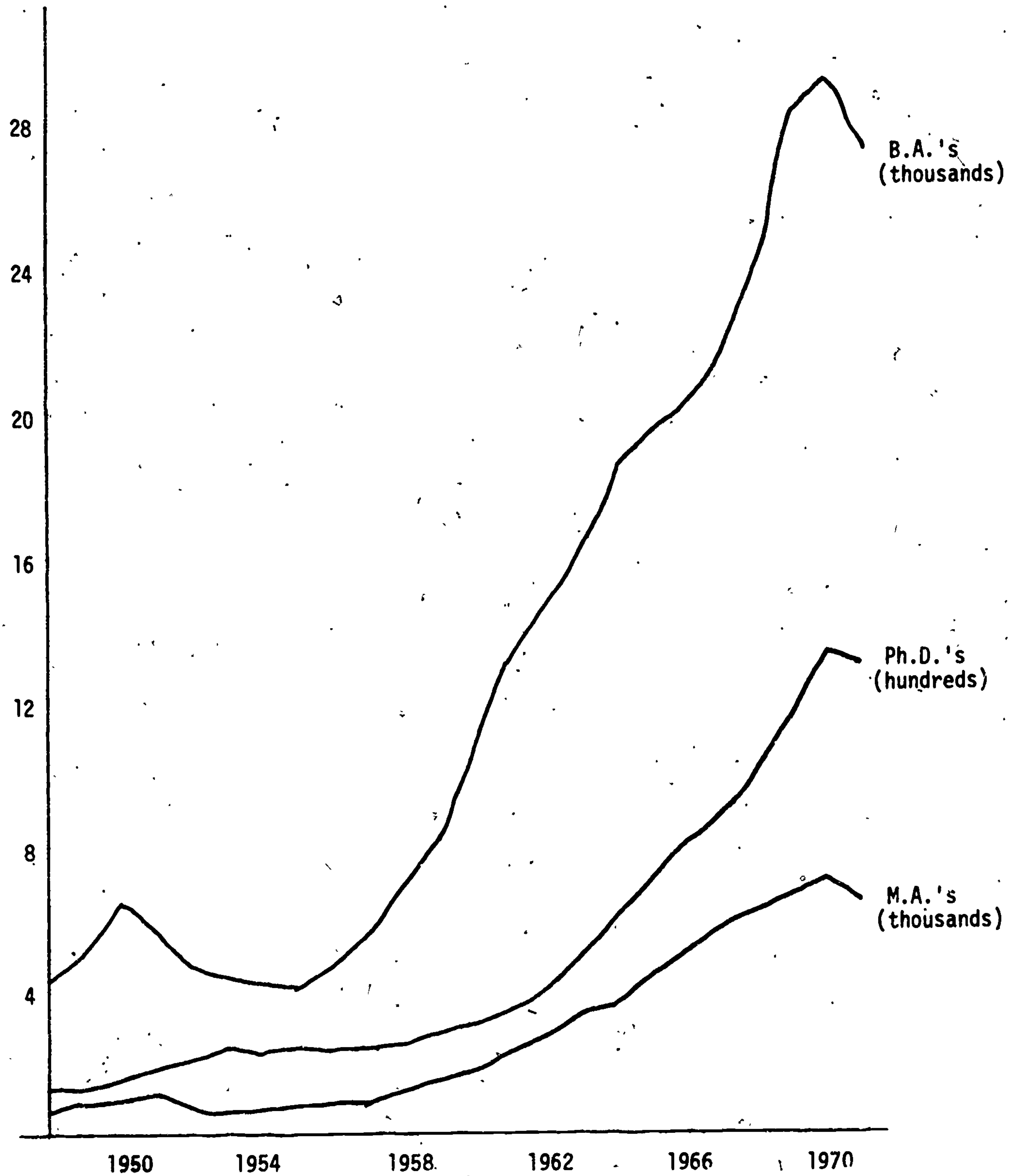
The field of computer science has a strong identity of its own, associated with the design of computer systems and hardware and with both theoretical and applied aspects of information processing, as well as with mathematics. The formation in 1949 of the Society of Actuaries, representing a long-standing actuarial profession, was actually through the coalescence of two older organizations: the Actuarial Society of America, founded in 1889, and the American Institute of Actuaries, founded in 1909. Its two classes of membership, Fellowship and Associateship, are unusual in that each requires the passing of certain professional examinations. The Operations Research Society of America and The Institute of Management Sciences are closely related organizations each formed in the early 1950's to recognize and represent a profession that arose out of the techniques of mathematical analysis of military operations and logistics developed during World War II. Today the majority of their members are employed in mathematical consulting to the industrial and business world. The Society for Industrial and Applied Mathematics was formed in 1952 to recognize and represent broadly the professional and educational interests of applied and industrial mathematics. It has played a leading role in recent years in encouraging the application of mathematical methods to problems of society.

Before we leave the mathematical professional societies, it should be noted that many persons belong to more than one of them. (One person I know belongs to eight out of the eleven!) Thus the unduplicated membership of these societies is certainly substantially smaller than the sum of their separate memberships; it is probably in the neighborhood of 100,000 persons, out of a total professional community of perhaps three or four times that size.

It is not generally realized how rapidly higher education in the mathematical sciences expanded during the years 1955-1970. The graph on the following page shows, in thousands, the numbers of bachelor's and master's degrees in the mathematical sciences granted each year during the period 1948-1971; it also shows, in *hundreds*, the numbers of mathematical science doctorates granted each year during that period. Following a peak in 1950, largely accounted for by bachelor's degrees granted to returning G.I.'s following World War II, the number of bachelor's degrees in the mathematical sciences sank back to around 4,000 by 1955 but then rose steadily so that by 1970 this annual number of degrees granted was more than 29,000 -- an increase over this fifteen-year period by a factor of over 7. The annual number of master's degrees granted during the same fifteen-year period increased by a factor of nearly 10 -- from around 750 to over 7,000 -- while the annual number of doctorates increased by a factor of over 5 -- from around 250 to around 1,350. While 1971 is the latest year for which the U.S. Office of Education has available figures on earned degrees, data collected by the American Mathematical Society show that the number of PhD's granted has continued to decline slowly, to slightly over 1,200 by 1974. As we shall see, this decline seems to be at least in part a response to a gradual saturation of the academic job market that began in the late 1960's and has become progressively more complete.

Where do those trained in the mathematical sciences get their jobs? We know, on an inadequate and anecdotal basis from college and university department chairmen, the kinds of things that graduates with bachelor's and master's degrees go on to do, but one of our serious lacks is any reliable and accurate percentage data on this. Many go on to jobs or professional training in other fields -- business and industry, other sciences, law, occasionally medicine.

DEGREES IN THE MATHEMATICAL SCIENCES, 1948 - 1971



Source: U.S. Office of Education, Earned Degrees Conferred

Many also go into mathematics teaching in schools or, for those with master's degrees, in junior colleges. Quite a few become computer programmers; and limited numbers go on to more advanced training in the mathematical sciences. Those graduating with mathematical science PhD's do mostly remain in the profession and constitute its central leadership. For them we do have pretty accurate and up-to-date figures on their initial employment, thanks to data that have now been systematically gathered for several years by the American Mathematical Society. I will now be drawing heavily on these data and on analyses by Professor Richard D. Anderson of Louisiana State University, who has for several years been Chairman of the American Mathematical Society's Committee on Employment and Educational Policy. More details are available in Anderson's recent article "Doctorates and Jobs, 1974 Report" in the American Mathematical Society *Notices* for November 1974.

The tabulation on the following page shows the main categories of employment of the 1148 new 1974 doctorates in the mathematical sciences based on information collected by the American Mathematical Society over the past summer. (A supplementary list of 1974 doctorates just published in the January 1975 American Mathematical Society *Notices* brings the total to slightly over 1200.) About 23% found employment in doctorate-granting university departments and about 10% each in departments granting the master's or bachelor's degrees as their highest degrees. About 2.4% were hired by two-year colleges and high schools. Under 4% went to jobs in government and about 10% to jobs in business and industry. Some 5% found jobs in Canada and about 11% in other countries.

The most distressing figure is the 111 -- nearly 10% -- who had not found employment as of the time last summer when they responded to the American Mathematical Society questionnaire. Presumably a considerable fraction of these have by now found jobs. Percentagewise this is about the same as it was for 1973-4, for which figures are shown in the right-hand column for comparison: out of some 1270 PhD's produced that year, some 118 had not found jobs as of the time they reported that summer. For 1974 the tabulation shows a significant breakdown: the first two columns give separately the figures for PhD's in pure mathematics and for those in applied and other areas. Out of the 640 pure mathematics PhD's produced, the "not yet employed" figure was 78 -- over 12% -- while for the "applied and other" category it was just 33 out of 508 -- under 6%.

It is still the case that the majority of new PhD's in the mathematical sciences find employment in academia: about 64% of them, counting in those with academic employment in Canada and in other countries. This represents, however, a very considerable shift from the employment picture of six or seven years ago, when academic work accounted for over 80% of the employment of new mathematical-science PhD's (see tabulation on page 7). In 1966 some 83.4% of the 790 PhD's produced that year found academic jobs, and this percentage (of a still-increasing number of new PhD's) declined only gradually over the next three years. However, a progressive saturation was setting in. It affected first the stronger PhD-granting mathematics departments rated by the American Council on Education. These accounted for over 38% of the jobs of new PhD's in 1966-7 but only about 22% by 1969-70. The percentage absorbed by the remaining PhD departments increased slightly in 1967-8 but thereafter decreased. The percentage for the "other U.S. academic" category (mainly four-year colleges, plus junior colleges and high schools) steadily increased from 1966-7 to 1969-70 but even it had declined by 1974-5, while the percentage for all PhD-granting departments had by then declined to around 23%.

1974-75 EMPLOYMENT OF NEW DOCTORATES IN THE MATHEMATICAL SCIENCES

Type of Employer	Pure Mathematics	Applied & Other	Totals	%	Totals 1973-4
U.S.:					
Doctorate Departments	168	99	267	23.2	281
Masters' Departments	77	38	115	10.0	333
Bachelors' Departments	78	41	119	10.4	
Two-year Colleges and High Schools	22	6	28	2.4	19
Other Academic Departments	6	44	50	4.4	--
Research Insts.	8	5	13	1.1	31
Government	13	30	43	3.8	57
Business and Industry	31	86	117	10.2	130
Canada:					
Academic	28	27	55	4.8	88
Non-Academic	1	5	6	0.5	
Foreign:					
Academic	63	36	99	8.6	133
Non-Academic	8	21	29	2.5	
Not Seeking Employment	5	1	6	0.5	4
Not Yet Employed	78	33	111	9.7	118
Unknown	54	36	90	7.9	76
Totals	640	508	1,148	100.0	1,270
Totals (1973-4)	700	570	1,270		

Source: American Mathematical Society *Notices*, November 1974, p. 335.

PERCENTAGE DISTRIBUTION OF EMPLOYMENT OF NEW DOCTORATES

IN THE MATHEMATICAL SCIENCES

<table>
<tr><th>Type of Employer</th><th>1966-7</th><th>1967-8</th><th>1968-9</th><th>1969-70</th><th>. . .</th><th>1974-5</th></tr>
<tr><td>ACE-rated PhD Departments</td><td>38.2</td><td>30.0</td><td>28.5</td><td>22.2</td><td rowspan="2">. . .</td><td rowspan="2">23.2</td></tr>
<tr><td>Non-rated PhD Departments</td><td>16.9</td><td>18.9</td><td>14.5</td><td>12.1</td></tr>
<tr><td>Other U.S. Academic</td><td>20.3</td><td>23.9</td><td>27.7</td><td>31.8</td><td>. . .</td><td>27.2</td></tr>
<tr><td>All Other</td><td>24.6</td><td>27.2</td><td>29.3</td><td>33.8</td><td>. . .</td><td>49.6</td></tr>
<tr><td></td><td>100.0</td><td>100.0</td><td>100.0</td><td>100.0</td><td></td><td>100.0</td></tr>
<tr><td>Number of New PhD's</td><td>790</td><td>890</td><td>1180</td><td>1367</td><td>. . .</td><td>1148</td></tr>
<tr><td>% Employed Academically</td><td>83.4</td><td>81.6</td><td>79.2</td><td>77.9</td><td>. . .</td><td>63.8</td></tr>
</table>

With this progressive saturation of the U.S. academic job market at various levels, how has this market been able to continue to absorb, as it has, around 600 new PhD's in each of the past three years? Part of the answer is that; for each of these years from 300 to 400 non-doctorate faculty have been replaced by doctorates, with perhaps half being self-replacements, that is, faculty members who have themselves received doctorates during this period. Now, however, indications are that except for such self-replacements, retirement or death, only dwindling numbers of new PhD's can be absorbed in this way. Furthermore, there is little prospect for expansion: in four-year colleges and universities the total mathematical faculty -- close to 80% of them now with either formal or "moral" tenure, and many of them decades from retirement -- has remained almost stable in size for four years in a row; and statistics indicate that undergraduate enrollments, on which faculty size depends, will remain almost constant until 1980 and then will diminish substantially for the succeeding decade. This all adds up to a very serious employment problem for young PhD mathematicians, both those newly entering the job market and those without tenure who are being released from college and universities faculties.

Within the professional mathematical community it is recognized that the continuing infusion of "new blood" is vital for flexible, forward-looking and innovative work in mathematical research and education, and that this is very seriously threatened by the present all-but-closed academic job market. What is being done in response to this situation? First of all, responsible mathematics departments are informing their graduate students of the increasingly tight job market and are encouraging only the strongly gifted and committed ones to work for PhD's. Second, there is beginning to be a shift in the specialities of the new PhD's: fewer in pure mathematics and more in computer science, statistics, and other applied areas where there is somewhat more demand. In line with this, consideration is also being given to a general broadening of both graduate and undergraduate mathematical training in order to prepare graduates for a wider range of possible jobs; but for this to be effective there is need for carefully thought-out guidelines that will have the strong endorsement of the entire mathematical community. It is also recognized that greater attention needs to be devoted to the training appropriate for teachers of mathematics in secondary schools and junior colleges, and to improving the teaching of mathematics to non-mathematicians.

Two other steps, closely related to each other, would greatly aid the continuing infusion of new blood for mathematical research but would almost certainly require Federal support: (1) the creation of a substantial number of postdoctoral fellowships available until age 35-40 to enable more young mathematicians to contribute effectively to the development of the mathematical sciences and (2) the establishment of regional research institutes in the mathematical sciences on the model of the Institute for Advanced Study in Princeton. The cost of sustaining the valuable U.S. research enterprise in the mathematical sciences through such measures is relatively modest and certainly much less than the cost of the difficult and long-term effort that will be required to regenerate this enterprise if it is allowed to languish and wither.

MANPOWER* AND THE LIFE SCIENCES

by

Donald R. Beem
American Institute of Biological Sciences

The subject of manpower resources and utilization is poorly developed in the biological sciences. There are several factors which contribute to this. First, there are a large number of biologists split into the many disciplines that make up the science of Biology as a whole. Second, the gradation from Biology per se to closely related fields such as agronomy, medicine and the allied health fields is ill defined, making the boundaries extremely indistinct. Individuals who majored in Biological Science in undergraduate school disappear completely from rosters of scientists--many probably going into allied health fields such as medicine or dentistry, and many entering the job market at the technician level. Should these individuals be classified as biologists? What is a biologist? These questions await definitive answers.

Third, there is an abundance of national scientific societies in the life sciences, 75 or more, and no one umbrella organization to which a majority of these societies adhere--although the AIBS with its 40 Adherents and seven Affiliate organizations comes closest to such an umbrella.

Fourth, average figures of any kind relating to life sciences manpower are nearly meaningless in that the population is at least bimodal in distribution. There are those biologists affiliated with the medical sciences and those who are not. Such issues as salary, employment opportunities, and other indices differ sharply between these communities. Therefore, for these reasons, generalizations stated about biologists or life scientists (an even less well defined term) should be considered with an open mind and perhaps a bit of skepticism. For instance, in 1970 the National Science Foundation (NSF) reported that there were 509,000 natural scientists of which 28% or 142,000 were life scientists. Yet, in the same time period only 47,000

*Generic use of the term

biologists were reported in the National Register of Scientific and Technical Personnel (NRSTP). This discrepancy may be explained in part by the method used to collect the data. NRSTP questionnaires were circulated by the AIBS and the Federation of American Societies for Experimental Biology (FASEB) to the members of the societies adhering to these two organizations. The membership of these societies tend to be made up predominantly of individuals who hold a doctoral degree. Thus, many biologists holding bachelor or master degrees were not contacted by this mechanism.

Now for a quick look at the supply of biologists. According to the U.S. Office of Education (USOE), biology is attracting students at both the undergraduate and graduate education levels at an ever increasing rate, while at the same time the physical sciences and engineering are witnessing decreasing enrollments at all levels. In 1961 there were 16,000 bachelor degrees and 2,600 master degrees awarded in the biological sciences. By 1974 these figures had risen to 50,800 bachelor and 6,800 master degrees per year, and are now projected to rise to 53,000 and 8,400 per year respectively by 1983. There were 1,300 doctoral degrees awarded in the biosciences in 1961, 3,900 in 1973, and it is projected that 5,350 will be awarded per year by 1984.

During the 1960 period the number of women in the biological sciences was growing. From 1960 through 1972, 14% of all of the doctorates awarded in the biological sciences were earned by women. In 1973, 21.5% of the doctoral degrees in the biological sciences were earned by women. I suspect that the number of minorities in the biological sciences is also increasing, although I have no data to support this hypothesis.

Where will we employ all of the biologists that are being produced? This is a key question with no clear answer. The employment prospects situation for life scientists is very murky. Biologists at lower degree levels appear to be having considerable difficulty in finding employment and new Ph.D.'s are entering post-doctoral programs in increasing numbers. 1972 doctoral graduates reported to the National Research Council in mid 1973 that 64% were employed full time in science, 2.2% were employed in non-science jobs, 2.1% were employed part-time, and 26% were in post-doctoral programs. On the other hand, the Cooperative College Registry, a non-profit placement service for college and university positions at the Ph.D. level, reports that between March 1973 and March 1974 the number of registrants decreased sharply and the number of vacancies increased substantially.

Vacancies appear to be occuring in the field of Physiology although apparently at high level positions of benefit only to new Ph.D.'s seeking employment where vacancies have been created by individuals who have moved to the higher positions. However, this is by no means a certainty in today's economic climate. At the moment, the areas of Pharmacology, Biochemistry, and Bioengineering look the most promising in terms of new job opportunities.

Biologists, more than any other group of scientists, are predominantly employed in educational institutions, including medical and allied health schools. Perhaps the wave of enrollments at all levels in the educational institutions is maintaining the employment market for the time being. Because there are forces at work that might generate a demand for people trained in the life sciences outside of educational institutions, perhaps this trend may continue. In particular, the public demand for broader distribution of health care services and the envisioned environmental monitoring program are such forces. Of course much of what is done to capitalize on these initiatives will depend upon the measures taken to reverse the nation's current economic plight and the effect of the new drive for energy independence and concerns for the environment and the quality of life.

If these envisioned programs do create new positions for biologists it might be a healthy trend for the proportion of life scientists employed in education to decrease, thereby opening up the job market in practical services to the community and decreasing the emphasis on the doctoral degree in biology.

From these brief remarks it should be apparent that the manpower situation in the biological sciences is, to say the least, confused. It is confused by a lack of manpower policy at the national level; it is confused by past, present, and future economic situations; it is confused by the real depth and meaning of the national and world energy situations; but most of all, it is confused by the lack of reliable data with which to draw conclusions and devise strategies.

Biologists, as are other scientists and engineers, are a national resource of highly trained individuals who can help solve the national ills. The compilation of data on this resource is the joint responsibility of the scientists, scientific organizations, educational institutions, and government of this country. Government must supply the majority of the financial resource as the other parties simply do not have the magnitude of funding that will be necessary for the continuous program that is required.

ENGINEERING MANPOWER, PRESENT AND FUTURE

by

John Alden
Engineering Manpower Commission of Engineers Joint Council

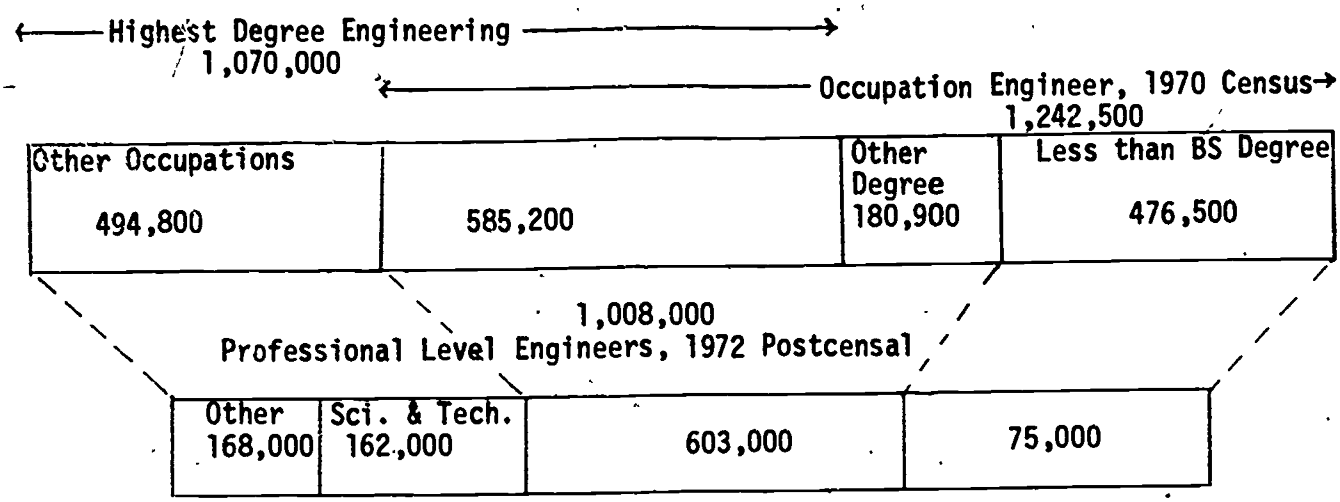
There are many intuitive reasons to believe that engineers and technologists will be in strong demand over the long term. The continued need for larger numbers of engineers than are currently being graduated from U.S. engineering schools, or can reasonably be expected to graduate in the next decade, is supported by all government studies to date. Engineers must necessarily play a key role in the achievement of major national goals such as energy production and conservation, pollution abatement, occupational safety, transportation, housing, and environmental protection, to mention only a few. However, engineering employment is very closely coupled to the state of the national economy. Recent experience has shown that short-term but abrupt peaks in engineering unemployment, when not properly dealt with, can trigger major reductions in the future supply of engineers by discouraging large numbers of students from entering engineering study. The resulting fluctuations in the engineering manpower supply are detrimental to an orderly employment market and lead to instability within the engineering profession itself. This in turn has undesirable consequences affecting the nation's ability to produce the goods and services it needs, and may even limit its capacity to achieve desired national goals.

A major handicap in trying to assess future employment prospects for engineers is the lack of current manpower data. No reliable and complete national statistics on the employment of engineers and scientists have been available since 1970 because of the termination of the Bureau of Labor Statistics surveys of scientific and technical personnel in industry. Although a new survey of industry is being developed by the National Science Foundation and the Bureau of the Census, it will take several years to place this program on firm basis and establish a reliable trend line. In the meantime, there is no assurance that the initial survey, scheduled for 1975, will even be repeated.

A major problem in the interpretation and use of national engineering manpower data in past years has been the lack of a single accepted standard for counting engineers. In the various national data series, three totally different concepts have been implicitly used. Educational data, which are important primarily for measuring the supply of new manpower, are based on the premise that engineers are the graduates of a recognized engineering curriculum. Employment statistics as compiled by the Bureau of Labor Statistics treated engineering as an occupation, described as doing work which requires knowledge acquired by the completion of a bachelor's degree curriculum in engineering, or its equivalent (which was left undefined.) Finally, demographic data obtained from the now-defunct National Register of Scientific and Technical Personnel identified the engineer as a member of a professional society. The census avoided the issue by listing people under whatever title they gave for their occupation. None of these data-gathering programs addressed the problem of determining the relationships between the populations covered by the various survey series.

Only recently have the first glimmerings of light been shed on the problem, with the processing and release of some data from the 1972 post-censal survey of scientists, engineers, and technicians. The results are shocking, as illustrated by the analysis of the 1,243,000 persons classified as engineers in the 1970 census. When the characteristics of these people were matched against a set of criteria based on appropriate combinations of education, employment, self-identification, and other information, only 55% were found to qualify. (Similarly, only 39% of those reported by the census as scientists were found to have professional-level qualifications.) On the other hand, large numbers of people meeting engineering criteria were discovered under other occupational titles, as listed below, bringing the total number of engineers back up to 1,008,000.

MEASURES OF THE ENGINEERING POPULATION



Source: U.S. Bureau of the Census

1,170,000
Employed as Engineers - 1974
BLS

Source: Bureau of Labor Statistics

ENGINEERING ENROLLMENTS IN FALL 1973
As Compared With Earlier Years

Engineering Students	Fall 1967	Fall 1968	Fall 1969	Fall 1970	Fall 1971	Fall 1972	Fall 1973
Freshman Year Full-Time	77,551	77,484	74,113	71,661	58,566	52,100	51,925
Sophomore Year, Full-Time	56,975	55,615	52,972	53,419	47,948	42,272	40,519
Junior Year, Full-Time	50,483	50,274	50,039	49,855	48,543	45,874	41,673
Senior Year, Full-Time	47,551	50,736	51,738	51,983	51,377	49,895	48,366
Fifth Year, Full-Time	4,589	5,133	4,668	4,812	4,391	4,586	4,222
TOTAL FULL-TIME UNDERGRADS	237,149	239,242	233,530	231,730	210,825	194,727	186,705
Part-Time Undergraduates	NA	20,754	20,984	18,445	18,222	14,149	15,692
Master's Degree, Full-Time	34,231	24,469	20,014	23,216	22,405	22,877	22,588
Doctor's Degree, Full-Time	15,376	15,768	14,298	14,802	14,100	13,460	11,904
TOTAL FULL-TIME GRADUATE STUDENTS	49,607	40,237	34,312	38,018	36,505	36,337	34,492
Part-Time Grad Students	NA	27,246	32,645	30,802	27,302	24,940	26,114
Number of Schools	274	271	269	275	282	283	285

Source: Engineering Manpower Commission

1970 Census Data		1972 Post-Censal Survey Classification		
Occupation	Number	Engineer	Scientist	Neither Engineer nor Scientist
Engineer	1,243,000	678,000 (55%)	2%	43%
Scientists	830,000	30,000 (4%)	39%	57%
Technicians	827,000	32,000 (4%)	2%	94%
Related Occup.	1,386,000	100,000 (7%)	9%	84%
4 yrs. College NEC	7,467,000	168,000 (2%)	4%	94%
		1,008,000 (Total)		

The problem, of course, is that the two populations, each of which has been labeled "engineers", are made up of distinctly different sets of people. In many important respects the characteristics of one population bear little resemblance to those of the other.

This problem of identity also exists in the labor force statistics compiled by the Department of Labor, but in this case we have no detailed information with which to assess the problem. Suffice it to say that the characteristics of the "engineering" labor force of 1,217,000 reported by the Bureau of Labor Statistics for the third quarter of 1974 are probably different from either of the populations identified from the census data. The population of living engineering graduates, estimated to number about 1,100,000, would have still another set of characteristics. The matter could be dismissed as trivial except for the fact that manpower planners, educators, and others who are interested in trying to relate supply to demand either fail to recognize the weaknesses in the data or are forced to make guesses involving undesirably large margins of uncertainty. The recently completed studies done in connection with Project Independence provided a prime example of the difficulty of deriving accurate manpower assessments from our vast national data banks.

PROJECTIONS OF ENGINEERING GRADUATE SUPPLY AND DEMAND

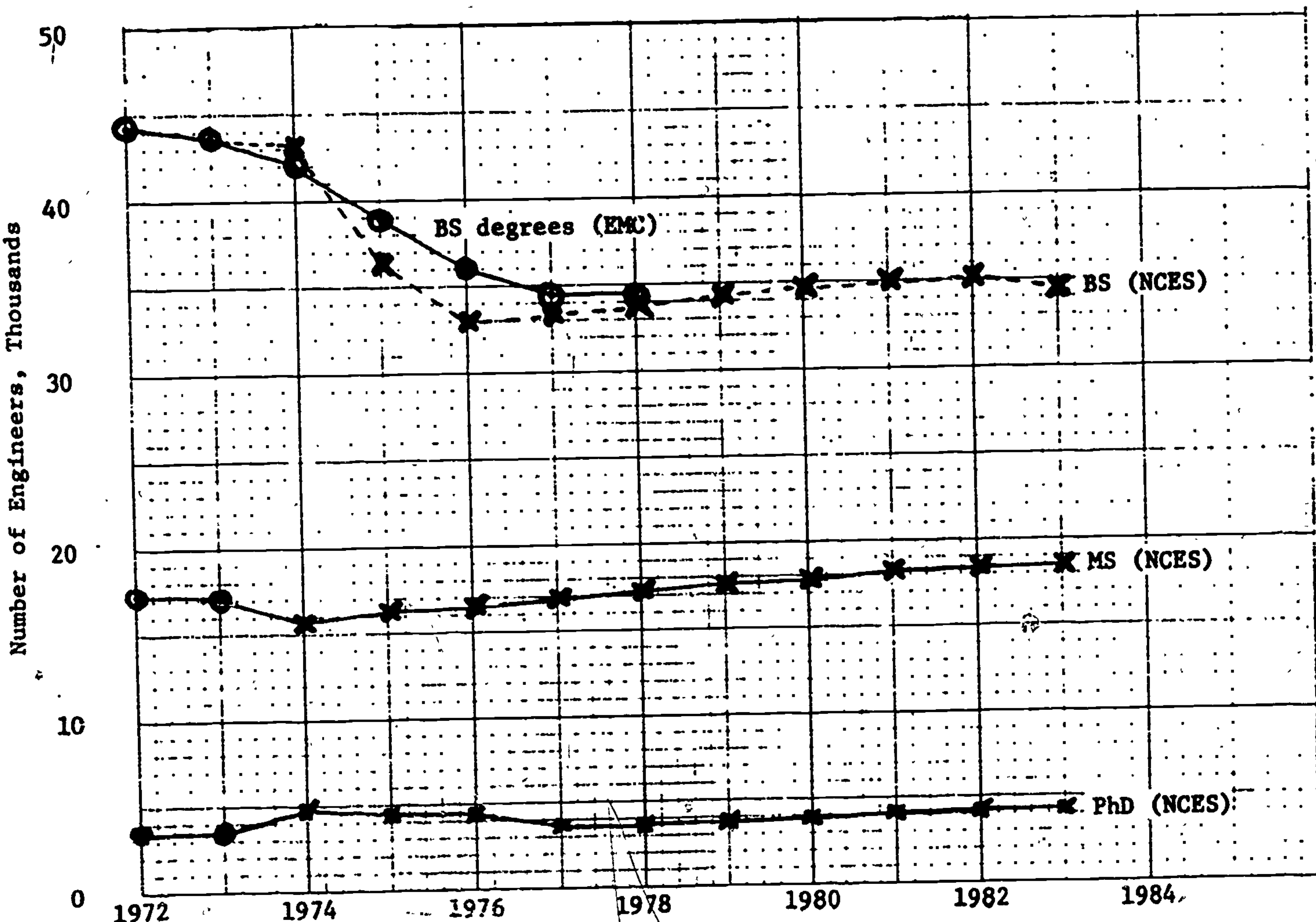


fig. 3

Source: Average annual demand estimated by Bureau of Labor Statistics
Annual demand adjusted by EMC in proportion to total engineering employment as projected by BLS.
Degrees for 1972 and 1973 as surveyed by EMC. EMC projections to 1978 based on current enrollment data. National Center for Educational Statistics (NCES) projections are from 1973 edition of Projections of Educational Statistics

Graph by J. D. Alden Engineering Manpower Commission, May 1974

Although the disastrous effects of the sudden and unforeseen increase in engineering unemployment in 1970-71 are only now being reflected in the output of our engineering colleges, the government has dismantled its programs for detecting, analyzing, and correcting future imbalances between manpower supply and demand. The following points were recently cited by the Engineering Manpower Commission in a position paper on the employment problem:

- Federal statistics do not adequately measure the extent of unemployment or underemployment among the different engineering and scientific disciplines, although experience indicates that wide variations are likely to exist from one specialty to another.

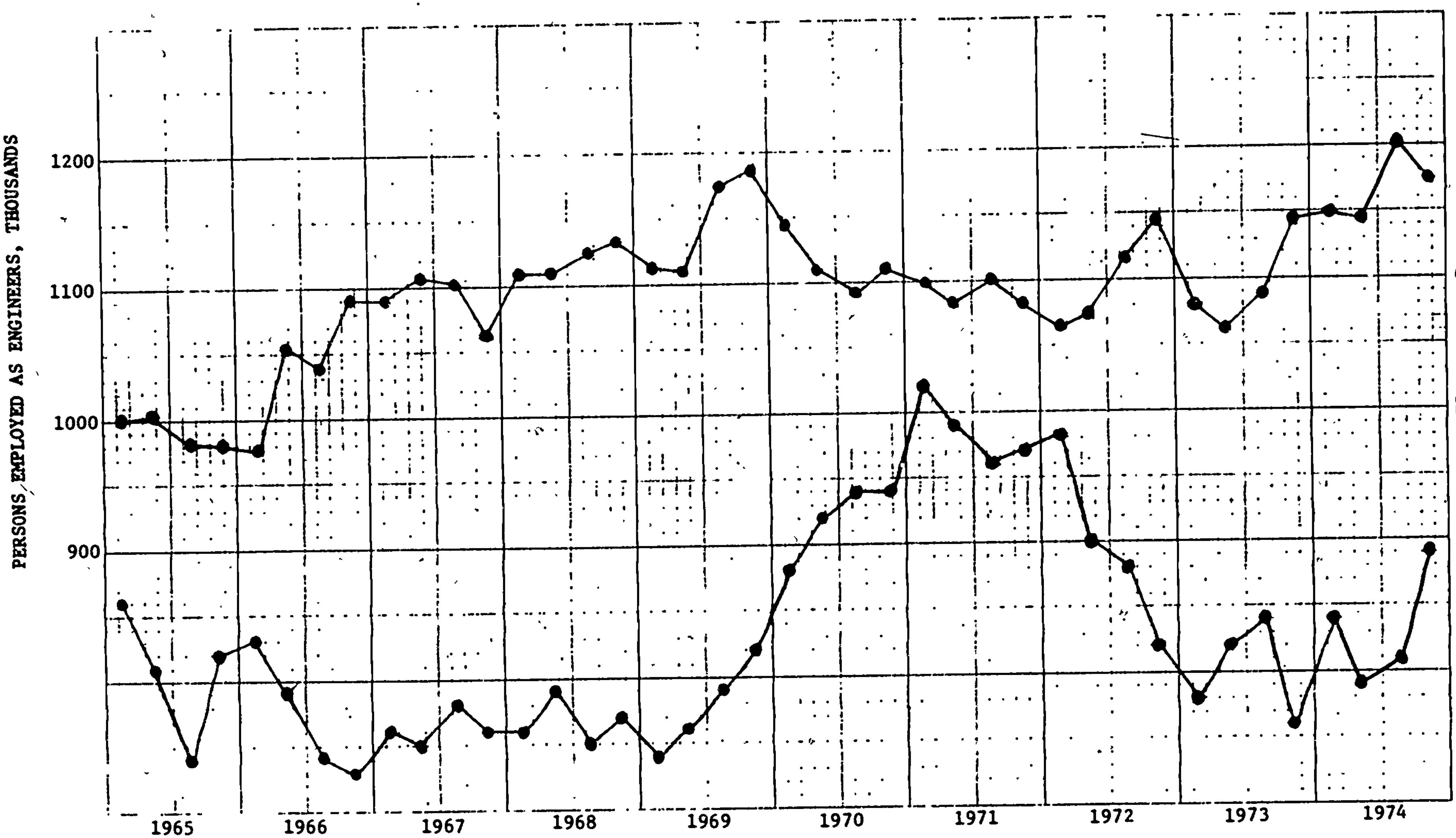
- No effective nationwide job matching service for professionals is currently in existence.

- The Public Employment Program, which is now the government's principal vehicle for dealing with unemployment, is inherently incapable of providing adequate numbers of engineering jobs in the public sector because most engineering work is in industry. Simultaneously, the decentralization of unemployment assistance to state and local administration makes it practically impossible to focus on scientific and technical manpower problems on a nationwide basis.

These deficiencies are matters for serious concern in view of recent signs of reduced hiring activity. Further deepening of the recession could easily result in a significant increase of unemployment and underemployment among engineers. In a climate of economic uncertainty, engineers are highly vulnerable to rapid changes in manpower demand. Excessive unemployment of professionals represents an inexcusable waste of a limited manpower resource that is urgently required to meet present and future national needs. This may be obvious to an audience of

fig. 1

ENGINEERING EMPLOYMENT AND UNEMPLOYMENT



Source: Data from Bureau of Labor Statistics unpublished reports. Employment figures prior to 1972 have been reduced 6% by EMC to account for changes in occupational definitions made by BLS in December 1971. Note: The BLS designation of "persons employed as engineers" does not correspond to the professional identification of engineers as commonly accepted within the engineering profession. EMC estimates that about 75% of the BLS engineers by occupation would meet professional qualifications.

Graph by J.D. Alden, Engineering Manpower Commission, January, 1975 scientists and engineers, but it seems to be an alien concept among today's policymakers in government.

On the positive side, we can continue to point out to young people that new engineering graduates will probably enjoy good employment prospects even if the demand drops from its current high levels. Even in a general recession, past experience indicates that engineering graduates will fare better than most other groups in the employment market. An engineering education is also excellent preparation for many other kinds of work besides the practice of engineering. The danger is not so much that large numbers of engineers will be out of work for long periods of time as that prospective entrants into the profession as well as older members will be turned away by unfavorable experiences or perceptions about the stability of engineering careers.

The roller coaster fluctuations in engineering demand have brought about a highly unstable manpower situation in the engineering profession. Because of the long lead-time involved in a scientific and technological education, the reaction of students to short term economic changes now seems to produce minimum numbers of graduates when employment demand is high and peak classes in the midst of recessions. It is ridiculous to say either that the mismatch is inevitable or that it can be left to be resolved by the harsh workings of the market mechanism. However, until our government policymakers relearn that the brainpower of our engineers and scientists is an indispensable but limited national resource, and reinstitute the basic data programs necessary to assess manpower supply and demand, efforts by private professional groups to achieve career stability within their own specialized fields will tend to be self-serving and largely futile.

THE BEHAVIORAL AND SOCIAL SCIENCES

by

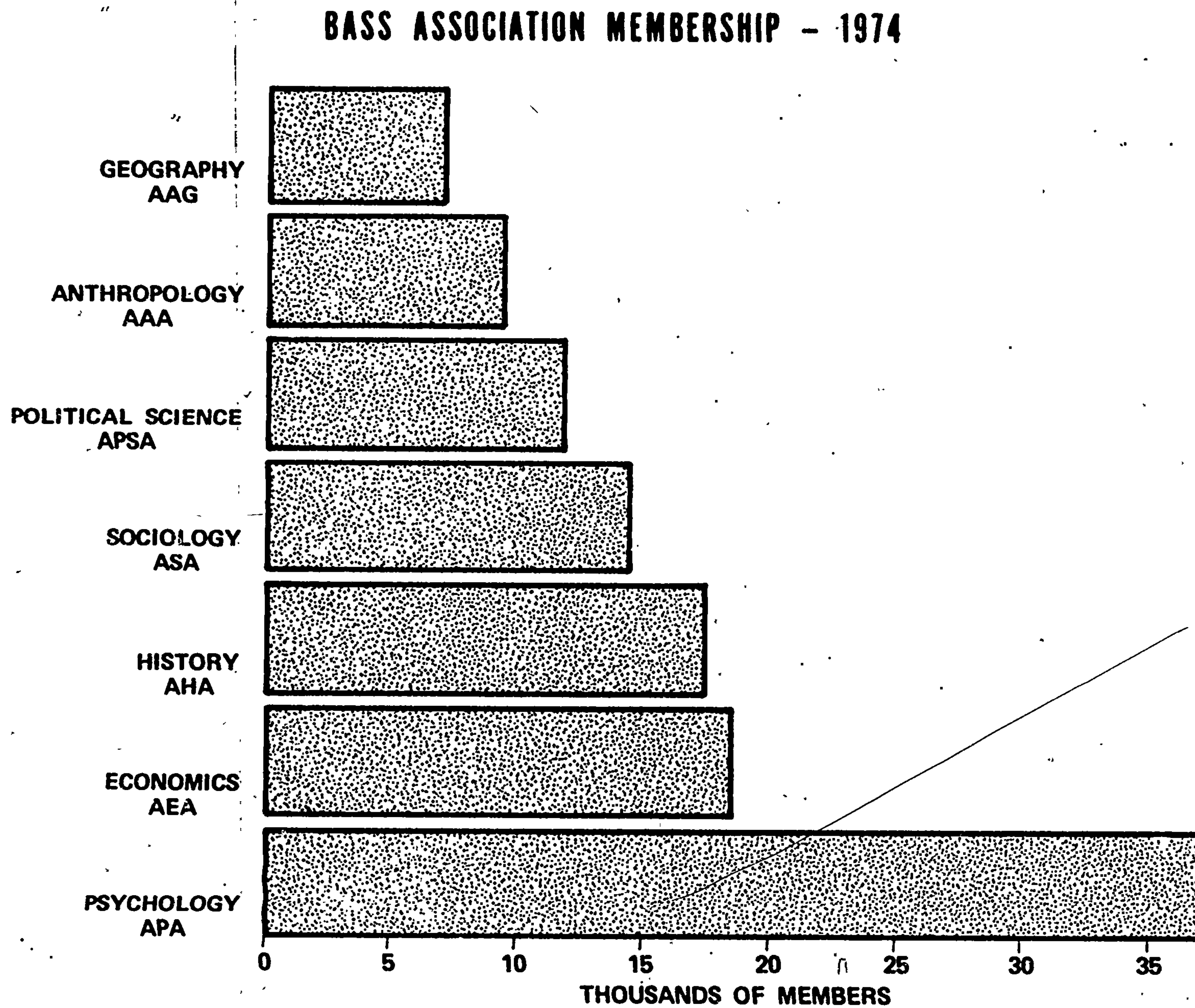
C. Alan Boneau
American Psychological Association

Coming at the end of this morning's survey of the disciplines, I conclude that I am supposed to sweep up the loose pieces. And indeed there are a good many of them still lying around. Which of all the pieces are to be swept into my dust bin of the sciences, the behavioral and social sciences? By consensus, the fol lowing disciplines are generally agreed upon as constituting the core of the behavioral and social sciences: Anthropology, economics, geography, history, political science, psychology, and sociology. These disciplines can be called science in the sense that they are all concerned with providing perspectives about the lawfulness of the behavior of man, his social processes, and his institutions. The methodology of these sciences extends along a dimension of complexity from simple description to the utilization of rigorous scientific and mathematical procedures and complex equipment; the domain, from biology and physiology at one end to abstract conceptualizations of human institutions as systems at the other. To be sure there are other disciplines and professions that are concerned with human problems and institutions: Psychiatry, education, and law, to name only the most salient ones, but they are more properly applied fields and are not considered to be basic or abstract branches. The question of definition is discussed at length in the 1969 report of the BASS*Survey Committee, a joint venture of NAS and SSRC.

In discussing scientific manpower in the context of the social sciences, it is necessary to recognize initially that not all the members of these disciplines are engaged in what would ordinarily be called scientific activities, and many individuals do not consider themselves scientists. Some historians, for example, think of themselves as following a literary tradition rather than a scientific one. Personally, I would hope that the literary tradition is orthogonal to the scientific one, and I note that the literary tradition may even on occasion intersect with science and produce significant literature. Nevertheless there are social scientists who feel most comfortable classified other than as scientists, perhaps as humanists, philosophers, pragmatic practitioners, or to a large extent primarily as teachers, particularly of the younger inhabitants of the educational system.

Since we are unable to disentangle the social sciences from the social philosophers or the social practitioners, we will be forced to deal with the whole unwieldy group. We could take one significant cut, however, that might help to narrow our focus somewhat. As a group of disciplines, the social sciences are a group for which the doctorate is the prerequisite for a post as an "anthropologist" or "historian" and most frequently this post is in an academic setting. Possible major exceptions to this generalization are psychology and economics, but even in these disciplines, those individuals functioning at less that the doctorate level tend not to be the bench or blackboard scientists but practitioners of a different sort. By focusing on the doctorate, we would tend to include in these disciplines the large portion of individuals who contribute to their conceptual growth. As we noted before, not all of these individuals would by consensus or choice be called "scientists", but that is probably true of any scientific discipline.

*Behavioral and Social Sciences


BASS ASSOCIATION MEMBERSHIP - 1974
GEOGRAPHY
AAG
ANTHROPOLOGY
AAA
POLITICAL SCIENCE
APSA
SOCIOLOGY
ASA
HISTORY
AHA
ECONOMICS
AEA
PSYCHOLOGY
APA
0
5
10
15
20
25
30
35
THOUSANDS OF MEMBERS

What, then, is the manpower situation in the behavioral and social sciences today? The data from the BASS are skimpy. My first figure shows the membership of the major discipline societies representing the social sciences by name in order of size as of 1974. The range from a high for the American Psychological Association of 37,000 to a low of 7,000 for the American Association of Geographers. The total membership of these major associations was 116,000, not counting overlapping memberships, which from APA data we know are relatively low. This figure gives a ballpark estimate of the number of individuals who are sufficiently involved in the social sciences to participate in and contribute to the activities of their major national associations.

Association membership requirements vary markedly. The APA has among the most stringent requirements: a doctorate for full membership or a masters plus one year's experience for associate (non-voting) membership. Other societies, however, admit as full participating members individuals with a bachelors degree in the discipline, undergraduate students, or simply, individuals who are interested enough in the subject matter to pay dues. Consequently society membership does not adequately describe the population of social scientists qua scientists.

Nor does society membership adequately represent the numbers of individuals who might be called "psychologists", "economists", "sociologists", and the like by virtue of their training and/or occupation. Let me illustrate by describing the situation in my own discipline, psychology.

As far as we can tell, the APA has as members almost 90% of those individuals who have a doctorate in psychology. The situation is somewhat unclear, however, because psychology doctorates are awarded by colleges of education and of business in sizable numbers in addition to those awarded in departments of psychology or variants thereof. By the end of 1974 there were probably between 35- and 40,000 psychology doctorates broadly defined of whom perhaps 32,000 are now members of the APA.

The story with masters is less clear. Sizable numbers of ostensible masters in psychology are produced in colleges of education--school psychologists, guidance counselors, special education specialists and the like. The total of such individuals including masters in psychology <u>per se</u> can run between 20- and 60,000 depending upon the definition.

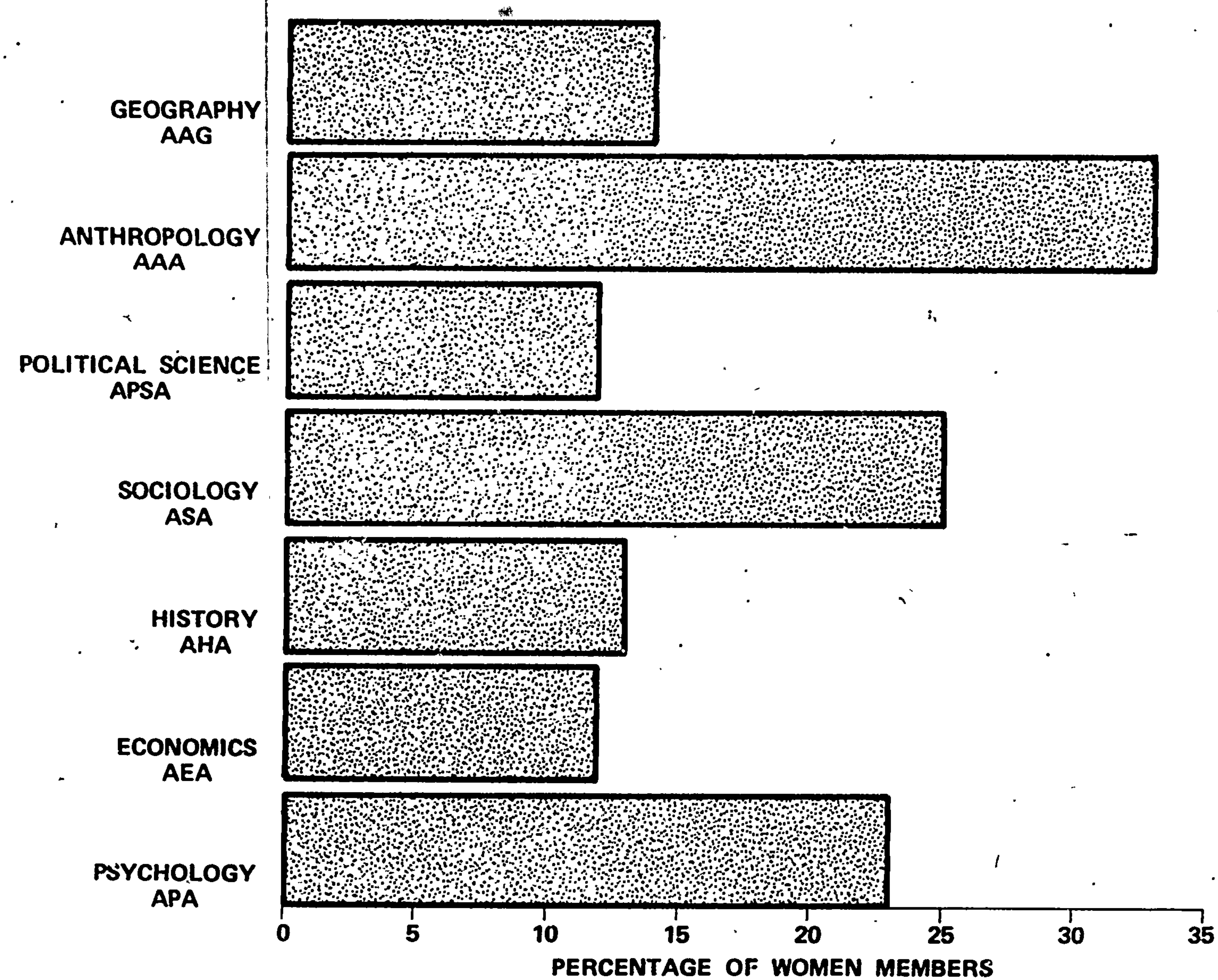
Thus the totality of "psychologists" at both levels is probably between 60- and 100,000, of which the APA's current (1975) membership of about 39,000 represents somewhere between 40% and 60%.

The number of individuals with a bachelors degree in psychology is beyond our belief, running in recent years close to 60,000 or 70,000 per year.

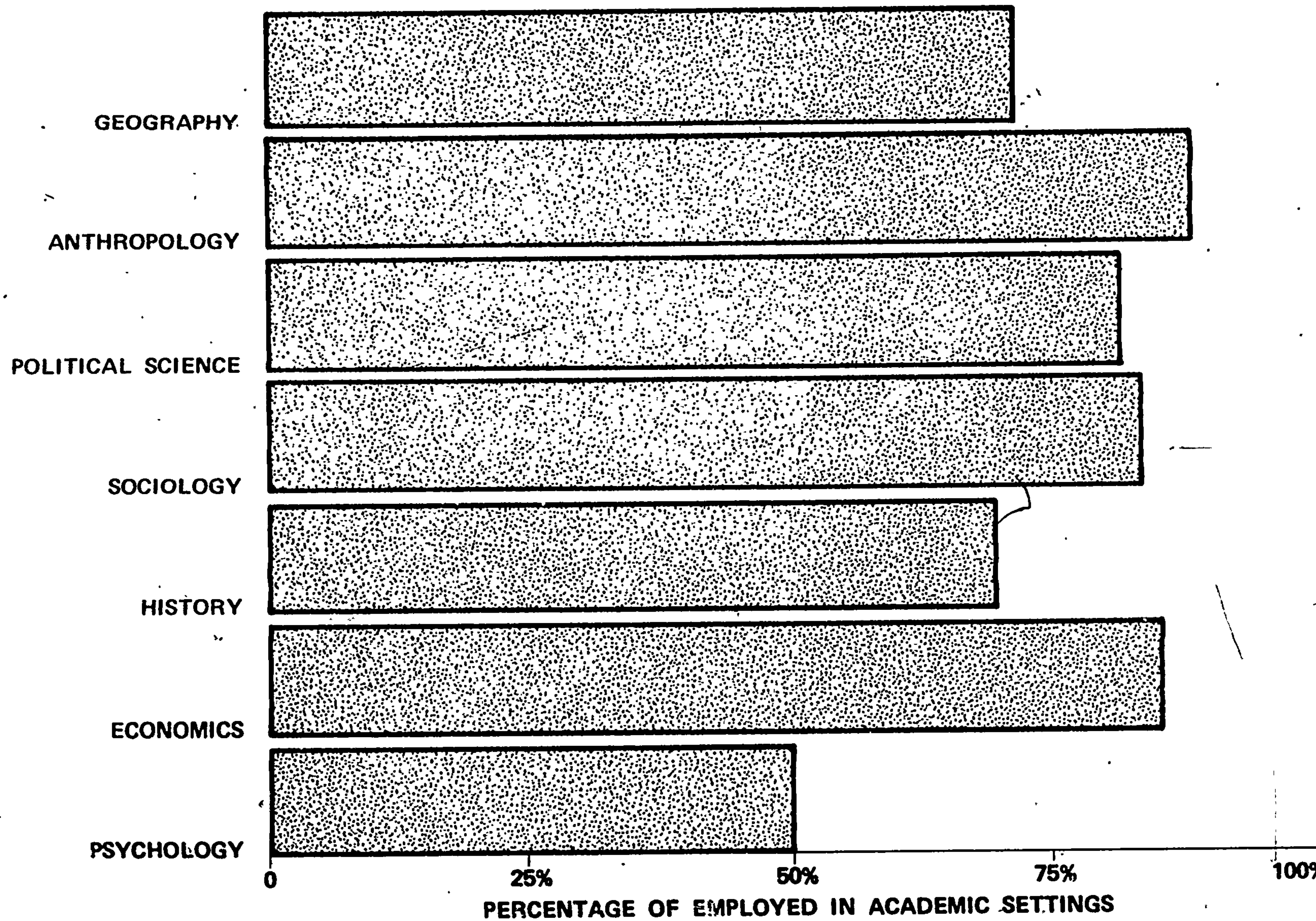
Clearly such considerations shed little light on the topic of this symposium. They do serve to point up, however, the necessity of paying careful attention to the task of framing precise questions in dealing with manpower issues in the behavioral and social sciences. With that caveat, we may proceed to a further examination of data.

Most societies now have information on the number of women and minorities in their membership. Figure 2 shows the percentages of women members by society. Minority representation in social science societies according to available data is

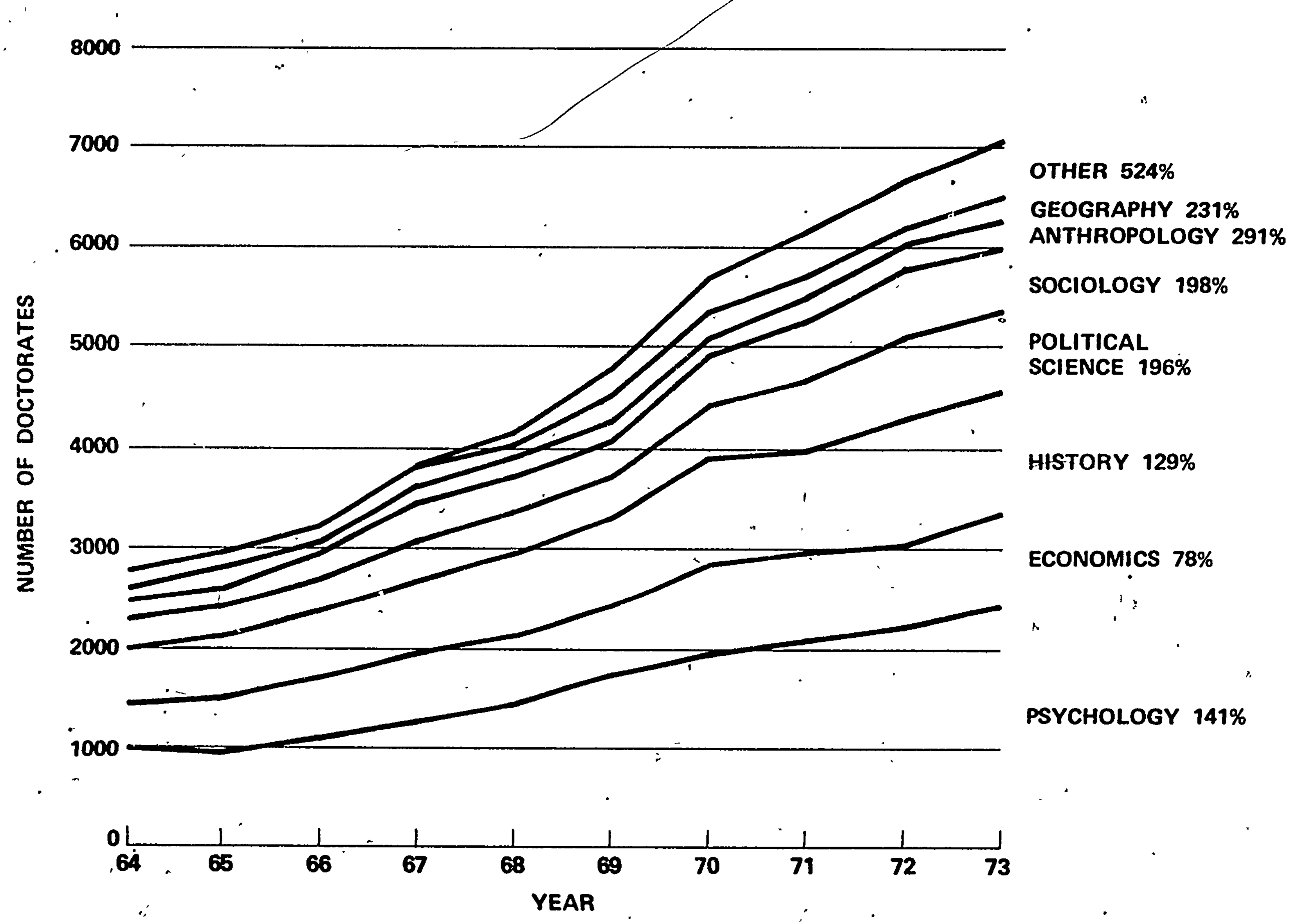
WOMEN AS BASS ASSOCIATION MEMBERS



BASS ACADEMIC EMPLOYMENT



DOCTORATE PRODUCTION IN BASS BY YEAR



miniscule. No society, at least in 1972, contained as many as 1.5% indentifiable black Americans and the total number of individuals for all societies together could not have been more than 600. Other minorities were similarly underrepresented. It remains to be seen how well recent attempts to increase minority participation have succeeded in brightening this bleak picture.

By employment setting the social scientists are primarily employed in educational institutions, as figure 3 shows. Significant numbers of psychologists and economists, however, are employed in federal and state government settings and in industry and business.

Because of the high level of employment in educational institutions for the social sciences in general, the specter of overproduction is fast assuming a palpable form. With universities having virtually achieved their full growth for the foreseeable future, and with social science faculty having a median age of around 40 years, the academic job market is now operating in a very weak replacement mode for most disciplines. The exceptions seem to be geography, which has been riding the crest of environmental concerns, and psychology, which is still catching up with its spurt in undergraduate enrollments and currently is placing about 1000-1200 new doctorates a year in academic positions.

Such information only assumes significance, however, in the context of the supply background. Let us examine production trends and existing production capabilities to see how they highlight the demand picture and then draw a few conclusions.

Let us restrict ourselves to doctorates to keep the picture not only simpler, but based upon one of the few relatively good data sources, the NAS Doctorate Record File. In figure 4, I have displayed the doctorate production by year for the behavioral and social science disciplines during the ten-year period starting in 1964 and ending in 1973. Over that span of time the total BASS doctorate production has grown from 2,794 in 1964 to 7,124, a growth of 155%. By way of comparison, the total of the other sciences grew from 7,142 to 13,644 or 91%, although the growth in absolute numbers is larger. Notice inflection at 1970.

The upshot of this analysis is that sufficient academic resources exist to produce at least 7,000 doctorates per year in the behavioral sciences. Because of the backlog in the pipeline the total production will probably peak at over 8,000 this year or next.

To sop up this flood, the data gathered piece by piece from the best guessers on such matters within the disciplines lead me to conclude that the sponge of academic jobs will absorb perhaps 2,500.

In terms of tomorrow's human resources in the social sciences, clearly there is going to be spillover of considerable magnitude. Surprisingly (or perhaps not) the disciplines are only now seriously beginning to develop coping behaviors. Generally this is taking the form of examining alternatives to academic roles for their doctoral students. I am participating Thursday, for example, in a symposium entitled Innovative Roles for Psychologists in Improving the Quality of Life. As it turns out, we can identify psychologists, and the other disciplines are similarly successful in identifying their own members, who have struck out into the great unknown and unfriendly world beyond the Ivory Tower and who have succeeded in performing useful applied functions.

I predict that we are going to see more of this kind of adaptation. After all, the big problems we face, even the technology-intensive problems such as energy, to a large extent involve problems of human attitudes and behavior and of the modification or creation of human institutions supportive of technological solutions (or partial solutions).

There is a place for social science technology. Creating a demand for such technology will involve profound changes in the training and retraining of social scientists and in the ways the social science disciplines exert their influence in the scramble for support for their efforts. Psychology, for example, has spawned two separate lobbying groups in the past few years, and the other disciplines are showing increased interest in political activities to make salient their contributions, potential or otherwise.

In conclusion, it would appear that the most interesting and challenging aspects of the utilization of behavioral and social science manpower are concerned with the future. Where on earth are these individuals going? Assuming they find jobs, which is likely, and make themselves useful, also likely, does this experience create a greater demand for these services? History would seem to answer affirmatively. What they will be doing, only the future knows.

EXAMINING PAST ASSESSMENTS:
YESTERDAY'S MANPOWER PROJECTIONS IN RETROSPECT

by

David W. Breneman
National Board on Graduate Education and Senior Fellow Brookings Institution

That past manpower projections have often been wide of the mark within a few short years is sufficiently well-known that I have not perceived my task to be the careful documentation of past manpower forecasts and their subsequent percentage errors. Instead, a more useful purpose will be served by an impressionistic and necessarily selective look at several of the widely publicized manpower forecasts of the past together with an analysis of the principal reason (or reasons) for their subsequent inaccuracy. This procedure will allow us to distinguish certain errors from which we have learned and need not repeat, from other deeper problems which may not have an obvious solution. Following this brief survey, I will note some promising areas for further development as well as some suggested strategies for coping with the irreducible element of uncertainty that will remain in future forecasts. The discussion will be limited to past projections for highly educated manpower, i.e., for those occupations requiring a Bachelor's or advanced degree.

The earliest forecast to be considered was that made by Seymour Harris in 1949.[1] This early attempt at forecasting is often cited by those who believe that it is impossible for this nation to produce too many highly educated people for the labor market to absorb. You will recall that Harris examined the occupational pattern of college graduates in 1940, projected this pattern unchanged into the 1960's, and concluded that the country would experience a serious over-supply of college graduates in the 1960's. Ironically, Harris actually underestimated the growth of college enrollments,

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[1] Seymour Harris, The Market for College Graduates (Cambridge: Harvard University Press, 1949).

but more seriously, he did not foresee the significant expansion of employment opportunities for college graduates in new activities in a dynamic and growing economy. From this experience, we have learned not to assume unchanging linkages between education and occupations, particularly over an extended period, and have also learned that the supply of educated labor has tended, within limits, to create its own demand. (This latter tendency is a continuing source of difficulty for any forecasting technique that relies on historic relationships between education and occupational structure and between occupational structure and the composition of GNP.)

From Harris' faulty predictions of an oversupply of college graduates, consider next a series of forecasts of severe manpower shortages, in this case projected shortages of Ph.D.'s. I refer to the biennial surveys of college and university teacher supply and demand, with accompanying predictions, prepared by the National Education Association from 1953 to 1965.[2] These publications projected a dismal picture of declining faculty quality in the late 1960's and 1970's, for the supply of Ph.D.'s was forecast to fall widely short of demand. By the middle 1960's, however, Allan Cartter had observed that these dire predictions were not being fulfilled, and he traced the major error to a mistaken parameter in the NEA's simple manpower forecasting model.[3] In making demand estimates, the NEA had assume a 6 percent annual replacement demand due to death, retirement and net outflow from teaching, but Cartter

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2 National Education Association, Teacher Supply and Demand in Universities, Colleges, and Junior Colleges, biennial reports issued from 1953 through 1965 (Washington, D. C.: National Educational Association).

3 Allan M. Cartter, "The Supply and Demand of College Teachers," Proceedings of the Social Statistics Section (American Statistical Association, 1965); and "The Supply of and Demand for College Teachers," The Journal of Human Resources, Vol. I-1, (Summer, 1966).

found that the actual rate was closer to 2 percent. When projected several years forward, this seemingly innocuous parameter error produced a large over-estimate of future demand for new faculty. This experience, although embarrassing for the NEA, has served to alert people to the sensitivity of projection models to certain key parameters and has, therefore, reduced the likelihood that subsequent manpower forecasting models will contain such elementary errors.

Consider next two studies performed for the National Science Foundation by the Bureau of Labor Statistics in the late 1950's and 1960's.[4] These projections of requirements and supply of scientists and engineers to 1970 generally underestimated the growth of supply and overestimated the growth of demand.[5] In a paper prepared for a 1974 Seminar on Scientific and Technical Manpower Projections, sponsored by the NSF,[6] Harold Goldstein, formerly of the BLS, discussed in detail the reasons for the failures in those early 1960 forecasts. Foremost among the errors on the demand side was the assumption that research and development expenditures would grow by 123 percent from 1960 to 1970, reaching a projected 3.7 percent of GNP.[7] This led to a forecasted doubling of demand for scientists and engineers in R&D employment by 1970; in actuality, R&D expenditures reached only 2.7 percent of GNP in 1970, and

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[4] Bureau of Labor Statistics, Department of Labor, The Long-Range Demand for Scientific and Technical Personnel: A Methodological Study (Washington, D. C.: National Science Foundation, 1961); Scientists, Engineers, and Technicians in the 1960's: Requirements and Supply (Washington, D. C.: NSF, 1961).

[5] A summary table of the pertinent figures is contained in Richard B. Freeman and David W. Breneman, Forecasting the Ph.D. Labor Market: Pitfalls for Policy, (Washington, D. C.: National Academy of Sciences, 1974), pp. 22-23.

[6] Harold Goldstein, "Experience in Projection of the Demand for Scientists and Engineers," paper prepared for the Seminar on Scientific and Technical Manpower Projections sponsored by the National Science Foundation, Hot Springs, Va., April, 1974.

[7] Ibid., p. 50 in the Draft report.

R&D employment for scientists and engineers increased by only 39 percent over the period. The differences between projected and actual R&D employment in 1970 was 237,000 positions.

On the supply side, these forecasts underestimated the response of students to the economic and other incentives to enter scientific and engineering occupations in the 1960's, as well as the ability of the nation's colleges and universities to expand the supply of places so rapidly. Trends in total graduate enrollments and Ph.D. production in all fields during the 1960's provide a good indication of the size and speed of expansion; graduate enrollments increased from 314,000 in 1960 to 816,000 in 1970, a 10 percent average annual rate of growth, while Ph.D. production tripled from approximately 10,000 degrees in 1960 to approximately 30,000 in 1970. Supply was simply more responsive than was foreseen at the start of the decade.

Changing patterns of student response have tended to upset many projections that have assumed some form of stability in enrollment patterns. For example, in a recent paper, Allan Cartter reviewed the several projections he has made since 1964, and observed that "The last several years, however, have confounded the seers--I, among them--and these events call for a careful re-examination of presumed enrollment trajectories and faculty demand estimates."[8] He went on to note that while his 1964-66 projections were within one or two percent of today's enrollment, his 1968-69 projections are off by 4 or 5 percent and his 1970-71 forecasts of enrollments in the mid-1970's are 7 to 10 percent off.[9] The principal reason for the errors in more recent projections is the sudden (and out of trend) drop in education participation rates in recent

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[8] Allan M. Cartter, "An Overview of the Academic Labor Market," prepared for a Conference on Graduate Education: Manpower and Costs, Urbana, Illinois, July 1974, p. 1.

[9] *Ibid.*, pp. 1-2.

years. The high school graduation rate, rather than continuing to increase, peaked in the late 1960's at 76 percent and has declined slightly since then. Similarly, the ratio of first-time college entrants to high school graduates rose steadily from 1950 to 1969, but has declined in each of the last four years. The ratio of first-year graduate school enrollments to bachelor's degree completions has also declined markedly since the late 1960's, after more than a decade of steady increase. These unforeseen changes have thrown off all projections based on simple trend extrapolations.

Even this cursory survey of past manpower forecasts would be incomplete without a mention of the experiences other countries have had with such projections. A recent book, edited by Bashir Ahamad and Mark Blaug, entitled The Practice of Manpower Forecasting,[10] provides 10 case studies of past forecasts in nine countries, and is an excellent single source for our purpose. The editors reach rather negative conclusions about the accuracy of past forecasts in the cases studied and about the value of the forecasts for policy purposes. In particular, they argue that the forecasts have not been helpful for purposes of educational planning. A quotation from the book's concluding chapter gives the flavor of their findings:

> We do not say that manpower forecasts of the traditional type are useless. Fairly accurate predictions can be made over short periods of time (say, two to three years) and this is useful for an 'active manpower policy' that seeks to intervene in labour markets. Indeed, we feel that manpower forecasting should become much more of an on-going activity and that short-term forecasts should be made fairly regularly at short-term intervals. This would afford greater flexibility and would also give more scope for improvement of the models used. In time we may even learn to predict accurately further into the future. However, short term forecasts seem to be less useful for educational planning than long-term forecasts:

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10 Bashir Ahamad and Mark Blaug (eds.), The Practice of Manpower Forecasting (San Francisco: Jossey-Bass, Inc., Publishers, 1973).

> we are therefore driven to the central conclusion that manpower forecasting has not so far proved to be particularly useful for educational decision-making; we may even go so far as to say that it has on occasion been positively misleading.[11]

What, then, are we to make of this brief examination of past experience with manpower forecasting? First, progress has been made in understanding the technical aspects of projections, and there is certainly a growing awareness of the traps that have beset earlier forecasts. Certain errors, such as the NEA's failure to realize the significance of an inaccurate parameter estimate, are not likely to be repeated. Nor are we likely to ignore the evolutionary nature of the relationship between highly educated manpower and the economy, as Harris did in 1949, although this remains one of the most difficult and unresolved problems of forecasting. (For example, models that use fixed-coefficients for various relationships of education to occupation, occupation to industry, and industry to GNP run into this problem.) Although one would not recommend that existing projection models become the basis for policy setting, continued work on systematic models that relate the higher education sector to the total economy is warranted.[12]

There is another direction for research, however, that I believe holds even greater promise than the continued elaboration of existing projection models.[13] I refer to the investigation of the working of labor markets for the highly educated, including the effects that various policies have on the

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[11] Ibid., p. 322.

[12] A good discussion of this topic is contained in Roger H. Bezdek, Long-Range Forecasting of Manpower Requirements (New York: Institute of Electrical and Electronics Engineers, Inc., 1974).

[13] The following discussion is developed further in Richard B. Freeman and David W. Breneman, Forecasting the Ph.D. Labor Market: Pitfalls for Policy, op. cit., pp. 20-36.

behavior of students, universities and employers. Initially, the purpose of such research would not be to make projections but to improve our understanding of the decision-making processes of the various agents involved; this behavioral information could be incorporated into subsequent forecasts.

Two considerations prompt me to recommend this approach. First, in the United States manpower projections are not used for centralized manpower planning, e.g., for the allocation of specific numbers of students to individual fields or for the allocation of spaces within universities. Since we rely on decentralized decision-making and allocation procedures, it is surely sensible to know as much as possible about the working of those procedures, including their limitations. Only through such research are we likely to develop sound governmental policies for intervening into the process at necessary points.

Second, recent research in this vein has shown promise in helping to explain some of the trends that confound the mechanistic projection models. Richard Freeman has successfully modeled the cyclical movements of the labor market for engineers on the basis of a plausible economic hypothesis of student behavior.[14] Stanley Nollen has also applied economic theory to predict supplies of college graduates;[15] his model also provides an explanation for the recent drop in college attendance rates noted earlier. If work in this tradition stands up under further experience, and as more is learned about the behavior of students, employers, and universities, both meaningful projections and better policy recommendations should be possible.

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[14] Richard B. Freeman, The Market for College-Trained Manpower (Cambridge: Harvard University Press, 1971).

[15] Stanley Nollen, The Supply and Demand for College-Educated Labor, unpublished Ph.D. dissertation, University of Chicago, 1974.

Even if our ability to make projections improves, however, there will always be uncertainty present in the forecasts of demand and supply. A wise policy, therefore, should ensure the country's continued capacity for high quality advanced education and research, avoiding abrupt shifts in financial support on the basis of immediate labor market conditions. Unforeseen events, such as the current energy shortage, serve to remind us of our dependence on science, technology, and trained intelligence. Although improved forecasts will help to reduce dislocations caused by shortages or surpluses of trained manpower in specific fields, complete reliance on such forecasts for policy purposes would be foolhardy. Maintaining a strong and flexible educational system will always be our best form of insurance.

THE NATURE AND QUALITY OF CAREER CUIDANCE FOR SCIENCE AND ENGINEERING

by
David R. Reyes-Guerra
Engineers Council for Professional Development

According to the press, possibly our greatest scientific accomplishment in the 60's was placing man on the moon. News reports tell us we owe to science and scientists our supremacy in space. However, we are also sorry to admit that all problems and failures occuring with the space program are due to poor engineering.

As a matter of fact, all our concerns with pollution and the rape of the environment we owe to technology. The major culprits in such goings on are, of course, the engineers.

Those statements are considered fairly accurate by over 60% of our population. There is another 30% who will not quarrel with such words, but do not believe them to be all that accurate. About 1% know that such statements are patently inaccurate. That 1% or slightly over 2,000,000 people are the scientists and engineers; they know that the space program is actually 95% engineering and 5% science; that the ones who are going to solve our environmental problems are not the social scientists nor the politicians, they will be the engineers and scientists. The sad fact is we are the only ones who know this. Those who need to know the facts--the other 98% of the population--are kept in a permanent fog about what we are all about. We are partially guilty for this ignorance because we tend to spend most of our time talking to ourselves rather than the outside world.

We are a highly developed civilization--we are the most technologically advanced population in the world. Such sophistication has occured in such a natural way that it is taken for granted. Few people realize who is behind our high standard of living.

In spite of our technological primacy, a careful look at our educational programs from kindergarten through the 12th grade show a complete lack of coverage of what engineering or science are all about. The former is really completely ignored--except in the vocational technical programs where the craftsmen and technicians receive their education. Science, fortunately, is not completely ignored. There are many ccurses in the pre-college curricula which are directly related by name to careers, such as chemistry and physics. The only semantic confusion in science occurs with the social and business areas which also use the word science in describing their courses.

The terms science and engineering mean many things to many people. Most young persons--between 12 and 17 years old--think of careers in science as being in chemistry, biology, and physics.

Engineering careers, on the other hand, remain a mystery.... "we never studied it in school."

Our main objective in engineering career guidance is not recruiting. It is a simple, but extremely complicated information program by which we try to reach young people, their parents and teachers. The message is a course in engineering literacy. The engineering profession attempts to describe what it is all about, as factually as possible, so that the young person seeking to make a career choice or decision can properly evaluate this profession on an equal knowledge level with others.

The engineering profession realizes that not everyone will want to become an engineer, but it wants everyone--as far as possible--to know what engineering is all about. It wishes to encourage those who have the aptitude, motivation and interest to consider engineering. It also wants to discourage those who are not qualified or are misinformed as to what the profession is all about.

It is not difficult to imagine the untold benefits we would all receive if our leaders in politics, business and industry would be fully cognizant of the short-and long-term effect of many of their decisions. This they could only accomplish by being very knowledgeable about technology and science, because a large amount of decisions in today's technological world involve science and engineering.

The entire guidance program is an informative effort, akin to public relations of the highest order--it involves a persons career choice--a lifetime commitment usually made at an age when a person cannot even vote. Because of the seriousness of such a responsibility, guidance must be above all, truthful. The only "dressing" allowed is that which is necessary to make the message attractive and interesting.

The guidance program is a communications program. We employ all the techniques and aids we can muster. We rely principally on the written word, from throw-away pamphlets to full-sized texts. Motion pictures, video tapes, panel presentations, speakers, role models, expositions, kits, slide shows, contests, film strips, and special courses,--all of these and many others are a part of our resources.

Educators, industrialists, practicing professionals and the engineering societies, all have joined to help carry out this effort. However, the magnitude of our enterprise is seldom ever placed in correct perspective: In 1974 there were 3,130,000 high school graduates--45% of whom would probably enter college. There are close to 35,000 secondary schools in this country with over 120,000 teachers of science and mathematics.

A single contact to the above public involves almost $35,000 in postage alone, not to mention the expense of the message itself, plus packaging. If one wishes to address all the high school students the costs must be quadrupled.!!!! There is no engineering professional group which can budget or afford to budget such a sum. Most of us are carrying a national program on less than a $25,000 annual budget.... It is a real miracle to have accomplished what we have.

The ideal guidance program involves a one-to-one contact between a knowledgeable engineer and a student. Notice the word knowledgeable. This is essential. One is dealing in most instances with a young mind in its early stages. The decision made by the person being guided may affect the rest of that person's life. There is no room in the guidance activity for a "sell," whether it be "soft" or "hard." There is too much at stake.

Our program relies on volunteers who carry out our message. These volunteers come from the profession, they are either engineers, engineering students, or faculty members. We prepare manuals for them to read and hopefully thus try to ensure that they will carry out a competent presentation.

Volunteers are what keeps us going, and gives our program a personal touch. However, much care must be exercised to train the volunteers. At national professional meetings, we try to give a short course to prospective volunteers. This is an attempt to ensure competency in guidance on the part of our representatives. It takes much skill to learn to be a good advisor. They are the role models of the profession. They need to be "tops."

We attempt to participate in national meetings of science and math teachers--as well as counselors. We not only set up booths manned by our volunteers where we distribute guidance materials, but we also volunteer to appear on their professional programs. Scientists and engineers have much knowledge to share with teachers and counselors. There are many programs where a speaker or panel member coming from our profession is a definite asset to the meeting.

Through the Junior Engineering Technical Society (JETS) we offer the students a club-type program where they can carry out many diverse types of projects which will help in acquiring a better understanding of engineering.

Our films and brochures describe individual disciplines as well as a broad panoramic view of the entire profession. Different publications are targeted at different age groups.

Our most successful recent film is called "A Piece of the Action." This film is geared to the minorities. However, the film is not intended to be a guidance program on its own. There is a teacher manual which explains the film and provides further study and project information. The students who watch the film receive a special brochure. This publication contains a simple self-administered test which will hopefully inspire the student to further exploration of a career in engineering. Thus the film is used as a motivator as well as an entertaining adventure into our world.

Though most secondary schools are equipped with film strip projectors, engineering continues to present its message through slides. The reasoning is simple: The volunteer who is making the presentation may have some local or personal areas of expertise he wishes to cover using his own slides. These he can always inject into the "canned" presentation if the latter is in slides, otherwise--in the case of film strips--he can not do this.

We also try to discourage a taped presentation. Though they are available, it is always best to let the volunteer do his own presentation. The slide program carries a written script which the volunteer can use at his discretion.

The best contacts and the most believable in guidance are the peer groups. Engineering tries to communicate with students through students. A good example of this approach is the Minority Introduction to Engineering (MITE) summer programs. Here, approximately 40 students are brought to a college of engineering for a two week period. The students live in college dormitories, listen to lectures, conduct experiments, and become thoroughly familiar with what it is like to be in an engineering college. These students are chosen at the end of their junior year in high school. After the program, when they return to their respective schools they are a source of much information for their fellow students.

We would rather have others talk about engineering than ourselves. We are always suspect...we are engineers. We know what needs to be done, we know how to do it; however, we are not the proper vehicle.

This presentation has simply skimmed the surface of what is being done or can be done. It is not a complete volume. However, it helps to give a perspective of the task, the books and mechanics being used to bring about a satisfactory solution to the guidance problem facing the engineering profession. Our concern is not to fill classrooms, recruit engineers or overpopulate the profession. Our concern is to provide the country with a means to become fully knowledgeable about what engineering is all about...If we only had a $250,000 budget, can you imagine what we could do....

GUIDANCE FOR GIRLS AND MINORITY YOUTH

by

Dr. Janet W. Brown
Office of Opportunities in Science - AAAS

Eight or more months ago, when I agreed to be on this panel, I would probably have hit a more optimistic note. "Barring a major economic crash," I would have said, "the job outlook in science and engineering is excellent for minorities and women who have good training. The demand for them is high, higher than for scientists and engineers in general. And though there is still widespread discrimination against women and minorities, especially with respect to opportunities in pay for women, there is a sufficient number of employers who are really trying to make amends for the past that there are indeed jobs out there for minority and women scientists with good training and/or experience. The more training these young people have," I would have said, "the better their chances."

That is what I would probably have said then, but two developments have given me pause. In recent months the rate of economic recession has tempered my optimism. Simultaneously, there has been mounted a major assault, not unconnected in my opinion with the worsening economy, on the principle and practice of affirmative action.

Unemployment rates have shot up, and though it is still primarily the less well-educated and the less skilled workers who are affected, there are reasons for concern in the professional areas. Hiring in the universities has slowed to a trickle. Thus, when we look at the opportunities for Ph.D's who have traditionally found much of their employment in academia, we must be concerned for them and for the wasted training their potential underemployment represents.

Although there is not yet an appreciable decline in R & D, one could not be labeled unduly pessimistic if one suggested caution in this area also. Hiring in energy-related research, development, and administration is not yet sufficiently marked to offset a slow-down in other areas. Meanwhile, conservation and environmental protection, fields in which a couple of years ago we all hoped there would be new jobs for scientists and engineers, are now clearly taking a back seat to national energy needs.

Eight months ago I was also more optimistic that affirmative action would gradually improve the opportunities for women and minorities. The federal government's affirmative action imperatives had stimulated long overdue attention on the supply of minority and women scientists. I do not mean to imply that affirmative action efforts had succeeded in making significant gains for women and minorities. That is simply not the case. In the universities especially, popular male and/or administrative belief to the contrary, the actual statistics show the gains to be miniscule, the largest and most prestigious universities, the ones that have protested most loudly about affirmative action, have for the most part made virtually no gains. There are, unfortunately, still departments like the Chemistry Department at Berkely which has a faculty of fifty chemists and not a single woman. (See "Women on the Chemistry Faculties of Institutions Granting the Ph.D. in Chemistry", American Chemical Society's Women Chemists Committee.)

Both the universities and the women and minorities agree that HEW administration of the regulations has been completely inadequate, a conclusion which surely accounts for much of the unhappiness with affirmative action, but in spite of the complaints, the existence of affirmative action programs had created an atmosphere that stood to benefit women and minorities who, as groups, had been severely discriminated against in professional and other employment. Affirmative action imperatives have resulted in serious and sincere effort in many institutions and in some have produced laudable results. They contributed greatly to an increased awareness of patterns of discrimination, and of the rights of women and minorities, and gave some of us a heady feeling that we were moving forward. We had the feeling for once, that the law was clearly on our side, and we had hope.

I should perhaps not use the past tense, for the affirmative action is still technically with us, but its use underlines a perceptible change in the atmosphere. The affirmative action effort has been erroded in recent months, a development which is not unconnected in my opion with the worsening economic picture. If the economy were expanding it would be easier to accomodate the increasing and justifiable demands of minorities and women. But as the economic picture worsens and lots of people become nervous about their jobs and security, latent racist and sexist attitudes bubble all to easily to the surface.

There are serious omens of backlash. The so-called "Lester Report" of prestigious origins claimed errosion of standards due to the forced nature of compliance. (Richard A. Lester, Antibias Regulation of Universities.) In the fall, Representative Marjorie Holt, her congressional district upset over the implementation of a court order to integrate the schools, introduced an amendment that would have eliminated federal enforcement. It failed in the Senate, but its intent was echoed in hearings before Representative O'Hara's subcommittee, which will surely introduce similar legislation in the next session. A December memo from Peter Holmes, head of HEW's Office of Civil Rights, "clarifying" the subject of "goals" vs. "quotas" represented a large step backward from Elliott Richardson's earlier pronouncements ("Memorandum on Affirmative Action", Peter Holmes, December 1974). Sidney Hook's concerted and organized attack on affirmative action ("Committee on Academic Nondiscrimination and Integrity", Letter to President Ford, Reported in New York Times, December 8, 1974.), is still further evidence of a growing backlash against equal opportunity.

For these reasons I cannot be highly optomistic about the opportunities for minority and women scientists, but neither would I be as pessimistic as some of my colleagues whose papers preceed this one. It is clear from their largely gloomy illustrations that academia cannot absorb all the Ph.D's being graduated and that the society will need to provide them useful employment in other sectors or waste their training. The other thing that is clear from the foregoing presentations is that pretty much the only hard data we have is about doctorates. Projections on future demand for them are difficult enough, so when we refer to non-Ph.D's as well, as I intend to in my predictions, we might as well admit that we are in a realm of speculation that far exceeds the data base.

I can say confidently that there are many continuing problems ahead of this nation that will require the service of scientists, engineers and others with good technical training, and I think the women and minorities will share increasingly in them. They are not going to catch up with majority males as fast as we would like, for the rate of improvement may be slowed temporarily, but we minority and female professionals will continue to make gains.

Where are the jobs going to be?

According to labor economists Rosenthal and Dillon, the employment of professional and technical workers is going "to continue growing faster that that of any other major occupational group" in the decade ahead. The number of jobs is expected to grow from 11.5 million in 1972 to 17 million by 1985 - that is more than than 1 1/2 times the increase forecast for all other occupations combined. (See "Occupational Outlook for the Mid-1980's", Rosenthal and Dillon, Occupational Outlook Quarterly, Winter 1974.)

Among the many fields included in the "professional and technical" category, the outlook in the sciences and science-related fields is certainly better than that in the humanities, as was so poignantly shown in the reporting of the dire job situation at the annual meeting of the College Art Association in Washington earlier this month. (Washington Post, January 24, 1975.)

The BLS prediction should hold in relative terms even if the total employment picture turns out to be much worse than the BLS predicts, for the tough lasting problems facing the society are all ones in which a high level of scientific and technical complexity is involved. Just think about what those problems are: energy, food, urban transportation and housing, pollution abatement and control, resources conservation and utilization, health, and so on. The solution of these problems is going to require scientific and technical manpower, though I will grant you that we do not know the scale of opportunities nor the kind and number of jobs we are talking about. Only in the energy and health fields have we even begun to try and figure out what those demands may be, and there the experience is revealing.

It is in energy that the most recent effort has been made to predict future demand. Robert Henze has already referred to the Gutmanis Study for the National Planning Association. The National Academy of Engineers has also produced a report which outlined the steps necessary to increase domestic energy supplies and decrease consumption by 1985, and estimated the costs in manpower, water, and materials. Their estimates are uniformly high on all counts, despite the fact that they deal only with primary demand, not with secondary effects. They seem to point to shortages. Although the engineers report does not mention social scientists, one can see in the picture a need for them also. (See U.S. Energy Prospects, An Engineering Point of View, a report of the Task Force in Energy of the National Academy of Engineering, Washington, D.C., 1974)

Our energy and other national problems are not going to go away. Their highly complex technical nature assures that well trained people with a good grasp of the scientific and technical are going to be needed to deal with them.

So, while the job picture is far from hopeful, it is not bleak. It is probably better for young people interested in the natural sciences than it is in most of the social sciences and humanities.

The advice I would give to young women and to minority youth, both female and male, is in most respects not very different from what I would say to any young person:

1.) You have relatively better chances of finding employment in the natural sciences and related fields than in humanities and social sciences; you have a better chance if prepared for a professional technical career than in service, sales, clerical, etc.

2.) Engineering, if you have the aptitude and inclination, is a sure bet, immediately and within the next ten years. As John Alden says, there is a "decade of unmet demand ahead." (See J. Alden, Engineering Manpower, Present and Future)

3.) Given the trend in undergraduate enrollments (See B.Vetter, Science and Engineering Enrollments) in the sciences, we are undoubtedly in for shortages, possibly acute shortages, of mathematicians and physicists in five to ten years.

4.) The supply of chemists may also become lean within the same period.

5.) We are in for a clearly greater demand for geo-scientists than we can produce (See B. Henderson, Geoscience and the Quality of Life).

6.) In the social sciences it is much more difficult to predict demand, because we have such an inferior data base from which to extrapolate any conclusions. We hope the social scientists will become aware of the need to do more on the collection of data, but in the meantime, about all we can say is that their knowledge also will be called on to analyze the problems and coordinate and administer the attack on them.

7.) In the biological sciences it is almost as difficult to predict because of the inadequacy of the data. There is some suggestion in B. Vetter's presentation that we may experience a temporary over-supply of people trained in the biological sciences. In the long-range, however, the generalizations made above about the other natural sciences must also hold true for biology.

8.) Those with the best and the broadest training will stand up best in the competition for the jobs that do open up. Good people, trained in more than one field and able to deal in an interdisciplinary way with the problems of energy, the urban environment, health care delivery, etc. will always be in short supply.

The need is there for more and better trained people with science backgrounds, people able to work on pervasive and lasting problems. I think the nation is in for a long, bad time economically, in which all of us are going to have to readjust some of our assumptions, and alter our sights and lifestyles, but I have confidence that the American people will decide, after a while, that the problems are to be attacked positively by putting people to work on them. This will, of course, require a series of political decisions, but it will eventually happen.

Putting people to work on problems means creating jobs - jobs related to food supply and distribution, energy consumption and conservation, urban transportation and housing, conservation of good air and water. People of all skill levels will be needed. In some respects they will need better training and will receive higher awards than similar technicians of the present, i.e., the auto mechanics that will be required to keep cars on the road longer will be required to do more complex repairs than at present when we junk cars for parts only. They will require more skills and begin to command higher pay that presumably will be more nearly competitive with that of the auto workers on the assembly lines that produce the new cars. At the other end of the spectrum, we will continue to need the best of scientific minds and experience applied to the highly complex research problems.

Additional kinds of efforts at a middle skills level will require more broadly educated problem-solvers--good, well-trained generalists with analytical training and wide societal knowledge and understanding. In the 19th century, especially in Europe, these generalists and problem-solvers were the classics scholars who graduated from the universities with honors in Latin, Greek, and mathematics, and helped to run the world through their respective colonial and civil services.

Today, they had best have more varied graduate course work and specialized graduate training to cope with the 20th and 21st centuries' more technological society.

Today, the student interested in working at societal problems, but unsure of just how, or of where the jobs are, might do best to acquire a good strong undergraduate major in mathematics, physics, chemistry, geosciences or biology, with a complementary dose of social science courses, especially economics followed by graduate work in business, economics, urban studies, environmental protection, urban or economic geography. And somewhere along the way they'd better take time to learn to write and speak effectively, for the experts cannot solve society's problems if they cannot communicate with each other and with public officials and the public.

Those of us in academia and the professional associations have for too long been concerned with training Ph.D's for research and university teaching. The projections of Charles Kidd and the colleagues you have heard this morning provide the writing on the wall. (See C. Kidd, The Implications of Changing Enrollments, and of Supply and Demand for Doctorates, For Universities) We should long since have seriously reconsidered what we provide for the young in our universities and how well we prepare them for tackling the problems of the world.

Young people whom we need in science and young people who need more and better science training are being discouraged by several factors. The spectre of unemployed engineers and Ph.D's frightens all but the most single-minded, and the information to the contrary that we have heard this morning is not reaching them. Secondly, they cannot readily see how science can contribute to the solution of societal ills; indeed, science is often blamed for them. So, many students who are highly idealistic in my experience, turn to other fields, to other majors which seem to them to have more direct application - to business management, to the social sciences, to computer science.

It is my considered opinion that they make a mistake. An undergraduate degree in business or social science equips one to do very little of societal significance. Undergraduate business majors do not ordinarily end up controlling big business that can affect rather than be affected by the economy - unless Daddy owns them. Nor are they significantly represented in positions of influence in our society. At least in the high technology areas like energy, food, etc. the quicker ways to the top are often through the technical and scientific jobs. The bench chemist who goes into an industrial laboratory with a BA in Chemistry and some electives in business and economics can move upward in management, and will sooner find herself or himself in a position of greater influence and larger remuneration than the BA recipient with a social science or business major.

With respect to minority males and women students from all racial and ethnic groups, this is the only area in which I would offer different advice. Minorities are found in even larger proportions than white male students majoring in business, social science, and education, and so will be even more strongly victimized by their failure to get adequate scientific and technical training. The business major at black colleges, for instance, seems to be growing faster than any other undergraduate field. In all colleges, 19% of the black students were majoring in business and commerce in 1972. Only social science had more black majors (21% of those reported), and business, social science, and education majors accounted for a whopping 59% of the total, while the physical and biological sciences and mathematics got only 8.6% all together. (Figures drawn from Social and Economic Characteristics of Students, October, 1972. Population Characteristics, Series P-20, No. 260, February 1974, U.S. Department of Commerce, Bureau of the Census.) Among Spanish Americans graduated in 1973, the percentages follow roughly the same distribution with 15% majoring in business and commerce, 37% in education and social sciences, and only 9% in the natural sciences and mathematics. (From Spanish Speaking Recruitment Sources, Office of Spanish Speaking Programs, U.S. Civil Service Commission. n.d.)

The distribution of women students from all ethnic backgrounds shows a similar distortion. They are vastly under-represented in the natural sciences and mathematics - but also in business - while in education they outnumber the men almost 3 to 1.

For women and minority students, their choice of majors, and the career choices implicit in those decisions, suggests that they may be unable to contribute fully to the solution of the really tough and lasting problems, i.e., where the jobs will be. It also assures that they will remain on the poorer end of the earning spectrum. Society has in the past formally and informally counselled women and minorities into the less influential, less well paid "helping" and "service" occupations regardless of their aptitudes. For this we are all responsible and to a reversal of such habits we all owe some energy.

My advice, then, to girls and to minority youth is to go into the natural sciences, mathematics and engineering if they have the aptitude and inclination. No matter what happens in the economy, chances are that the women and minorities will be relatively better off than those who major in education, business, the social sciences or humanities. The real social challenge of the next few decades is going to be in the scientific and technological sectors and the chances for employment are greater in these fields.

To educational institutions and educators I will offer some further gratuitous advice. To them I would say cultivate the interest of minority and women students in mathematics, natural sciences and engineering, and recruit them to fill your empty laboratories and classrooms. At the same time, reexamine your curriculum and requirements, especially on the graduate level, to prepare your graduates for varied and useful service to society. Do not worry, as some of my colleagues do out-loud, over the morality of advising minorities and women to go into science when you are not really confident that there are jobs waiting for them out there. You will find the minorities and women impatient with such advice, even hostile. They remember, only a few years back, when there were lots of jobs thought to be out there, and recall that their kind were not encouraged to go into science then either! As one of the Chicano advisers to our office retorted one day when faced with this kind of solicitous concern, "Don't you educators worry about jobs for us. We just want equal opportunity for our people to join the ranks of the unemployed Ph.D's!"

SCIENCE AND ENGINEERING ENROLLMENTS

Who's in the Academic Pipeline

by

Betty M. Vetter
Scientific Manpower Commission

At a time when more and more students are entering the nation's institutions of higher education, enrollments in the physical sciences and engineering are falling both as a percentage of all students enrolled, and in actual numbers; while the biosciences are moving in the opposite direction.

As a percentage of all bachelor's degrees granted, the combined total of those in physical science and engineering fell from 20% in 1950 to 14% in 1960 and to 8% in 1970-71. Those in the biological sciences held steady at about 4 to 4.5%. Current projections from the National Center for Educational Statistics indicate a further drop to below 5% by 1981 in physical sciences and engineering, and a rise to 5.3% in the biological sciences by 1983. (fig.1)

At the master's level, engineering is about where it was 20 years ago, although the percentage of science and engineering degrees together has dropped from 14.6% to 9.7% in the past ten years. The drop is expected to continue through 1983. At the doctorate level, the pattern resembles that for bachelor's degrees. The biosciences again held steady at both advanced degree levels - at about 3% of all master's and 11% of all doctorates, and will level off at about this year's proportion.

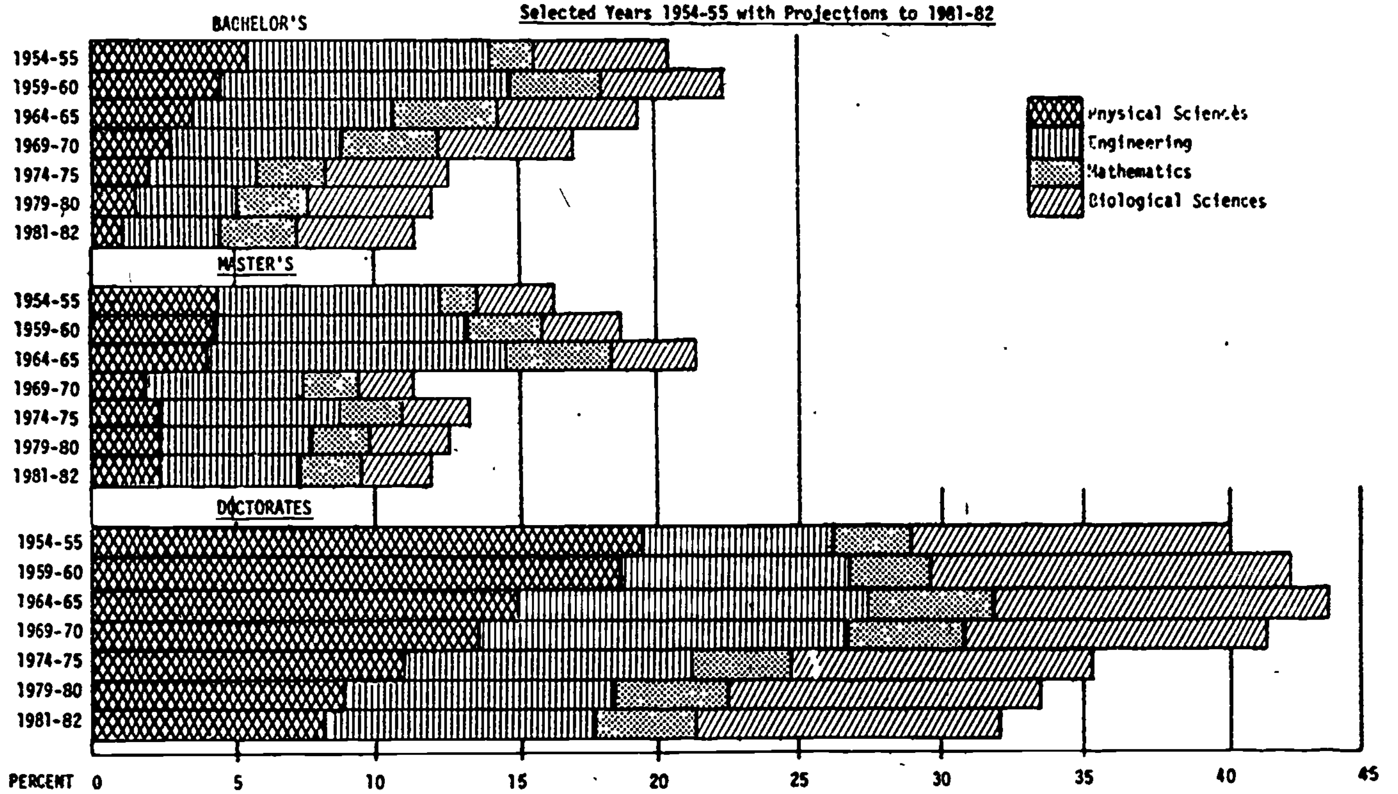
Despite falling percentages in the physical and engineering sciences, because of the increasing size of the college population, the actual <u>numbers</u> of degrees granted in these fields generally held steady or increased through the sixties at all degree levels, while those in the biological sciences rose fairly rapidly. (fig.2)

However, while the college age population still continues to expand, as it will for another 7 or 8 years, both the percentage <u>and</u> the number of actual enrollments have fallen over the past two years in the physical sciences and engineering, while rising rapidly in the biosciences.

In engineering where we can measure intended majors even at the freshman year, the drop from the fall of 1970 to the fall of 1971 was a whopping 18%, followed by a further 11% drop in the fall of 1972. In Fall 1973, the drop was.3%. When freshmen enrollment is plotted against bachelor's degrees four and one half years later, we can see that the supply of new engineering graduates may drop as low as 28,000 by 1976, and the Labor Department projects demand for 53,000 new engineering graduates per year through the mid-1980's. Early returns on enrollment questionnaires for Fall 1974 show an increase of about 15% in freshmen engineering enrollment, but we are still well below the classes of the sixties. (fig.3)

PHYSICAL SCIENCE, ENGINEERING, MATHEMATICS AND BIOLOGICAL SCIENCE DEGREES AS A PERCENTAGE OF ALL DEGREES GRANTED

Selected Years 1954-55 with Projections to 1981-82



Source: Series of Earned Degrees Conferred, U. S. Office of Education; and Projections of Educational Statistics to 1981-82, National Center for Educational Statistics, 1973 (in press)

Fiq. 1

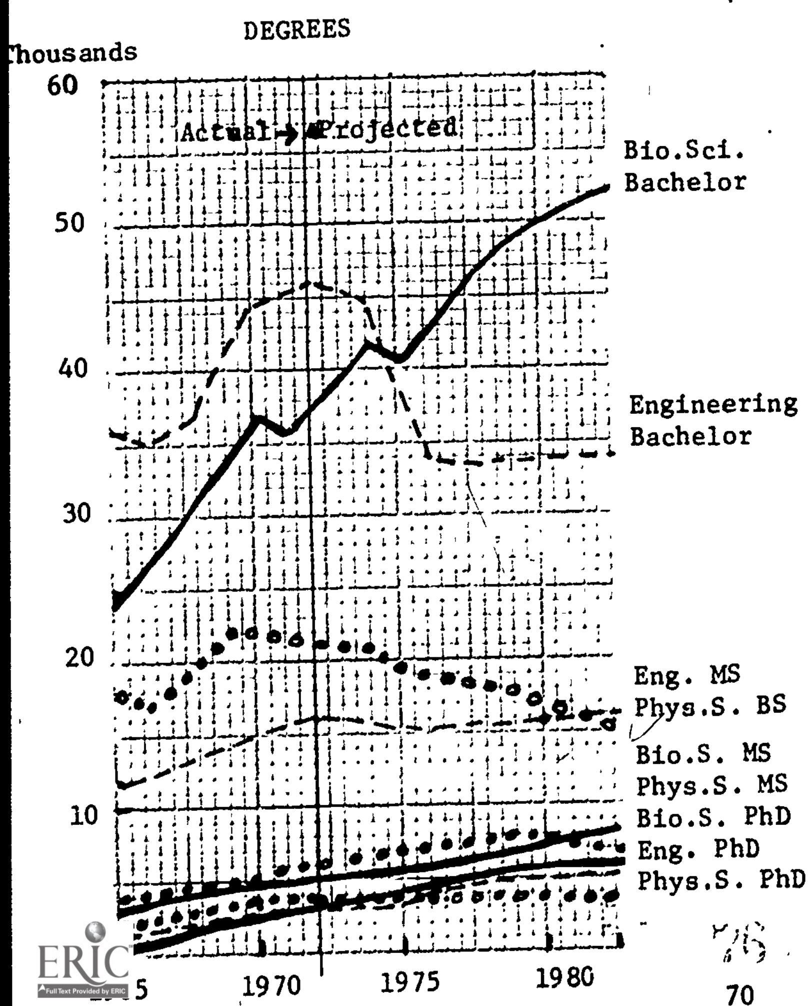
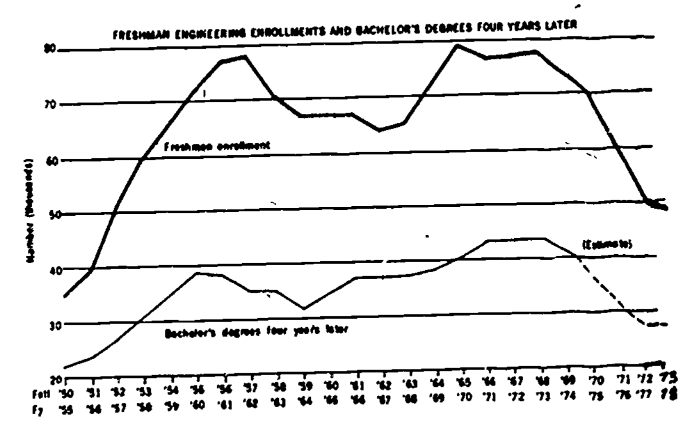


Fig. 2



fiq. 3

← Source: U.S. Office of Education
National Center for Ed. Statistics

In physics, the enrollment drop is similar to that in engineering, and the number of bachelor's degrees granted began to fall in 1969-70. Junior year majors have dropped steadily since 1967-68. The American Institute of Physics reports that only 4,900 new bachelor's degrees in physics were awarded in 1972-73. Master's degrees fell 8.5% to 1,961 - the first time in a decade that fewer than 2,000 degrees were awarded. The number of doctorates held steady at 1,445, but first year graduate enrollment in fall 1973 fell to 2,680, 38.5% below 1965. (fig.4)

In chemistry, the number of bachelor's degrees began to drop in 1970 and doctorates in 1971. The American Chemical Society expects the number of new Ph.D's to rop below 1500 by 1976. (fig.5)

Enrollment of geoscience majors increased 9% at the bachelor's level in 1973, but dropped .8% for master's and 1.5% for Ph.D. candidates. Women students accounted for most of the increase. (fig.6)

In geology, largest of the geoscience fields, enrollments have fluctuated widely over the past two decades. While undergraduate majors increased in the early seventies, graduate enrollments dropped last year. (fig.7)

In the biological sciences, the number of bachelor's degrees increased from about 16,000 in 1961 to 50,800 this year, and are projected to hold at between 50,000 and 53,000 per year through 1983. (fig.8)

Master's degrees climbed from 2,600 in 1961 to 6,800 this year, and will rise to 8,400 in 1983. At the doctoral level, about 1,300 in 1961 increased to 3,900 in 1973 and will hit 5,350 in 1984.

The related health professions, (which do not include the professional degrees of M.D., D.D.S., etc) also are climbing rapidly. Bachelor's degrees rose from 13,000 in 1962 to 35,000 in 1973 and will top 45,000 by 1980. At the master's level, the number rose from 1,600 in 1962 to 10,000 in 1973 and will hit 14,000 in 1982.

Doctorates rose from 148 in 1962 to 1,000 in 1973, with an increase to 2,300 projected for 1983. (fig.9)

The number of M.D. degrees also is increasing faster after many years of very slow rise. The entering first year class took forty years between 1930 and 1970 to almost double from 6,400 to more than 11,000, but is now increasing at a more rapid rate. In 1960, we produced fewer than 7,000 MD's, but we will graduate almost 12,000 this year and the forecast is for almost 16,000 by 1980. Many of our undergraduate biology majors are, of course, hoping to enter medical schools. But given the number of medical school places and the number of expected applicants, less than half of those qualified will be accepted. (fig.10)

Incidentally, the solid segment of the bar graphs showing first year classes represents the proportion of women in each class - up from 4.5% in 1930 to almost 17% last fall. I believe that this, too, is a continuing trend.

Lets drop back for a quick look at undergraduate enrollments by field.

The Higher Education Panel of the American Council on Education began in 1970 a survey of enrollment by field of junior year students in order to obtain informa-

PHYSICS ENROLLMENTS AND DEGREES

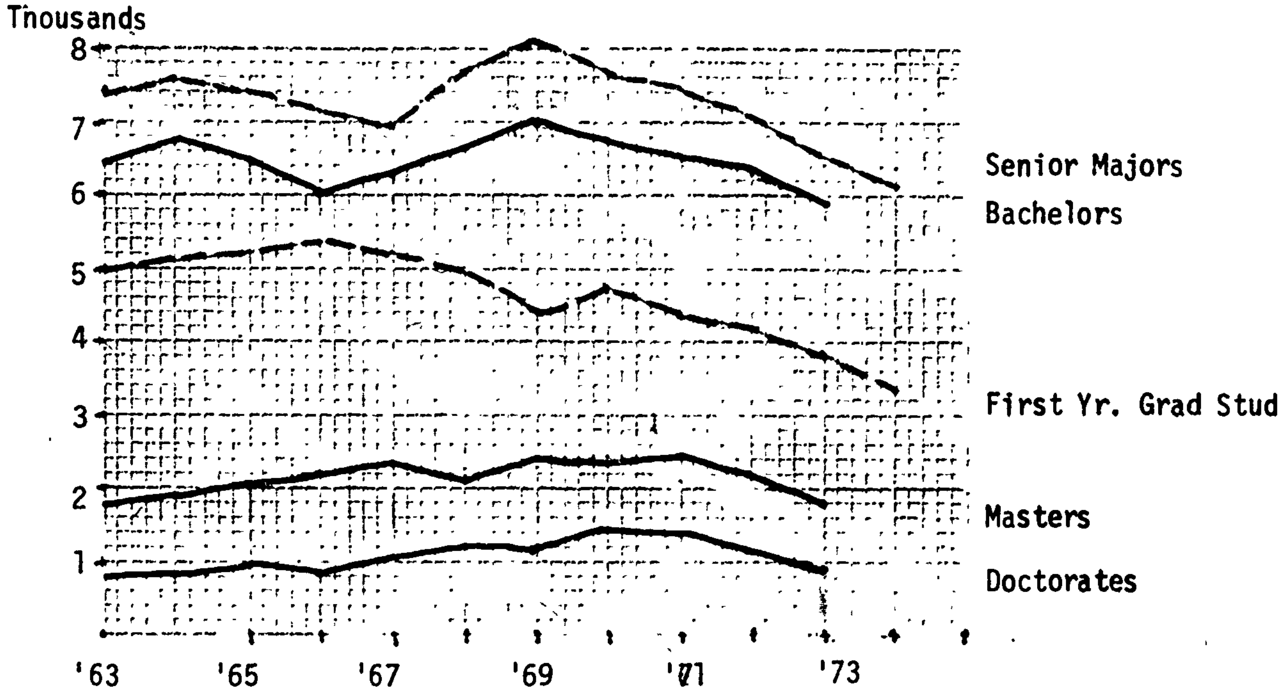
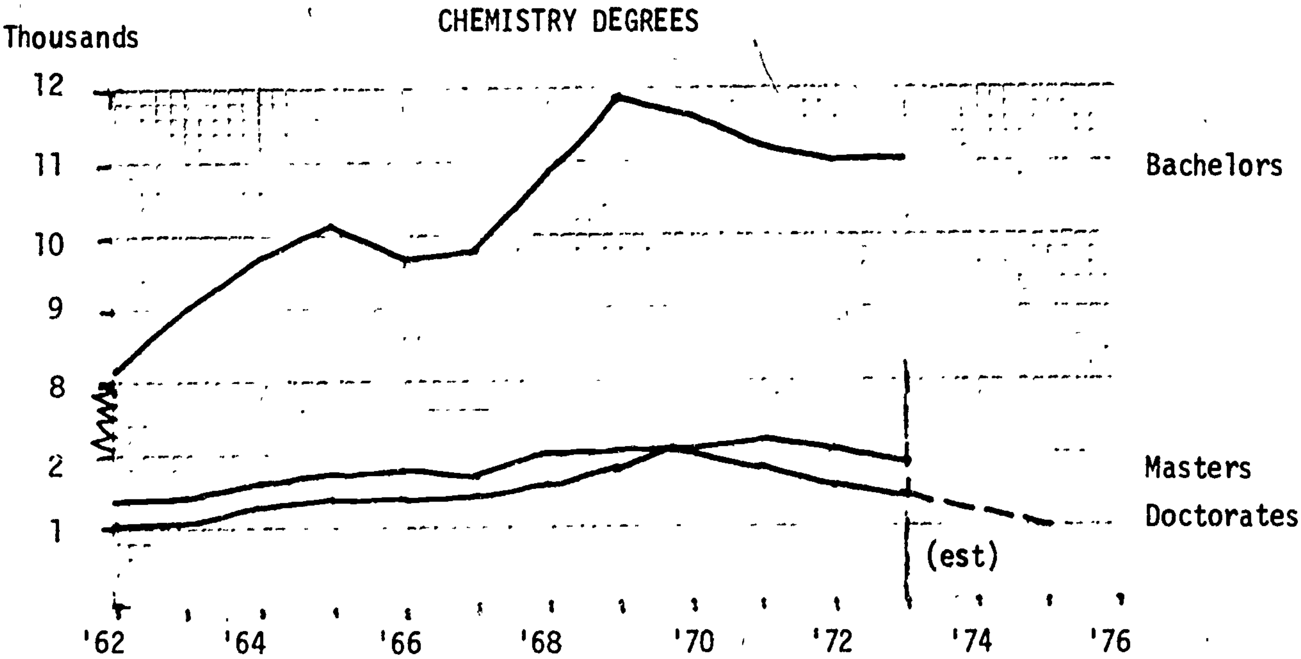


fig. 4

Source: American Institute of Physics

CHEMISTRY DEGREES



Sources: U.S. Office of Education
American Chemical Society

fig. 5

STUDENT ENROLLMENT IN GEOSCIENCES

	'72 - '73	% of TOTAL	'73 - '74	% of TOTAL	CHANGE in 1974
U'GRADS					
WOMEN	2,994	15.3	4,002	18.8	+33.7
MEN	16,547	84.7	17,327	81.2	+ 4.7
TOTAL	19,541	100.0	21,329	100.0	+ 9.0
MASTERS					
WOMEN	646	13.4	670	14.0	+ 3.7
MEN	4,186	86.6	4,119	86.0	- 1.6
TOTAL	4,832	100.0	4,789	100.0	- 0.8
DOCTORS					
WOMEN	242	7.9	292	9.7	+20.7
MEN	2,803	92.1	2,707	90.3	- 3.3
TOTAL	3,045	100.0	2,997	100.0	- 1.5

fig. 6

GEOLOGY ENROLLMENTS AND DEGREES 1956-1974

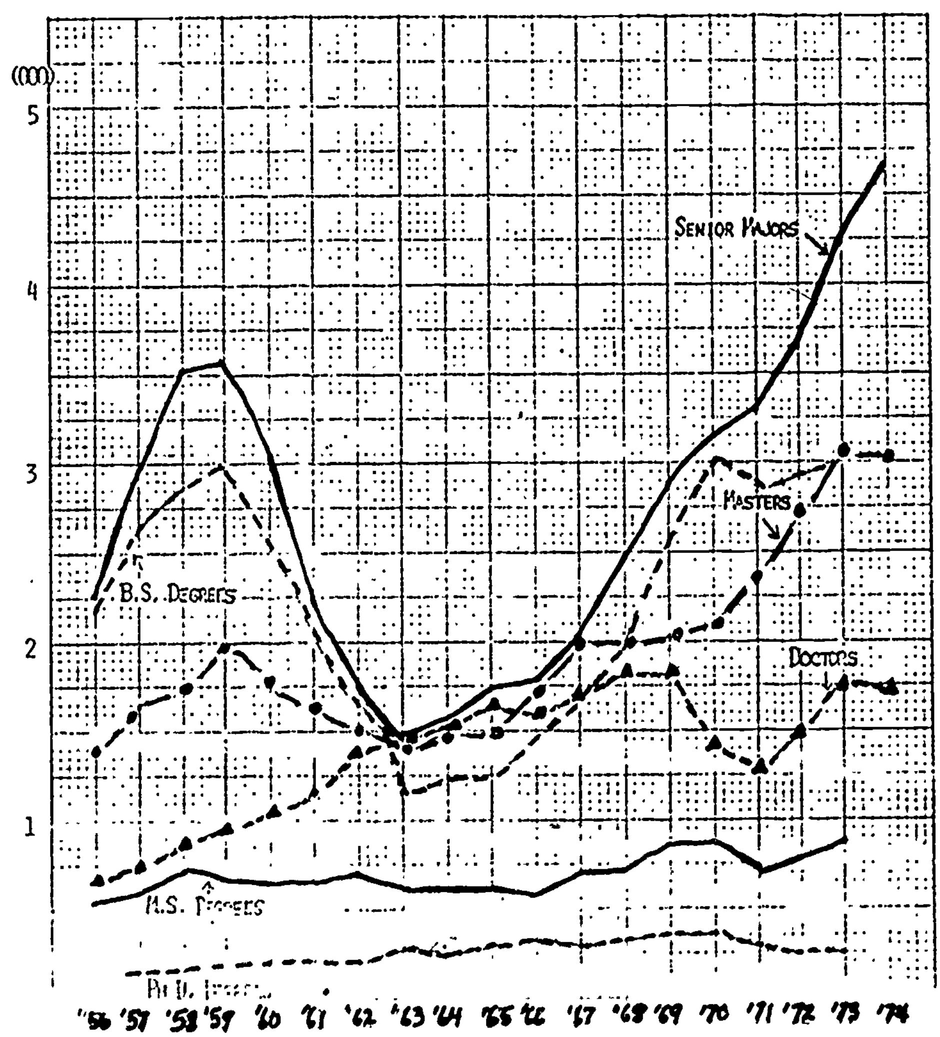


fig. 7

Source: American Geological Institute
U.S. Office of Education

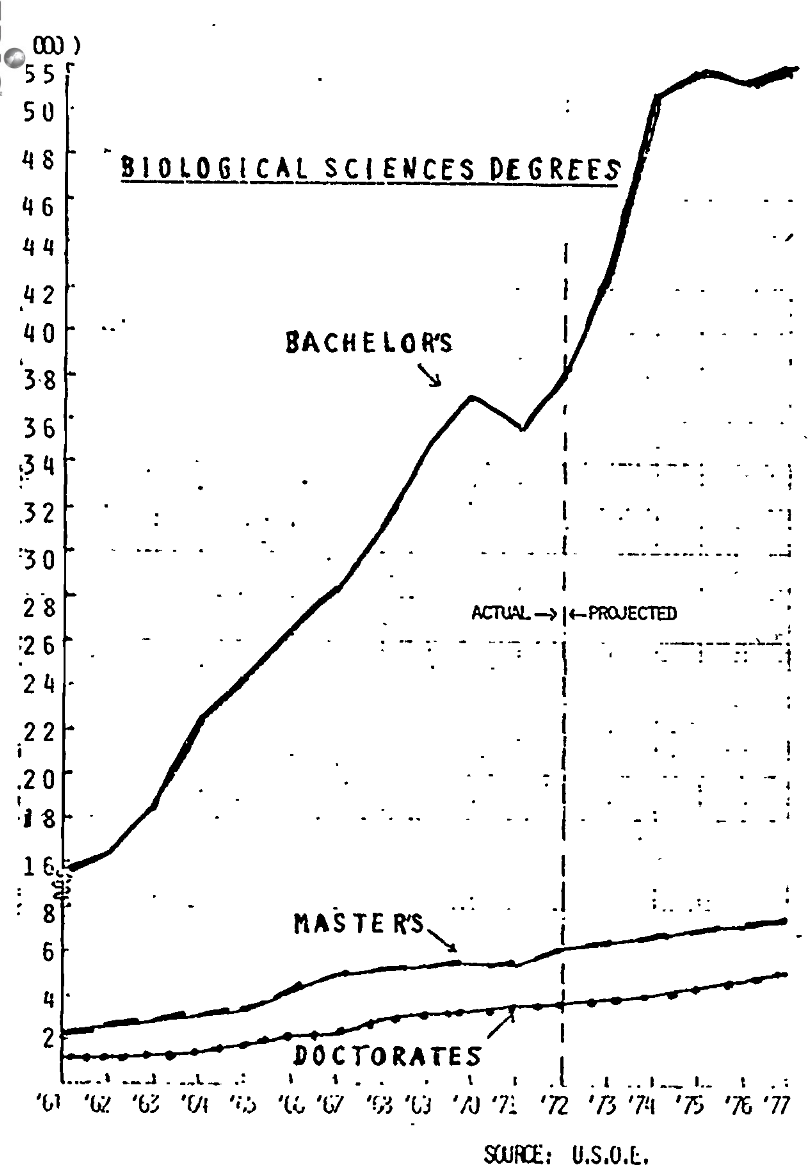


fig. 8

Source: U. S. Office of Education

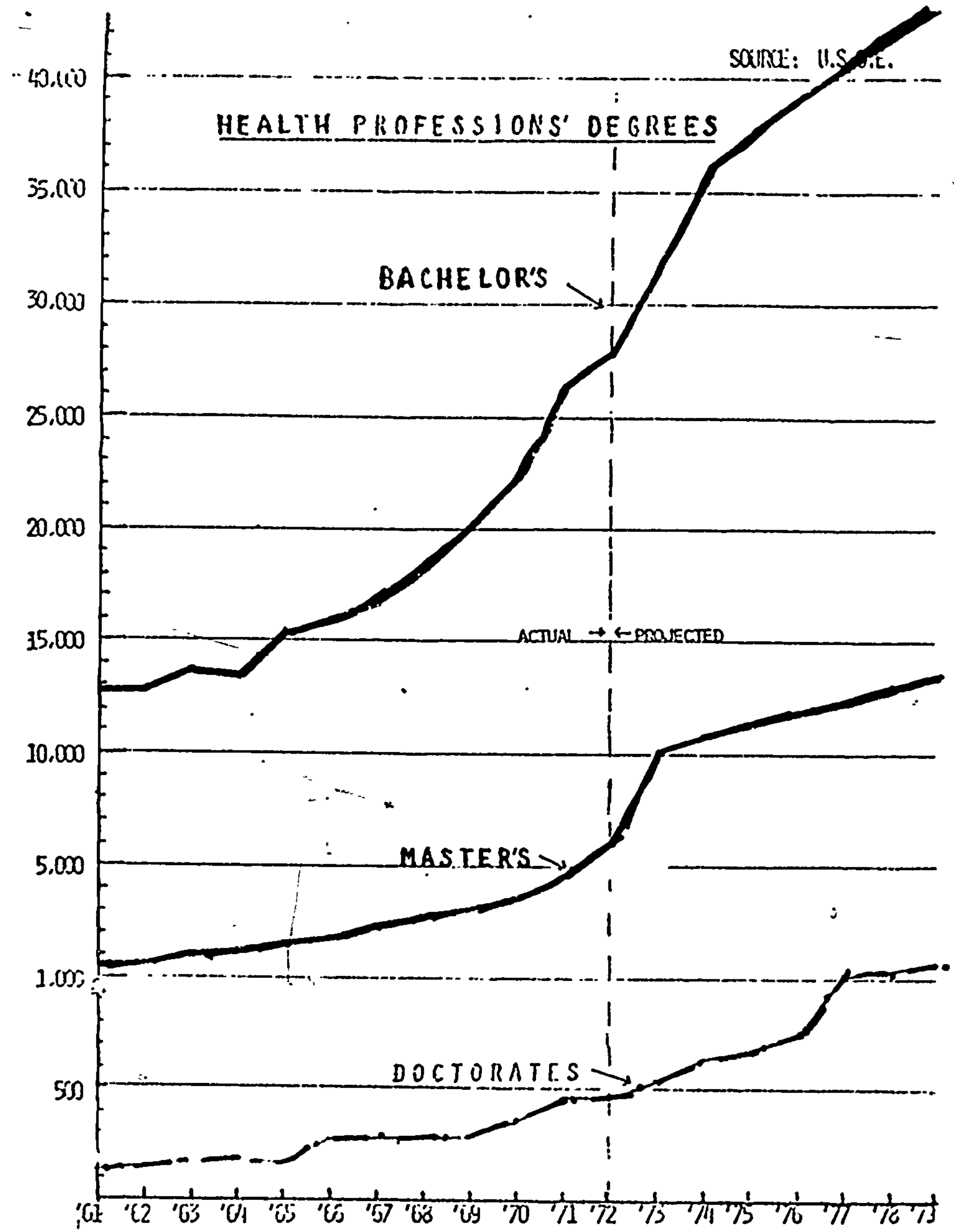
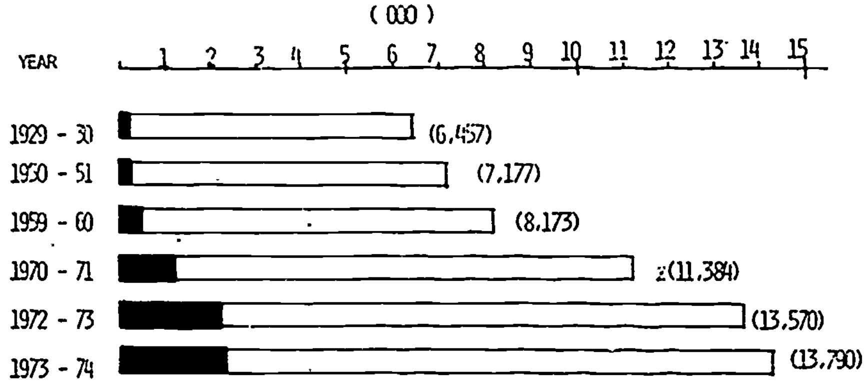
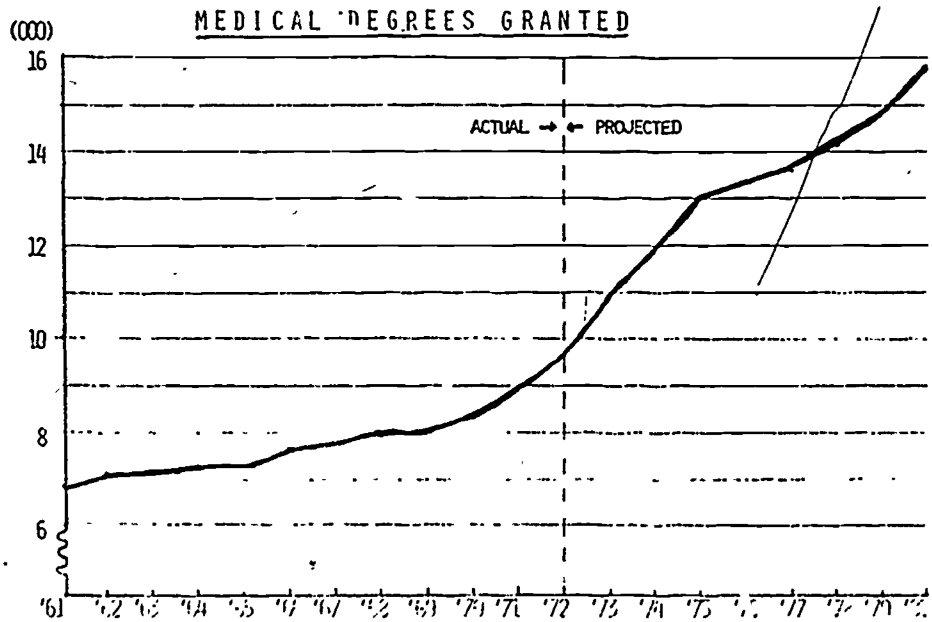


fig. 9

Source: **U.S.** Office of Education

FIRST YEAR ENTERING CLASS - MEDICAL SCHOOL





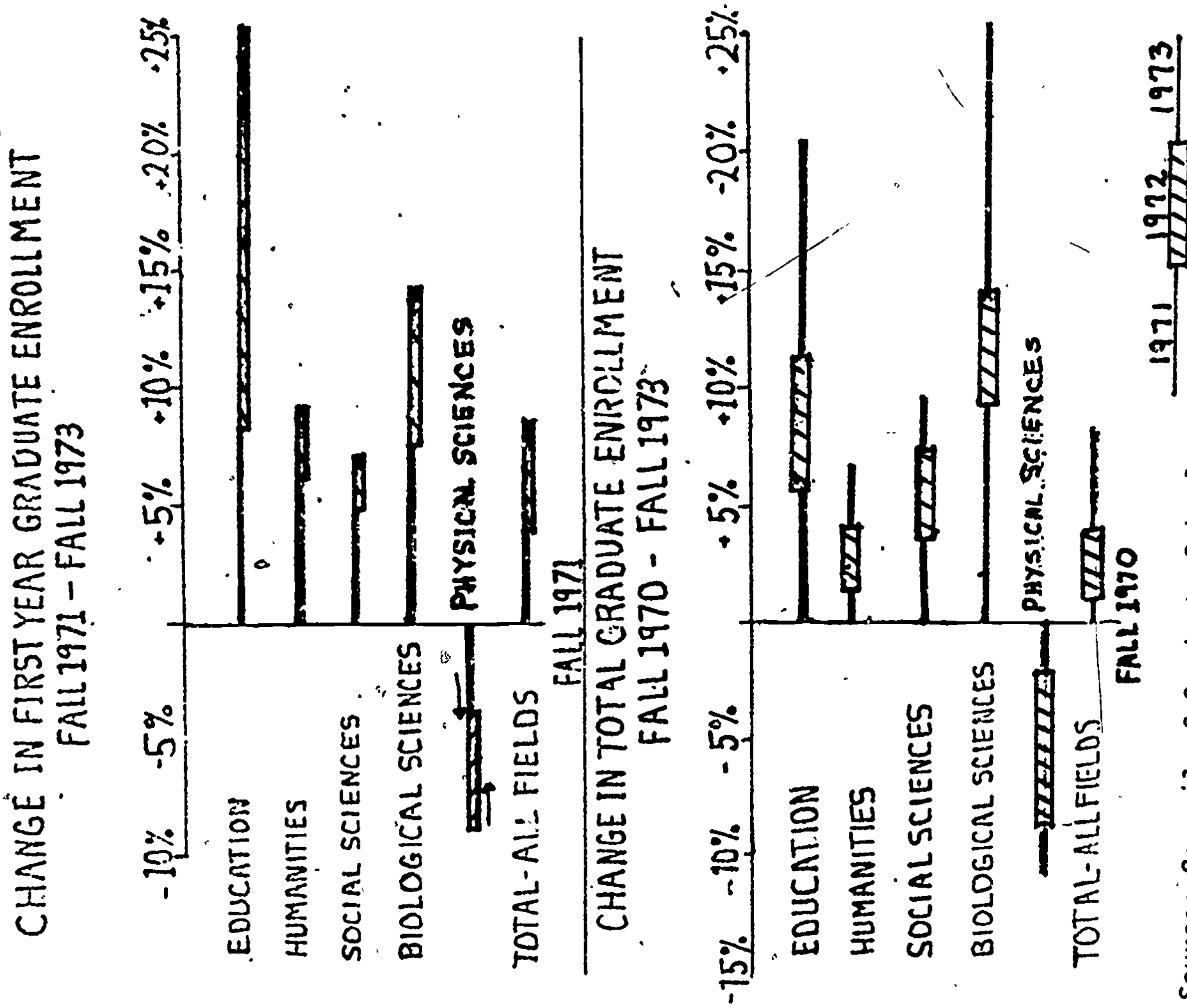
SOURCES: U.S.O.E.
A.A.M.C.
KOEHLER AND WILLIAMS

fig. 10

tion about trends in choice of major field in advance of the usual data on baccalaureates granted. Between the fall of 1970 and the fall of 1971, (solid lines), total field enrollment (shown at the bottom) rose 7.6% with the largest increases in the health professions, the life sciences and applied social sciences. The fields that showed a drop in enrollment between these two years were engineering, mathematical sciences, chemistry, and physics. From the fall of 1971 to the fall of 1972, (wide lines), total junior year enrollment rose 3% while physics dropped again along with mathematics and engineering. In chemistry, a 2.9% increase cancelled the drop of the previous year. The biological and life sciences rose another 12% and 30% respectively. (fig.11)

Since a high proportion of bachelor's degree holders in the sciences do not enter the profession in those disciplines, trends in graduate degrees may be a better measure of the new supply a few years in the future than bachelor's degrees. A survey by the Council of Graduate Schools found a drop of 8.6% in first time graduate enrollment in the physical sciences from the Fall of 1971 to Fall 1972, followed by a rise of 5.5% this past fall. However, total graduate enrollment in these fields continued its three year drop for a total of 12% below 1970. All other fields of study show increases, with biological sciences again leading the rise. Graduate bioscience enrollment climbed 25% in three years, compared to only an 8% increase in total graduate enrollment. (fig.12)

In summary, enrollments in the physical sciences and engineering have been dropping at both undergraduate and graduate levels, except for increasing numbers of women entering these disciplines. First year engineering enrollment is up this year, and first year graduate enrollment in the physical sciences increased last year, although total graduate enrollment in the physical sciences dropped for the third year in a row. The biosciences and the health professions are attracting increasing proportions of students at both undergraduate and graduate levels. Some supply/demand imbalances are expected because of these changing enrollment patterns.



Source: Council of Graduate Schools

fig. 12

PERCENT CHANGE IN JUNIOR YEAR ENROLLMENT, BY FIELD, FALL 1970 TO FALL 1972

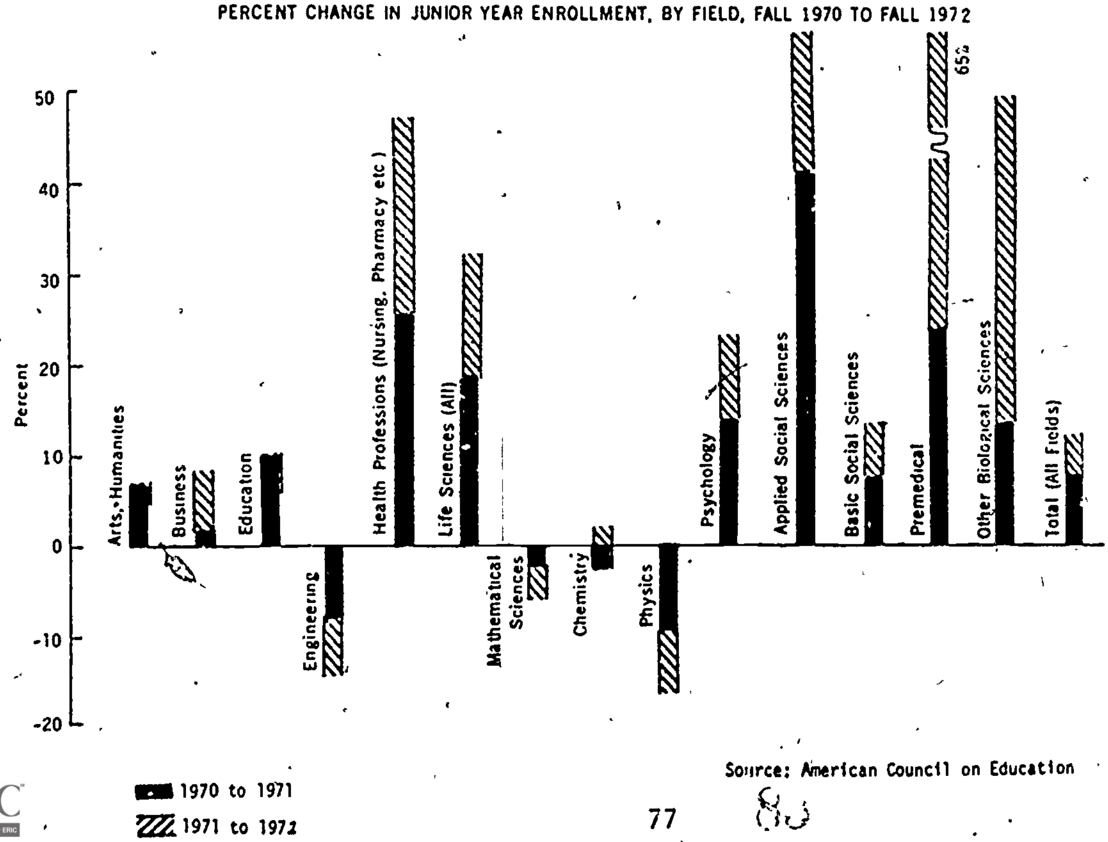


fig. 11

Source: American Council on Education

THE IMPLICATIONS OF CHANGING ENROLLMENTS, AND OF SUPPLY AND DEMAND FOR DOCTORATES, FOR UNIVERSITIES

by

Charles V. Kidd
Association of American Universities

I. Introduction

In approaching the question, "Implications for Action by Universities," it is useful to ask, "The implications of what for universities?" My choice is to discuss not only the implications of changes in enrollment but also the implications of the long range supply and demand situation for scientists and engineers, and my preference is to deal with implications for universities whether they involve action or not.

My theme is the proposition that the long range supply and demand outlook for scientists and engineers does have important implications for universities, that their response will not be clear and decisive because they are subject to a number of conflicting forces, and that there will be a strongly resented trend towards decisions made closer to the center of universities. What follows is a sketch of some aspects of this complicated question and not a fully rounded treatment of the subject.

II. The Complexity of Adjustment

Even though the point is obvious, it is worth noting that universities are complex institutions, and that as a group they form a complex system.

The complexity of a university can be immediately grasped by asking what action by a university means. In a sense only actions by university wide groups -- the regents or trustees, the academic senate, or the president -- are literally actions by the university as an entity. But these actions -- important as they may be -- are at least one order removed from the substantive work of the university -- the teaching, research and service that are in total what is actually done within if not by the university.

In contrast with most institutions, such as industrial concerns or governmental organizations, universities derive their direction and strength not from central leadership and control, but from the independent ideas and actions of individuals and small groups. This is not entirely true, of course, but it is true enough to generate constant, strong tension between the individual faculty members -- or clans of faculty members in departments -- and all of the numerous volunteers who would have the faculty do their bidding. One consequence of this tension will be to generate different responses within each university, depending upon personalities, philosophies, funding and a number of other things. Accordingly, it will generally be difficult to identify any consistent, clear cut responses of individual universities to changes in the prospective supply and demand situation.

The fact that universities comprise a complex system also has implications for the response to the long range outlook for supply and demand of scientists and engineers. Universities perform different functions in different ways and their individual responses are properly quite different. This is in contrast with the implicit assumption, which is sometimes made in discussions of what universities should or should not do (or what they will or will not do), that because a given change in the system seems desirable, every part of the system should react in the same way. For example, it may be in the best interests of students, professors, the university and the nation if many departments in our university system continue to train scientists without modifying the curricula in the slightest degree to take into account energy problems, ecological problems, the population problem or any of the well known list of urgent public issues to which graduate education is exhorted to be relevant. Accordingly, it will be difficult to perceive a clear, consistent response of the entire university system to changes in the manpower situation, just as in the case of individual universities.

The rather amorphous and random responses of universities to external forces will probably characterize their actions in response both to the overall manpower demand and supply situation in science and engineering (and, in fact, in all fields), and their response to pressure to apply academic resources to the diagnosis and solution of important problems of society.

While the individualistic, unplanned, decentralized character of each university and of the system as a whole arises from internal needs and forces, these very characteristics are those that are called for when our prophetic capacities are in the early stages of development. A system designed logically in the sense that it would respond in a planned manner to predicted changes would probably produce more large scale catastrophies than far seeing adjustments.

The essential characteristics of universities are in many respects a protection, and those who call for a crisp and clear academic response to the problems of either the present or the future are suggesting a dangerous course of action.

Fortunately, the real problem lies in the other direction. That is, in the face of these elements of the future that do seem predictable -- such as a low demand for faculty members in relation to the future supply -- how is an appropriate response to be generated in the face of strong academic inertia? Or, as another example, how is a reasonable response to the needs of society for help from universities to be generated?

III. The Response to the Manpower Outlook

While the subject is debatable, it seems to me that the response of universities -- or more precisely departments of science and engineering -- to the prospective manpower situation has been appropriate. Particularly in these fields, close attention has been given to prospective enrollment, to the prospective demand and supply situation, and to the kinds of responses that are called for. The primary difficulties in these fields arise not from the inadequacy of academic response, but in the force, suddeness and unpredictability of the externally generated shocks imposed upon the system.

IV. Universities and Problems of Society

Universities must respond to forces affecting not only the supply of and demand for Ph.D.s, but also the nature of the training that will be called for. One of the most obvious external forces that may affect the content of graduate education is the demand that the education be relevant to current issues. In this connection, the obligations of universities to help with the diagnosis and solution of problems important to society are widely recognized and widely accepted. Whether the obligations are adequately fulfilled is a matter of sharp debate. There are those who argue strongly that universities are too stodgy and unresponsive.[1/] Others maintain that they will willingly wander wherever a dangling dollar leads them, to the detriment of their integrity.[2/] The fact that the voices on both sides are equally loud may indicate that the level of involvement is just about right.

In any event, the pressures on universities to participate will continue and will probably increase.

1/ Newman Report.

2/ Barzun, J., The American University; How It Runs; Where It Is Going, Harper and Row, 1968.

One mode of participation is to educate, or train, scientists and engineers who can contribute most effectively to the solution of urgent problems of society. This rather vacuous truism can be made more interesting by asking what kind of education and training ought to be offered. A substantial proportion of scientists and engineers should certainly be broadly educated in the fundamentals of their profession, without any narrow specialization designed to make them particularly capable of working in specified fields. There are several reasons for this. One is that many employers prefer to provide specialized training themselves, and they find that rigorously and broadly educated students work out best. Another reason is the fact, which keeps recurring in this paper, that no one knows what the specific jobs of the future will be, but it is known that they will be markedly different from those of today. The person best equipped to shift his field of work is one who has a broad, rigorous education in the fundamentals of his profession.

For these reasons, much of the protest that curricula and research structured along disciplinary lines produces persons unable to work effectively on important problems is misguided. The proper protest is against shoddiness, sterility and lack of quality in general, and not against a disciplinary approach.

In many fields, what seems to be called for is not a radical change in the curriculum, but a deliberate effort on the part of the faculty to change the values and aspirations of students. The higher the proportion of students who have traditionally entered upon academic careers, the greater the need for this change. Fortunately, the problem is not as acute in engineering and in many fields of science as it is in the arts and humanities.

In responding to external needs, the most productive university response is often not a radical redirection of departmental programs, but the establishment of new structures in the form of institutes, laboratories, or whatever they may be called. Part of the obligation to train students to solve problems in a specific area can be met by ensuring that a teaching function is built into the specialized organizations.

V. Equality of Academic Opportunity

Universities control access to careers of status, influence and affluence. They therefore have not only a legal but a moral obligation to admit students without discrimination based on sex, race, ethnic origin, religion or any other factor unrelated to capacity to perform. This is not the place to explore the difficult ethical and legal issues that arise in undertaking to operate a system that is non-discriminatory. Instead, issues will be examined from the narrower perspective of the influence of enrollment trends and the changing job market on equality of opportunity.

During the remainder of the 70's the outlook is for about 15,000 new junior faculty jobs in higher education per year. However, more than 30,000 Ph.D.s per year will be produced. This is a gross overall picture, and the situation will differ markedly by field.

In the physical sciences and mathematics not many additional black Ph.D.s will be hired simply because few are being produced -- 36 in 1973, for example.1/ (Table I) Only 18 Ph.D.s in engineering were awarded to blacks in 1973, and only 46 in all of the medical sciences. In contrast, 338 doctorates in education were awarded to blacks.2/

1/ Throughout this section references are to the numbers of doctorates awarded to citizens because it is assumed that the obligation to provide equal employment opportunity does not extend either morally or legally to non-citizens. An unknown number of the 3,484 non-citizens who receive doctorates in 1972-73 will later become citizens. The non-citizen recipients were distributed by racial and ethnic group as follows.

Total	1,691
Black	144
Chicano	79
Oriental	1,468

2/ Preliminary data from the NRC Doctorate Record File.

Table I. Ph.D.'s and Ed.D.'s Awarded to Black Citizens and to Female Citizens, by Field, 1972-73

Field	All Black Citizens	Female Black Citizens	All Females
Total	566	151	4,209
Physical Sciences 1/ and Mathematics	36	1	237
Engineering	18	0	17
Medical Sciences 2/	46	11	553
Agricultural Sciences	5	1	22
Psychology	33	2	502
Social Sciences 3/	38	10	366
Arts and Humanities 4/	35	14	1,105
Professional Fields 5/	17	6	136
Education	338	105	1,271

1/ Physics and astronomy, chemistry and earth sciences

2/ Basic medical sciences, other biosciences and medical sciences

3/ Economics, anthropology, sociology, political science, public administration, international relations and other

4/ History, English, American language and literature, other arts and humanities

5/ Eight fields including theology, business administration, social work, home economics and journalism

Source: National Research Council. Doctorate Record File.

The number of women who received doctorates in 1972-73 was 4,209. They were distributed by ethnic group as follows:

Total	4,209
Black	151
Chicano	30
Puerto Rican	7
American Indian	24
Oriental	48
White	3,949

All but about 5 percent of the women receiving doctorates were white.

As contrasted with ethnic and racial minority groups, there are substantial numbers of women doctorates in all fields except engineering and agricultural sciences. Whatever the problems of increasing access to doctorate may be for women, they are not as great as those faced by members of ethnic and racial minority groups.

The situation will shift during the 80's. The prospect is for only 3,000 to 5,000 new academic jobs in higher education, and the number of Ph.D.'s awarded per year will probably exceed 35,000.[1/] The annual number of women and members of minority groups who receive doctorates will probably increase substantially. Competition for academic jobs threatens to be fierce, and the current debate over such questions as the obligation to correct past injustice, reverse discrimination, the extent to which merit should govern hiring decisions will almost certainly be intensified.

During the 70's, increasing attention must be paid to expansion of the supply of women and members of minority groups with doctoral degrees, and this will require action by universities.

For white female citizens the problems associated with employment -- getting a job, equitable pay and promotion, etc. -- appear to be greater than the problems of access to graduate education, and the job situation is likely to accentuate this trend. This is the reverse

1/ The Chronicle of Higher Education, December 9, 1974, p. 3. Allan M. Cartter. Address at meeting of Council of Graduate Schools.

of the problem faced by ethnic and racial minorities. For them, the problem of access is now greater than the problem associated with employment. However, they will also be affected by the decline in the annual number of new academic job openings.

V. Advice to Prospective Students

One clear implication of prospective changes in the job market is that students should be informed of the job prospects in various fields so that their choices will be better informed, as other speakers in this symposium have emphasized. But this is easier said than done. Who is wise enough, bold enough or foolish enough to tell students that they should or should not study engineering or science because of the projected job situation 5, 10 or 20 years in the future? I do not know what students are told, but I suspect -- and I hope -- that they are told that life is a process of making decisions in the absence of adequate data, and that if they are intelligent, healthy in body and spirit, and strongly motivated to study engineering, or one of the sciences they should do so regardless of the prospective career outlook.

VI. Implications for Faculty and University Management

In spite of the skepticism with which manpower forecasts are properly viewed, I accept the general assumption that the academic job outlook is poor -- primarily because of the prospective levelling off of undergraduate enrollment. Decreasing demand for new faculty members will have numerous and serious implications not only for students and curricula but also for the existing faculty, for the vitality of teaching and for the management of universities. Some of the effects that can be anticipated are:[1]

1. The average age of faculties will increase. While the average level of wisdom may increase, the average level of enthusiasm, creativity and innovation may fall.

1/ Kemeny, J.G., The University in Steady State, in Daedalus, American Education: Towards an Uncertain Future, Vol. II., Winter 1975, p. 87.

2. The proportion of faculty with tenure will increase, thereby decreasing the capacity of universities to adapt to new conditions.

3. There may well be increasing tension between the older tenured group and the younger faculty group, very few of whom can expect tenure.

4. The tenure system itself will come under increasing attack. Experimental modifications can be anticipated, and controversy over the terms of such plans is to be expected.

5. Hiring practices will probably shift as universities try to avoid having almost all of the faculty on tenure. There will probably be less direct recruitment into tenure ranks, pressure to continue the use of graduate teaching assistants, more visiting professors and more short-term non-renewable appointments.

6. New early retirement plans will be devised, and they will probably stress phased retirement.

In total these management problems are a serious challenge to the wisdom and effectiveness of university administrators -- defining administrators as all of those responsible for making decisions affecting significant groups of faculty members. For this purpose, department heads, institute heads and deans as well as presidents and their staffs and trustees are administrators. The tasks for most of them will be complicated by the fact that the adjustments must be made during a period of declining income and rising costs.

VII. Conclusions

In summary, the outlook is for a greater degree of management of universities as a consequence of a number of forces -- among them stable enrollments, downward pressure on income, rising cost pressures, and level federal funding. By management, I mean conscious consideration of alternative choices in part based upon better data systems, and a centripetal shift of authority to make decisions not only on the budget and expenditures, but on matters traditionally considered as academic and reserved to departments. The dangers as well as the advantages generated by this prospect need not be elaborated.

IMPLICATIONS FOR ACTION BY PROFESSIONAL SOCIETIES

by

Paul H. Robbins
National Society of Professional Engineers

In considering implications for action by professional societies in the whole professional manpower field, I would like to suggest that there are several areas that need rather extensive, and probably expensive, exploration. Unfortunately, the scope of the problem exceeds the capability of any one or perhaps grouping of professional societies. It may well be that to get effective solution to whatever problems we may see at this meeting evolving from the supply and demand of technical manpower requires studies and accumulation of information of such a scope that can be accomplished through funding of a magnitude possible only from the Federal Government.

Be that as it may--there are elements of the discussion to which societies can address themselves. I would like to suggest that there are three areas in which societies, at least in the engineering profession, have traditionally been involved. They are the question of definition--who are we talking about? Secondly, the gathering of statistics, albeit most inadequate and subject to estimates and assumptions which may or may not be valid. And, three, guidance for young people interested in careers in the technical field.

In the first of these--the matter of definitions--we find the greatest contributing factor to questions about any accumulation of information or projections therefrom. In many technical fields, particularly the engineering field, the demand side is not limited to numbers which even by the broadest definition would be identified as engineering. An appreciable portion of engineering-trained people can be found in many other career identities. Likewise, in divisions of the scientific fields, we will find people trained under one definition, with careers under another definition, and a sizable interchange between definitions applied to education and correlated definitions applied to careers. Whether it be a matter of definition or a matter of changing patterns, there has occurred, again at least in engineering, a rather extensive change in the educational processes. Thus, projections based on previous statistics, even though definitions may be the same, will not hold true for future projections.

I would like to suggest as my part of the panel some of the reservations and elements of consideration which I feel on this subject of supply and demand. I would like to present these not in the sense of a protagonist, and not in the sense of some of the emotionalism that these discussions seem to generate. I must at the outset make it clear that my observations pertain primarily to engineering, since this is the field with which I am most familiar, but some of the observations may also be pertinent to other elements of the scientific and technical brainpower pool. Right at the start I suppose someone will have in mind a question as to whether or not I believe a shortage of engineers will exist. I have to answer by saying "I don't know". I am not at all sure that I draw the same conclusions, and I certainly have questions as to projections, based on some of the information which has been given here today. For example, I get concerned when we try to equate supply and demand and project that by such and such a year the demand will be in excess of the supply by such and such numbers.

I am not at all impressed with charts of projections from the past. Conversations with those who are in industry bring forth very clearly that the job that is expected of the graduates of today is entirely different than the job that was expected 10 or 15 years ago. Correspondingly, the education, at least in engineering, is entirely different now than it was as recently as 12 or 15 years ago. The great bulk of statistics which we accumulate are statistics based on production of formally-trained people, and in many of the charts this is limited exclusively to the traditional four-year B.S. degrees. We do not take into consideration, for example, in engineering the fact that we are graduating and probably will continue to increase the number of graduates of two- and four-year technicians. It is usual that demand studies request of employers the number of people to do jobs which "usually require a four-year education". Yet, statistics which come therefrom, and again particularly in engineering, will show as high as 40 to 50 percent of these jobs filled by individuals without this formal education. For us to jump immediately to say that these jobs in the future must be filled by four-year graduates is a questionable conclusion in my mind. Until we get a better correlation of what people are doing in the technical spectrum, and whether or not it is essential that these jobs be filled by people with a B.S. level education, I think we will continue to have questions of the projection of supply and demand.

Correlated with this concern is another aspect on which we have no quantitative figures, and yet we tend to ignore, I am afraid, in our projections. This is the degree to which there exists under-utilization of scientific and engineering brainpower. Unfortunately, a great many of our projections are

based on the fact that we produced a certain number of people with certain kinds of training in the 50's and 60's and project trendlines into the 80's and 90's without a solid evaluation of whether or not either the requirements of our society call for this kind of linear projection, or whether our educational mix has changed so much in the interim that the projections will be filled by other kinds of education rather than the parallels of the past.

Now, I come to the third action program of many societies. And that is the area of assisting young people in the choice of their career. I have great reservation relative to the image we are creating of scientific and engineering personnel when we continue to predict dire shortages in years ahead. I know, for example, in engineering that we have been predicting a shortage of engineers ever since World War II. It seems to me that there is no question we are going to have a high demand for technical brainpower in the future, but I would like to suggest that at least for talking with young people that we emphasize the real satisfactions of an engineering or scientific career rather than so much emphasis on the supply and demand numbers as we may accumulate or project them. For those who have aptitudes in math and science, there are many rewarding paths in which these proficiencies can be used.

My plea, then, is that in guidance for young people we get off the numbers kick. We seem to be the major professional group who continues to be so exercised about numbers entering our various professional units. I would like to suggest that our publicity stress the things engineers and scientists do, the real challenge of applying science and mathematics to the solution of societal problems, an explanation of the relationship of applied science and technology to the things in which young people are interested, and showing them that careers in these fields can be as rewarding as any other--rather than, in effect, trying to seduce them via the numbers and scare tactics that have been our practice for so many years in the past.

IMPLICATIONS FOR INDUSTRIAL ACTION

by

Robert L. Stern
Xerox Corporation

In seeking implications for action by industry, one must state at the outset that "industry" per se is not an institutional group that can act in a highly focused manner on issues related to scientific and engineering education or manpower. Industry, after all, is composed of thousands of corporations, ranging from the largest multinational employers whose rolls stand at 800,000 to the smallest establishments which still include a few scientific or engineering graduates. With regard to action, the universities, the professional societies and even the government have more cohesive forces working within their institutional grouping than industry does. On the simplest level, the competitive forces in industry limit concerted actions. Then on a more subtle level, the largest firms--say the 50 largest manufacturing firms in the world--are growing more through diversification rather than concentration, i.e. chemical companies are going into the fertilizer and synthetic textile business, electronics firms are expanding into geophysical exploration, petroleum firms are adding packaging and even real estate divisions.

The broadening of the business base of these companies also means that their needs for scientists and engineers now spans a large portion of the spectrum of intellectual specialization. In earlier days, there were companies that employed chemists almost exclusively while others had only physicists or electronic engineers or metallurgists. But now the corporate voices would need to speak about the combined prospects of all those disciplines. The interaction of industry with universities is therefore on a broadening front rather than an intensification of interest in certain disciplines. This phenomenon may even account for the growing practice in American companies to direct their philanthropy to education on an unrestricted basis--without special emphasis on disciplines that are thought to be related to its business interests.

Next, it is important to appreciate that most of our scientists and engineers do not work in R & D. National Science Foundation data shows that in 1973 only one-third of all employed scientists and engineers worked in R & D--the occupational site that presumably makes the fullest use of their professional training. And yet, the mental image that pops up in our minds when we discuss scientists and engineers is R & D. What about the other two-thirds? Unfortunately, the records and data about the majority is much sketchier than about the minority. John Alden already alerted us to this this morning when he revealed the discrepancies between those 1,250,000 people who were classified as engineers in the 1970 census and the fewer than 700,000 who seemed to qualify on grounds of education, employment and self-identification. You will recall that he also told us that only 39% of those 830,000 scientists (or 320,000 scientists) reported by the Census were found to have professional level qualifications. For the sake of comparison, NSF reported that the whole population of scientists and engineers was 1,600,000 in 1973, while the 1970 Census records slightly more than 2 million, and the 1972 Post-Census Survey indicates slightly less than 1 million. With these kinds of discrepancies, analysis and induction of trends becomes rather risky.

Since we can say so relatively little about the scientists and engineers who do not work in research and development, we are backed into the position of dealing primarily with the 530,000 who do the research and development. This is somewhat analogous to the drunken man, late at night, who looks near the street lamp for his lost house key because that's where the light is best, even though he dropped it a half block away. Of these half a million R & D workers, 70% are employed in industry and the federal government, and colleges and universities each employ 12%; the remaining 6% are affiliated with non-profit research institutions and federally funded R & D centers.

From here on, I will address myself primarily to that 70% (about 350,000 professionals) who are performing R & D in industry. In terms of understanding the dynamics of this part of the group, one would like to have characterizations that span the working life of that population. However, the statistics that are available refer almost exclusively to the young graduates and their first professional placements. Concern about supply and demand also centers on this entering population. This has the unfortunate consequence of focusing our attention on the outer most skin of the onion or just the bark of the tree while we really need to know what goes on in the whole organism. Industrial careers of scientists and engineers span perhaps an average of 40 years (25 to 62 years) and therefore our concern should also span the same period. As things are now, the decision to enroll in a scientific or engineering curriculum is strongly affected by the experience of those who seek employment in the related careers at the same time. That is, the high school juniors and seniors are influenced by what they hear about the contemporary college seniors, and those college seniors contemplating graduate school weigh the current market for Ph.D's. A long range decision is made on short-term data. Because of the absence of longitudinal data, we unwittingly let the dynamics at this "outer surface" have an undesirably large effect. As a consequence, the feed-back effects on the universities come from only that short-range data base. We desparately need to look at the supply/demand relationship at various stages in careers and then adapt our educational institutions to this more complete understanding of needs. Furthermore, at the present time, most universities preparing for the professions still operate on a model that calls for what I would term "single-pass education". That probably was reasonable up to World War II. One could consider that one professional scientific and engineering education could prepare an individual for a working lifetime. Today and even ten or fifteen years ago, that is or became an unreasonable assumption. However, neither industry nor the universities have made adjustment to these needs.

An example may dramatize the new needs and the new tempo of technological and scientific progress. The vacuum electric tube was invented by Lee de Forest in 1907; it took forty years of joint exploitation by industry, government, and the universities before that technology reached the peak of its extent of application. Then the transistor came in to displace the tube, as a result of work at the University of Illinois and Bell Labs; the fullest power of that technology and the peak of its utility was reached in seventeen years. Currently the integrated circuit is on a fast track to its peak, which it may reach possibly in only eight years after introduction. Theory, models, experimentation, empirical observations, refinement in measurement technique and design--are all functions performed in both the educational setting and the industrial setting. The necessary training for the human resources at work in both settings is much the same but the most effective kind of collaboration between them is now in action.

Out of industry's growing dissatisfaction with--or at least the better recognized inadequacy of the "one-pass" university technical education, comes a significant opportunity. Industry and the universities need to work together on the redesign of the relationship of education to career. The old system will not continue to work. The new relationship should be symbiotic. It needs to provide the university prompt feedback on emerging technologies that are becoming the fastest growing or fastest changing fields of specialization. I have in mind fields such as crystal growth, high molecular weight polymers, inorganic polymers, holography, systems analysis, fermentation chemistry, hormone synthesis--where advances are being made in both industry and the university.

New links can shorten the cycle between potential industrial utility and the understanding that comes from the rigor of academic disciplines with by-products for both parties. Under such circumstances, industry would see, in a relatively few years from the first recognition of the importance of a new field of science or engineering, a trained cadre of graduates that could advance the field further. The inertia of curriculum change would be reduced. Universities would at the same time become more confident of the relevance of their students' training as well as the currency of the faculty and university researcher. Conversely, the innovations and insights realized in the universities would more quickly diffuse into the industrial environment. On this last point, the most valuable interaction between the industrial researcher and the professor is likely to come from those involved in their second or even third pass through the educational institutions, because the student on his first pass can only absorb knowledge and technique and cannot yet radiate back to the university.

In this new inter-relationship arising from the concern of industry and the university for the human resources of science and engineering, a third partner can play a vital coordinating role. I have in mind the institutions that Paul Robbins just talked about: the professional societies. The great advantage that they have is that they are organized by disciplines just as university departments are and incorporate members from industry and the university (as well as government and research institutes). They can therefore be a strong link and participant in the process I have been describing.

If we return for a moment to our original concern about the inadequacy of the statistics and analysis on the utilization and generation of human resources for science and engineering, we should also be finding ways to estimate the quality of those resources, not just their quantity. The numerical data we now struggle with does apply primarily to the new graduates and therefore their quality is in part calibrated by our knowledge of the academic standing of the training institutions. We do not have such a measure for the working professional and that is certainly important for planning and adjustment purposes.

At least one further point needs to be made--and it is in regard to government. In the 1950's and 1960's some very large programs involving scientific and engineering manpower were undertaken: the atomic energy and space exploration activities and national defense, supported by government funds, created many new disciplines, and also markets for high-technology goods quite outside the range of needs of the civilian economy. Universities played a strong role in the research and education that made it possible to achieve the new missions. However, these highly unusual and sudden needs, especially because of their magnitude, distort what might otherwise have been a better balanced relationship between industry and the university.

Since government can cause such large distortions, it bears a special responsibility to provide for adjustment mechanisms. Again, such adjustments, in both the cost of scientific and technological manpower and in its disciplinary orientation, cannot be made in the absence of good data and forecasts.

Therefore, returning to my initial point, we need to get the help of industry, the professional societies and government to provide the data and the analytical bases for the universities to play their role in the creation and preservation of the human scientific and engineering resources.

Science and Engineering Manpower: Implications for Legislative Action

by

James W. Symington
Congress of the United States

Ladies and Gentlemen, I am pleased to have such a distinguised forum to discuss what legislators can do to help maintain a balance between the supplies of scientists and engineers and our demands for them. As a member of the House Committee on Science and Technology and Chairman of the Subcommittee on Science, Research and Technology, I am acquainted with some of the problems surrounding this issue and the questions the various science and engineering societies are asking themselves concerning their role, especially in the national science research and technology development effort.

To define these roles, and the impact which legislators have on them, we must consider where research and development is at the national level, and how it fits into our economy and society. R and D in this country has leveled off from what it was in the fifties and early sixties. Furthermore, the national R and D effort still emphasizes development, with NASA and the Department of Defense doling out a good portion of the funds.* While it is discouraging to some to see so much effort still going toward development in the military, it should be noted that the rate of increase in development funds was 15% between 1967-1972, while applied research increased at a rate of 27%, and the basic research rate was 23%. This very cursory review of recent federal R and D efforts is necessary if we are to examine what such trends mean in terms of employment opportunities and educational support.

First, it should be noted that when money gets tight in government and industry, basic research is the first expense to be cut, followed closely by civilian-oriented applied research. Since money is tight now due to Administration attempts to control inflation, the federal R and D effort is not likely to be much enhanced in 1975, save perhaps for the energy-related fields. Another aspect of the economy which will affect employment opportunities for scientists over the next few years is the amount of federal funds available for the purchase of goods and services, for the support of R and D, and for academic science. At this time, the Administration seems to have other priorities for federal monies. This brings us to the question of national goals, which directly affect the demand for Ph.D scientists and engineers. To what extent will a re-ordering of national priorities toward societal problems call for Ph.D's and new Ph.D. programs?

There is little doubt that our many societal needs with their technological components will require the services of many more scientists and engineers than we have at present. Yet we must be honest with ourselves and say that the utilization

* The major portion, or over 60%, of national R & D dollars goes toward development. It was anticipated that about $20 billion would be spent for development in 1974. Federal funds finance about 52% of it now (as opposed to 67-69% between 1957-1964). Industry performs about 83% of the national development effort. The government performs another 13%, with DOD making up 2/3 of all the federal intramural development activities.

of this technical manpower is not simply a function of our needs, which are practically unlimited; utilization of scientists and engineers is more a function of the resources which society is willing to spend on those needs. Such resource allocation decisions, as we all know, are influenced by political, social and other factors, as well as the limitations of the resources themselves. As Lincoln Moses stated a few years ago in Science magazine:

> "Problems of ecology, transportation, crime, and health all call for trained manpower, but until substantial appropriations are made for solving these problems, there is no basis for counting on them as increasing the demand for Ph.D's. When scores of billions of dollars were put into the space program, thousands of engineers needed to be trained for the projects. When the higher education effort was multiplied two or threefold, many new Ph.D.'s were required to staff it. Until some comparably massive public programs are mounted in these problem areas, they should not be considered as having any effect on the demand for Ph.D's. (Science, Aug. 11, 1972)

These are strong words, but they deserve consideration and response, especially from the Congress. Our science, research and development efforts are so important to the nation's political and economic viability that they deserve better than the hatchet treatment in times of economic stress. It is now recognized that we need a long-term commitment to maintain a continuing and consistent R and D effort at the federal level which would guarantee a scientific and technological base capable of responding to problems of national concern. Anything less than a national R and D strategy wastes resources and valuable manpower, and certainly limits future options.

Several efforts aimed at shifting our national priorities and setting long-term technological goals have been made in the last few Congresses. The most notable piece of legislation is Senator Kennedy's S. 32. In its various forms it seeks to achieve the goals it sets forth through a retraining of scientists and engineers; one version of the bill was passed by the Senate last year. It has been re-introduced by Senator Kennedy in this new Congress. Economic conversion, as this re-training has been called, is certainly one proposal worth considering. However, such consideration must be cast in the light of the role the federal government should play in determining what scientists and engineers are produced. In this regard we confront the problem of the Federal government dictating to the private sector in yet another instance; will universities and professional societies appreciate being told what types of technicians they should produce? And to further complicate the issue, we can ask whether or not it is feasible for the government to attempt to predict what manpower resources we will need in the next ten or twenty years. Certainly there are some obviously long-term problems, the energy and food crises being among them. Yet, how appropriate is it for the government to dictate comprehensive manpower planning to the private sector? Congress, the government, academia and industry must work together to balance manpower with federal priorities.

In this regard, Congress can act on several fronts.

First, it can continue its practice of eliciting timely information from industry and academia and bring that input to the national attention through hearings and reports.

Second, we can work more closely with the Executive Branch and with the Federal agencies to coordinate plans and policies for research and development and to avoid overspecialization and duplication of effort. This point was recently stated in an excellent report from the National Academy of Science, prepared by a committee under the chairmanship of Dr. James Killian, "Science and Technology in Presidential Policymaking: A Proposal." I cannot emphasize it enough.

Another landmark Killian report, prepared in 1964, addressed the very issue which concerns us today: "Towards a Better Utilization of Scientific and Engineering Talent." Hopefully we will pay more heed to his latest report than we did to the one in 1964, for we certainly need policymaking and planning at the Executive Branch level. Without an office or a council having direct access to the President, an office which packs some clout in coordinating federal agency plans, our agencies have the tendency to work toward separate ends, rather than putting their collective efforts into meeting the entirety of our national goals. Congress can exercise its oversight powers to ensure accountability, responsibility and accurate reporting by those agencies which must coordinate a response to national needs.

There have recently been a host of suggestions as how best to incorporate science advice into the decision-making processes of the Executive Branch. The NAS report to Congress and the President proposed a Council for Science and Technology. So did S. 32, the Kennedy bill I mentioned earlier. The House Science Committee will continue to give this matter the highest priority in the 94th Congress. In fact, our Chairman, Olin Teague, considers the issue to be of such importance that he has conducted the hearings before the Full Committee, and soon he will introduce a science policy proposal of his own for the Committee to consider. This proposal is an outgrowth of the Science Policy hearings the Committee conducted in the 93rd Congress.

Third, Congress must help assure that the Government, which exerts a strong influence on the development and utilization of scientists and engineers, uses this influence to maintain a balance between supply and demand. As Dr. Killian's first report on manpower stated:

> "This influence imposes on Government an entirely new responsibility to prevent malutilization. Government must assess in advance the effect of its decisions on the deployment of large numbers of scientists and engineers, both in undertaking new projects and in discontinuing old ones."

This recommendation has special relevance today because it is clear that specialties will be changing with increasing rapidity in the future. Again, I note that Congress, the Executive office and the agencies have to work together to avoid a proliferation of overspecialized jobs that may be obsolete in a few years. We in Congress hope that our new Office of Technology Assessment will help us in this role.

Fourth, Congress has an internal responsibility to coordinate its own thoughts on the planning and training for scientific and technical manpower. The new budget committees of each House, as well as the authorization and appropriations committees, should strive for harmony with goals outlined by committees directly involved with science and manpower concerns, e.g. the House Committee on Science and Technology and the Senate Aeronoutics and Space Committee.

I have focused here on the need for general policies and priorities for science and technology because I believe that we cannot create adequate measures for manpower policies unless they are part of a broader plan of science policy. To fulfill its responsibilities in developing such a policy, government and Congress must rely on timely information and guidance from academia, professional societies, industry, and other knowledgeable sources. This information and advice must not await a formal request, but should come at the initiative of nongovernmental groups as well as in response to governmental or congressional inquiry.

Perhaps some of you are aware of a growing concern over brain drain in this country: not the attraction of foreign brains to the U.S., but rather the exodus of talent from the United States to other countries. A recent study by the Congressional Research Service at the Library of Congress indicates that there has been a marked decline in immigration of scientists and engineers to this country and increased emigration of our own scientific and technical manpower. While the numbers are not overwhelming, I feel that the trend is a warning that we cannot continue to operate with the lack of organization and planning which have characterized the past. We cannot afford to have less than the most attractive and productive climate for science and technology in the world.

I hope that in the next ten to twenty years we will not have to reflect on the past as a time of lost opportunity. Our failure now, and in the next few years, to produce a balance between supply and demand for scientists and engineers may prove difficult. With your help and counsel we should be able to avoid that difficulty.