Trends in Graduate Enrollment in Engineering—A Primer

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ABSTRACT

This paper discusses current trends in graduate engineering enrollment and the number of graduate engineering degrees awarded. It explores some reasons for these trends and includes a large number of references. It is hoped that this information will encourage a well- informed debate of the issues involved.

INTRODUCTION

Last fall, in his *President's Message to ASEE Members,* Gerry Jakubowski, ASEE's current President, identified a need to increase the number of domestic students getting graduate degrees in engineering and challenged the Society to take an active role in the process.

Here is what he said.:

> *ASEE needs to increase its efforts in promoting research and graduate education. There is the perception that ASEE is involved only in promoting and improving engineering education, specifically teaching, at the undergraduate level. We need to change that perception by expanding ASEE activities related to research and graduate education. Furthermore, there is a need to increase the number of Americans seeking and completing engineering graduate degrees. Currently, the number of Americans completing graduate degrees is alarmingly low, and as a result, the United States needs to fill this void by importing them from foreign countries. This has the potential of jeopardizing the quality of undergraduate engineering education as well as putting the United States at a technological disadvantage in comparison with other countries. ASEE needs to help promote the importance of graduate level engineering education.*

I hope that the Society will accept Gerry's challenge and find multiple opportunities in its Councils, Divisions, and meetings to explore, debate, and formulate appropriate actions on this important topic. However, any discussion needs to be well grounded in the data which concerns this topic. With this end in mind, to stimulate discussion of the trends in graduate enrollment in engineering and their causes, and specifically to dispel the preconceptions and questionable

anecdotal information that tend to creep into such debates, I have written this paper.

In an attempt to provide as complete a picture as possible, I have sought to include data relative to historical trends in engineering enrollments and degrees awarded as well as the factors which are generally regarded as influencing these trends. These factors include such issues as the economy, the demographics of the U.S. population, the number of undergraduate degrees, the number of international students, the role played by gender and ethnicity, and the barriers to enrollment and degree completion for under-represented groups. Finally, if strategies are going to be developed for dealing with these issues (which, after all, are a desirable purpose of any discussion) then information on "best practices" needs to be included as well.

This is clearly an ambitious project. Honesty therefore compels me to subtitle this paper *A Primer*. The dictionary defines *primer* to be "giving the first principles of anything" and that is all I can possibly do here. There is much more information on this topic that I could possibly include in such a paper. This is only a beginning.

In the coming year, I hope that the readers of this paper will begin their own investigations into this topic and share the insights which they acquire with me and with one another. I will be asking the Graduate Studies Division to set up a web site to provide access to this information.

In this paper you will find references, including web site addresses in many cases, where much of the available data on this topic can be found. I will keep my own interpretation of the data to a minimum and rely on documents accompanying the data to provide this. After all, it is discussion which I am attempting to provoke here, and we all know from our teaching experiences how damaging it can be for the instructor to dominate the conversation.

I understand full well the complicated nature of identifying the factors which influence human behavior. This is, from a fundamental perspective, what we are dealing with here when you consider the choices which an individual must make in electing to pursue a degree in engineering either as an undergraduate or a prospective graduate student. I will limit my comments to introducing the topic and offering what I think are the most obvious connections, realizing that in some case, I might be guilty of oversimplifying the situation or even overlooking an important factor. In such cases, I hope that I will hear (and learn) from you. You can contact me at my email address which I have included at the end of this paper.

Data on graduate education is no different from data on practically any other topic. I have found that, in some cases, the data from various sources, and even various publications of what would appear to be the same data from the same organization differ--sometimes by significant amounts. Care must be taken not to mix data coming from different sources. I have tried to be careful and so should you. In any event, I have tried to provide sufficient references to the data that I have presented so that any one who is determined to resolve these differences will have the resources available to do so.

With regard to references, I have given them a letter and number designation. The letters are keyed to the categories into which I have divided the references, and the number refers to the reference in that section. You will also see that in some cases I have listed two URL's. In most

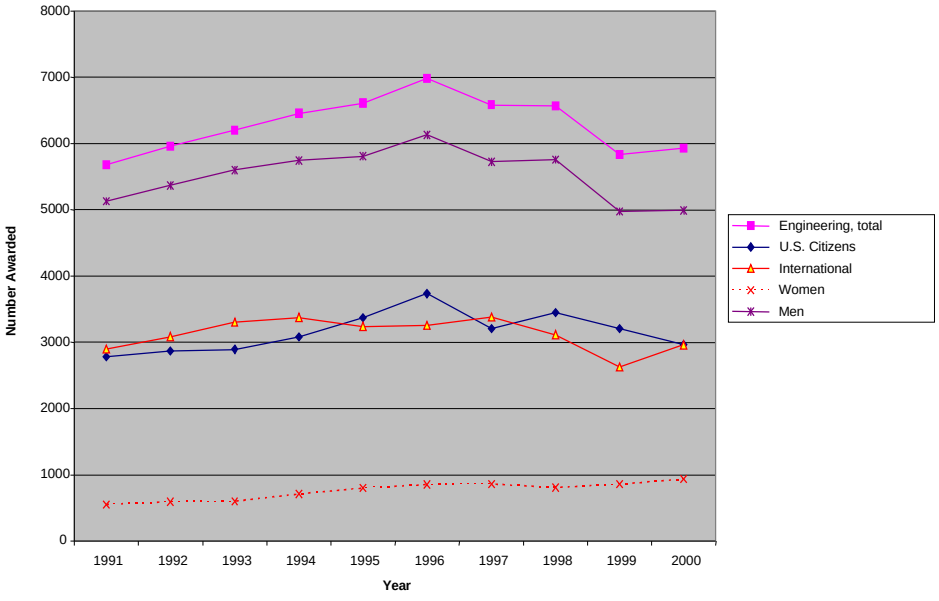
cases the first refers to the complete document and the second to the actual source of the data used. There are also references without numbers. I have chosen not to refer to them in this paper, but in most cases they contain interesting and relevant information which should be consulted by those who wish to develop a comprehensive understanding of the issues involved.

A final comment about references—the most comprehensive current reference on the topic of engineering degrees awarded and data related to the general area of research and education in the sciences and engineering is *Science and Engineering Indicators 2000*, published by the National Science Foundation (SEI1).

Graduate Engineering Degrees Awarded

Figure 1 comes from the American Association of Engineering Societies (EDH1). This data and much more, including detailed data by discipline and institution can be found in their yearly publication entitled Engineering & Technology Enrollments. Similar data, including institution-specific information is available from the American Society for Engineering Education (EDH2). You will see that I have provided separate MS and PhD plots and have disaggregated the degrees awarded into the categories of total, US citizen, international, women, and men.

Fig. 1 Engineering Doctorate Degrees '91-'00



A clear peak in the number of engineering doctorates awarded is seen in 1996 with subsequent yearly declines with the exception of 2000 where it again increases, due to a strong upturn in international degrees. The number of domestic (U.S. Citizen) degrees awarded continues to decline with the year 2000 marking the year when the number of domestic and international degrees awarded was equal. The number of degrees awarded to men continues to greatly exceed the number awarded to women, although there are steady increases in the latter. It is interesting to note that if similar data from the Survey of Earned Doctorates (EDH3) sponsored by the

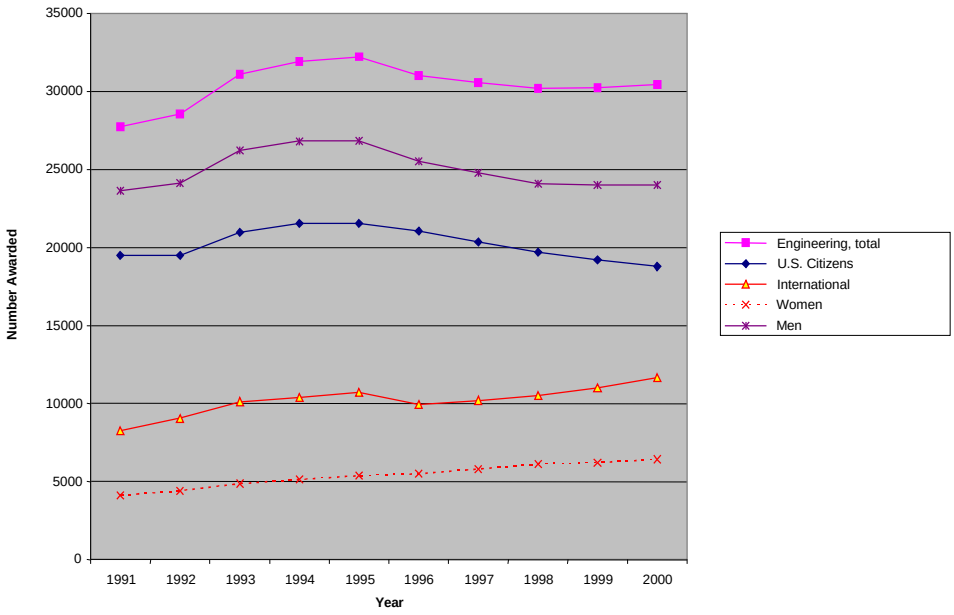
National Science Foundation and others is plotted, similar trends will be seen; however, the number of degrees in all categories will be somewhat less.

The plot of masters degrees awarded, Fig. 2, shows similar trends, but with the peak in degrees awarded occurring about a year earlier than the peak in doctorates awarded. Similar to the doctoral degrees, steady declines are seen in the masters degrees awarded with a slight upturn in 2000 again due to a strong increase in international degrees. Men greatly outnumber women again, but by a smaller margin than for the doctorate degrees. (Note the change in the vertical scale compared with the previous plot.)

Graduate Engineering Enrollment

This can be looked at as a predictor of future graduate engineering degrees, and is a more sensitive indication of annual trends. This data again comes from the American Association of Engineering Societies (EDH1). Looking first at the doctoral enrollment, Fig. 3, the upward trend in 2000 is much sharper than the increase in doctoral degrees awarded shown in Fig. 1 and is made up of the expected increase in international enrollment, *accompanied by a rise in domestic enrollment*, ending a trend of decreasing domestic enrollment which began in 1993. Note that 1996 marked the year when the number of international students enrolled equaled the number of domestic students enrolled.

Fig. 2 Engineering Masters Degrees '91-'00



Masters enrollment, Fig. 4, shows similar trends with sharp increases in enrollment in 2000. Traditionally the domestic masters enrollment has exceed the international enrollment. This situation was reversed in 2000.

We have been looking at full-time graduate enrollment up to this point. Let's have a brief look

at part-time masters and doctorate enrollment from the same source for the same period which appears in Fig. 5. (This information might be of importance for institutions which are interested in attracting the "mature learner.") The results are surprising. Despite the upward trends visible particularly in full-time masters enrollment, the trend in part-time masters and doctorate enrollment is steadily down at an average rate of almost 2000 students per year.

INFLUENCING FACTORS

It is useful to speculate on the factors which play a role in influencing these annual trends. This is especially true in terms of deciding what the Society can influence and what it cannot. Certainly one example of the latter is the demographics of the US population. An example of the former is the undergraduate engineering enrollment. Let's begin with enrollment.

Fig. 3 Engineering Doctorate Enrollment '91-'00

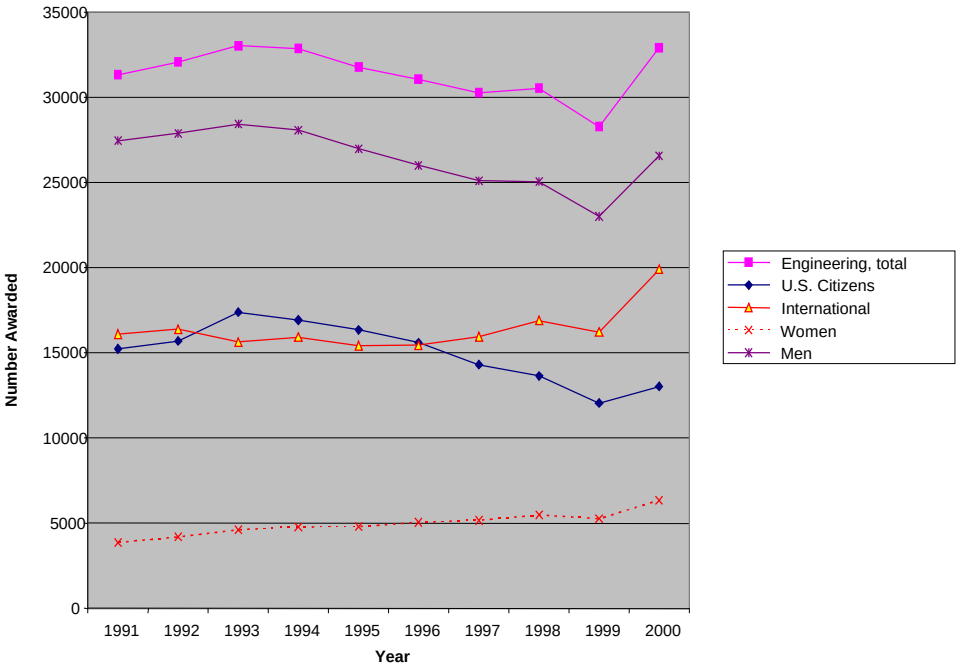


Fig. 4 Engineering Masters Enrollment '91-'00

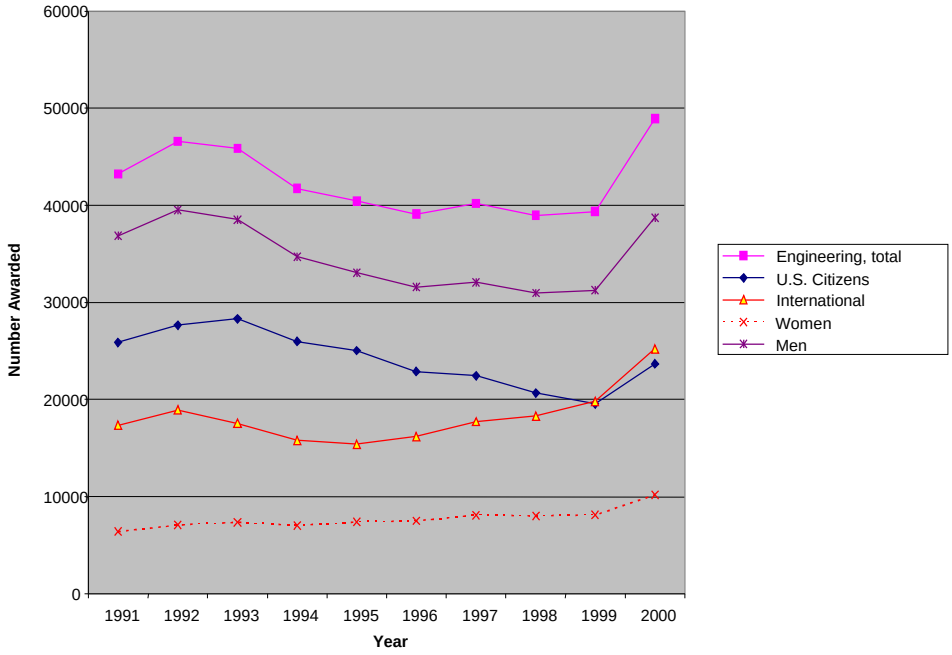
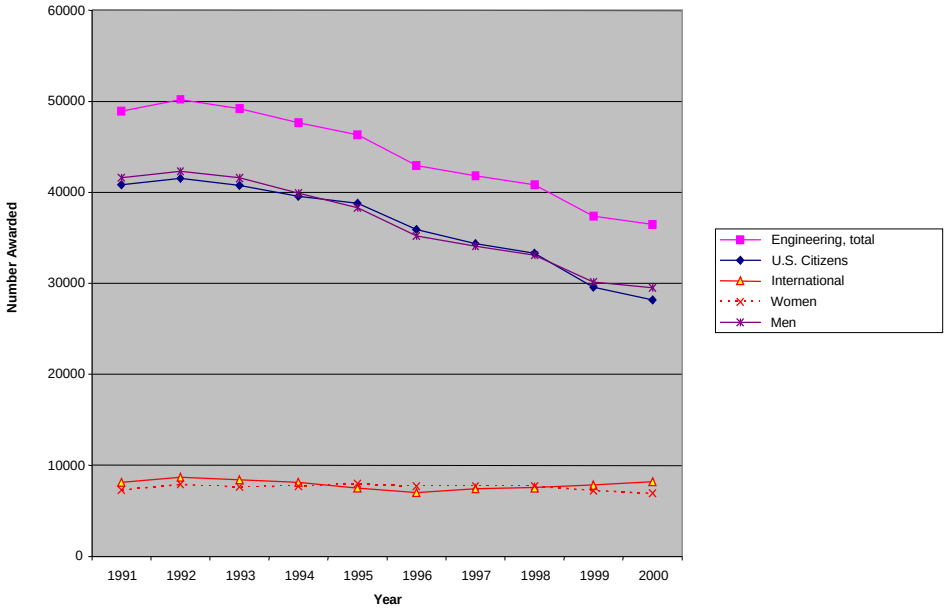


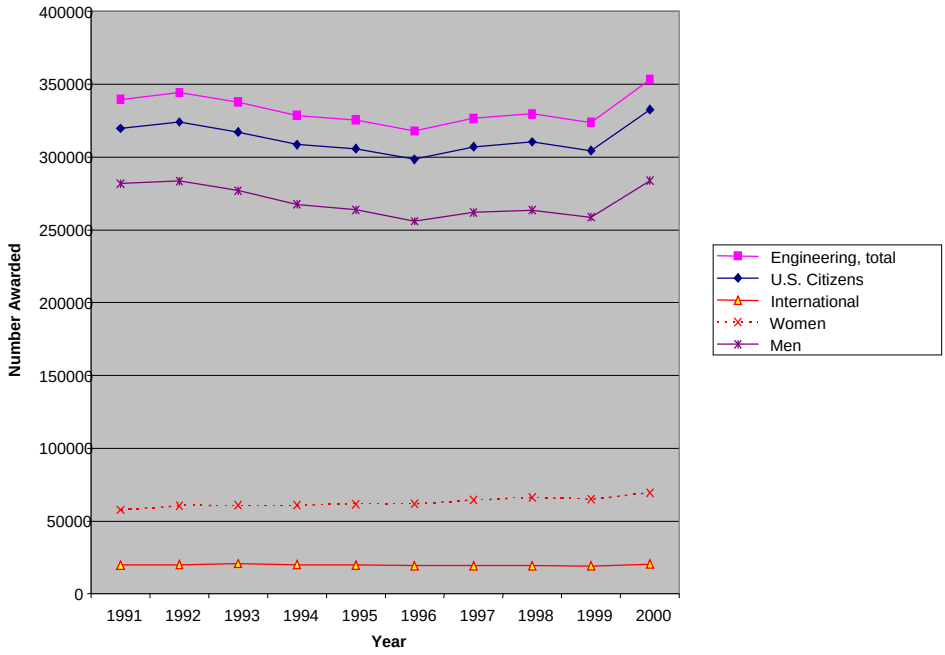
Fig. 5 Engineering Masters+Doctorate Enrollment--Part Time '91-00



Undergraduate Engineering Enrollment

The data in Fig. 6 again comes from the American Association of Engineering Societies (EDH1). The trend in undergraduate enrollment has been more or less flat for most of the past decade until 2000 when, as in the case of graduate enrollment, we see a sharp increase. This increase amounts to 25,000 students and unlike the situation for graduate enrollment is made up *entirely by an increase in the number of domestic students.*

Fig. 6 Engineering Bachelors Enrollment '91-'00

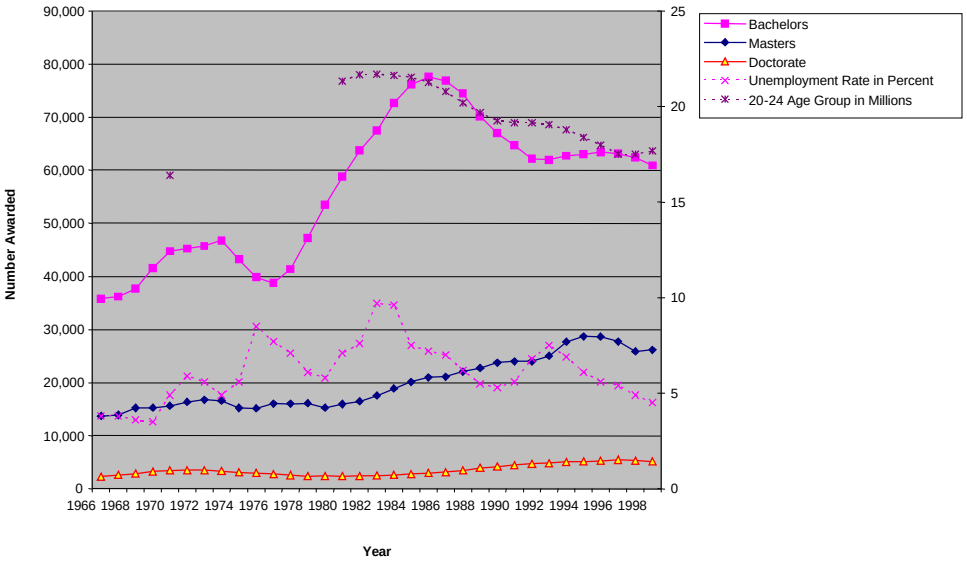


Economy and Population

Unlike undergraduate engineering enrollment, the economy and the population are factors about which the Society has no influence, but must nevertheless be understood and taken into account. The data which I have plotted below comes from the National Science Foundation (EDH4), the Bureau of Labor Statistics (IFE1), and the US Census Bureau (IFD1).

The solid lines, Fig. 7, are similar to the degree awarded data which I presented before. Note however, that this data is from EDH4 and not EDH1. This is because I wanted to give a 30-year picture. The first of the broken lines (read the right scale) is the trajectory of the 20-24 age group over the past three decades and the second broken line is the annual unemployment rate.

Fig. 7 Engineering Degrees Awarded Compared with Unemployment Rate and Demographics



There appears to be some correlation between degrees and demographics. It could be argued that the long-term rise in the 20-24 age group from (at least) 1970 to 1982 produced the spectacular rise, nearly a doubling, of undergraduate engineering degrees. And notice since that time the number of undergraduate engineering degrees and the size of the "college-age" population have both decreased. Isn't it surprising that this doesn't seem to have influenced the number of graduate degrees awarded, though?

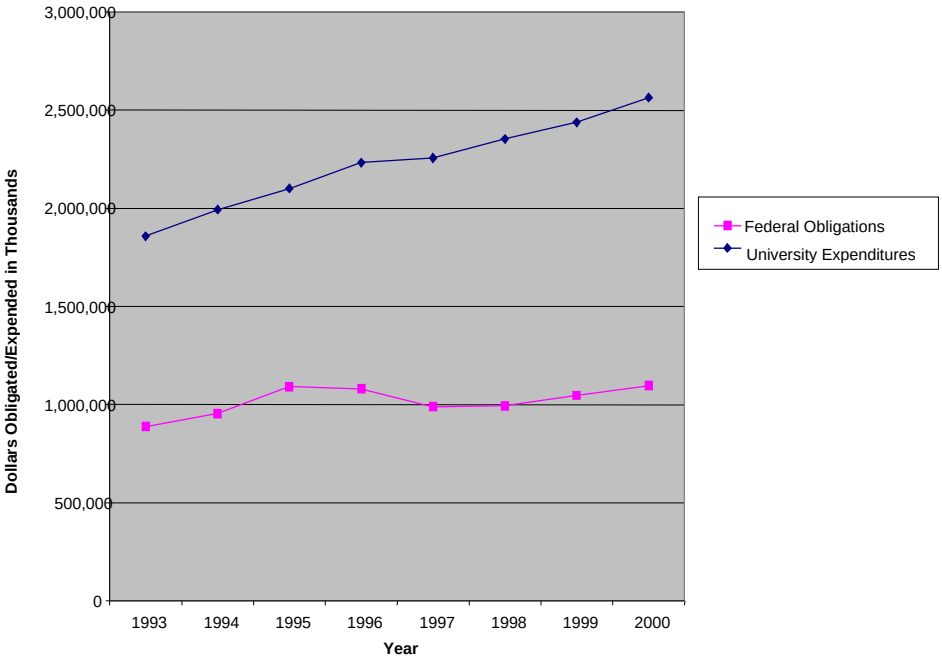
And then there is the matter of the economy. Look at the unemployment rate, the lower broken line on the plot. There is an "urban legend" that when the economy is bad, graduate education booms. Well, at first glance, this is hard to see. There doesn't seem to be any long-term connection. But look carefully at the masters degrees awarded in the1994-96 period. You see a small peak in the number of masters degrees awarded, and in the three or four years preceding this you see a period of rising unemployment. Why the connection in 1994-96, but not in previous years? This might be a worthy topic for further study.

Research Funding

Figure 8 comes from the National Science Foundation (IFRF1, and IFRF2).

Whether you look at engineering research funding in terms of data provided by the federal agencies (federal obligations) or the amount of research funding spent by universities coming from the federal government (university expenditures), there have been increases (considerable increases when you look at university expenditures) over the past several years. This runs counter to the level or decreasing trends in graduate enrollment and degrees with the exception of 2000. Is the increase we are seeing in 2000 just the lag in the time required to recruit the additional students which these increases should make possible? Again, further investigation is required to sort this out.

Fig. 8 Federal R&D Funds Obligated to Universities and University R&D Expenditures Reported As Coming From Federal Funds



The connection between research obligations (both federal and private) and engineering enrollment in the various engineering disciplines is the topic of a recent National Research Council report (IFRF3) which bears reading. There is clearly a large difference between obligation and expenditures as the previous plot points out. Care therefore needs to be taken in drawing conclusions based *exclusively* on either set of data. My co-author (MMR) is chairing a multi-society task force which is currently looking into this matter. It will shortly be publishing an article on their findings. Meanwhile, it might be helpful to read pages 2-52 and 2-53 of *Science and Engineering Indicators 2000* which seeks to sort out some of these issues.

Under-Represented Groups

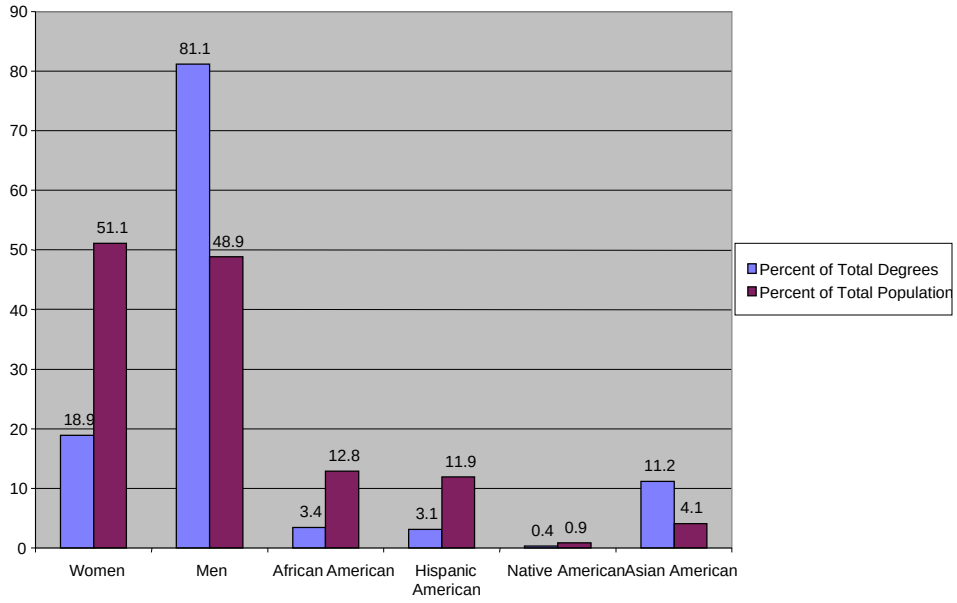
Looking at the enrollment and degree plots which I have already presented gives an indication of the relatively small fraction of women who are seeking graduate degrees in engineering. It depends on whether you are looking at enrollment or degrees awarded, masters or doctorate, and year, but it varies between 10 and 20 percent. Figure 9 provides a more detailed look at engineering doctorate degrees awarded to women as well as various racial groups in 2000. I have plotted the number of engineering degrees awarded to women, men, and African, Hispanic, Native, and Asian-Americans. It shows that women are under-represented in engineering degrees awarded by a ratio (percent of population divided by percent of degrees) of about three, African, Hispanic, and Native-Americans by from three to four, and Asian-Americans *over-represented* by approximately the same amount that women are *under-represented.*

Science and Engineering Indicators 2000 (SEI1) contains a summary of some of the obstacles to increasing the numbers of various racial groups in science and engineering and much has been

written (and read by engineering faculty) on this topic. In contrast, I believe that the issues involving the obstacles to increasing the number of women in engineering are not as widely known and appreciated. In IFBW1 I found this statement:

> *In our discussion we do not mean to imply that men do not have some of these same experiences as well as different ones. However, the lack of social and professional connections available to most women in academic science and engineering departments, in concert with overt and covert gender bias as well as differences in socialization, creates special and unique problems for women.*

Fig. 9 Engineering Doctorates Awarded to US Citizens in 2000
Distribution by Gender and Ethnicity in Percent



This problem is not confined to the United States (IFBW2). But looking at the number of women engineering faculty as an indicator, nowhere in Western Europe is it as low as it is in the US (less than 1 percent).

Other Considerations

This is only a part of the picture. I have already drawn attention to the increasing numbers of international graduate students in connection with the enrollment and degree information which I have presented. Foreign-born scientists and engineers now make up more that twenty percent of the total science and engineering work force and more than thirty-five percent of the academic workforce (SEI1). On one side there are those who believe that large numbers of international students and faculty discourages US citizens from pursing carriers in engineering and, on the other, there is ample evidence of the significant contributions which this growing portion of our industrial and engineering workforce is making to our nation's economy and research activities (SEI1).

Are the best students attracted to engineering? Why aren't there more of them? Dan Goldin, NASA's former administrator, provocatively poses these questions and relates this to his agency's manpower needs in a recent article in the *Atlantic Monthly* (IFAD1). The issue of quality is pursued in some detail in "Best and Brightest Part Two: Are Sciences and Engineering Graduate Programs Still Attracting the Best Students?" (IFAD2) Another way of framing the question is to ask why students migrate to other disciplines. Some answers can be found in *Talking About Leaving: Why Undergraduates Leave the Sciences* (IFAD3). Perhaps students are not as well prepared for a career in engineering as they might be. What some view as the sorry state of preparation in science and mathematics that is provided by our primary and secondary schools in pursued in (IFQP1). This reference introduces yet another question: "Why isn't engineering as popular among college-age students in the US as it is in other countries?" Food for thought on this question can be found in IFIP1. Yet another perspective is provided by studies of the perceived level of satisfaction of recent PhD recipients (IFLS1, 2) and disparities between the nature of employment desired and achieved (IFLS3).

Finally, what are some best practices that have addressed some of these issues? Let me suggest looking at: 1) the Program Development Fund website maintained by the Society of Women Engineers (IFBP1) for some projects directed at increasing the number of women in engineering, 2) the Meyerhoff Scholar Program (IFBP2) for increasing the number of minorities entering engineering, and finally, 3) the proceedings of the annual meeting sessions sponsored by the Graduate Studies Division of the ASEE (IFBP3) for examples of effective graduate student recruiting methods.

CONCLUSIONS

I hope that this information on graduate enrollment and degree trends in engineering and the factors which influence them will stimulate the members of the Society to begin a vigorous and knowledgeable debate of this issue. I would be pleased to hear from any reader who has a point of view or additional information to share with me and look forward to the possibility of posting information of general interest on the Division's website. You will find my email address below.

ACKNOWLEDGEMENTS

I would like to thank Michael Gibbons, Program Manger for Surveys and Statistics of the ASEE and Dan Bateson, Publications Coordinator of the AAES, EWC, for sharing their thoughts and data on engineering degrees and enrollments with me. Finally I would like to acknowledge the contribution made by members of the ASME Engineering Research Task Force, chaired by my co-author (MMR), in stimulating me to write this paper and for suggesting the inclusion of some of the issues raised here.

BIBLIOGRAPHY

"President's Message to ASEE Members"
http://www.asee.org/welcome/presidentmessage.cfm

Science and Engineering Indicators **(SEI)**

1) *Science and Engineering Indicators 2000*
http://www.nsf.gov/sbe/srs/seind00/start.htm

Enrollment and Degree History: **(EDH)**

1) Engineering & Technology Enrollments, AAES.
http://www.aaes.org/content.cfm?L1=1&L2=4&L3=2&PID=2

2) *Profiles of Engineering and Engineering Technology Colleges: 2000*, ASEE
http://www.asee.org/colleges/part1.PDF

3) *Science and Engineering Doctorate Awards: 2000*
http://www.nsf.gov/sbe/srs/nsf02305/secta.htm

4) *Science and Engineering Degrees: 1966-98*
http://www.nsf.gov/sbe/srs/nsf01325/start.htm

Doctorate Recipients from United States Universities: Summary Report 2000 (Survey of Earned Doctorates)
http://www.norc.uchicago.edu/issues/sed-2000.pdf

Science and Engineering Degrees, by Race/Ethnicity of Recipients: 1990-98
http://www.nsf.gov/sbe/srs/nsf01327/htmstart.htm

Science and Engineering Degrees: 1966-98
http://www.nsf.gov/sbe/srs/nsf01325/start.htm

Graduate Students and Postdoctorates in Science and Engineering (Graduate Student Survey)
http://www.nsf.gov/sbe/srs/gss/start.htm
http://www.nsf.gov/sbe/srs/nsf01324/htmstart.htm

Influencing Factors:

General

Science and Engineering Indicators: 2000
http://www.nsf.gov/sbe/srs/seind00/access/toc.htm

Short Reports on the General S&E Workforce in U.S.
http://srsstats.sbe.nsf.gov/workforce.html

Science and Engineering Degrees
http://www.nsf.gov/sbe/srs/sed/start.htm

Economy **(IFE)**

1) Labor Force Statistics from the Current Population Survey, BLS
http://www.bls.gov/cps/cpsaat1.pdf

Demographics **(IFD)**

1) *Statistical Abstract of the United States: 2000*, USCB
http://www.census.gov/statab/freq/00s0012.xls

Women, Minorities, and Persons With Disabilities in Science and Engineering: 2000
http://www.nsf.gov/sbe/srs/nsf00327/access/toc.htm
http://www.nsf.gov/sbe/srs/nsf00327/c1/fig01-03.gif

U.S. Census Bureau National Population Projections
http://www.census.gov/population/www/projections/natsum-T3.html

U.S. Department of Health and Human Services
http://www.aoa.dhhs.gov/aoa/STATS/natlpop.html

National Estimates: Annual Population Estimates by Sex, Race and Hispanic Origin, Selected Years from 1990 to 2000
http://eire.census.gov/popest/archives/national/nation3/intfile3-1.txt

Population Profile of the United States: 1995
http://www.census.gov/population/pop-profile/adobe/appdxa.pdf

Research Funding **(IFRF)**

1) Federal Funds for Research and Development: Detailed Historical Tables: Fiscal Years 1951-2000
http://www.nsf.gov/sbe/srs/nsf01334/htmstart.htm
http://www.nsf.gov/sbe/srs/nsf01334/tables/hist62.xls

2) Academic Research and Development Expenditures: Fiscal Year 2000
[Early Release Tables]
http://www.nsf.gov/sbe/srs/srs02402/start.htm
http://www.nsf.gov/sbe/srs/srs02402/tables/b4.xls

3) *Trends in Federal Support of Research and Graduate Education*
http://www.nap.edu/catalog/10162.html

Federal Funds for Research and Development: Fiscal Years 1999, 2000, and 2001
http://www.nsf.gov/sbe/srs/nsf01328/sectc.htm

Academic Research and Development Expenditures: Fiscal Year 2000
http://www.nsf.gov/sbe/srs/srs02402/start.htm#tables

Guide to R&D Funding Data, AAAS
http://www.aaas.org/spp/dspp/rd/guide.htm

Barriers to Women **(IFBW)**

1) "Barriers to Women in Academic Science and Engineering"
http://www.ai.mit.edu/people/ellens/Gender/EKNU.html

2) "Euro-Women in Science," *Science*, January 4, 2002, p. 41
http://www.sciencemag.org/content/vol295/issue5552/r-samples.shtml#295/5552/41b

Women, Minorities, and Persons With Disabilities in Science and Engineering: 2000
http://www.nsf.gov/sbe/srs/nsf00327/access/toc.htm

Women and Minorities in Science and Engineering
http://www.mills.edu/ACAD_INFO/MCS/SPERTUS/Gender/wom_and_min.html

"Study Documents Dearth of Women in European Academe"
http://chronicle.com/daily/2002/01/2002010805n.htm

Talking about Leaving, Why Undergraduates Leave the Sciences, E. Seymore and N. Hewitt, Westview Press, 1997

"Science and Policy: New Perspectives For an Era of Angst," an address by Rita Colwell, Director National Science Foundation
http://www.ineer.org/Special/ColwellAWISKeynote20011019.htm

Attraction of Other Disciplines **(IFAD)**

1) "Help Wanted," *The Atlantic Monthly*, September 2001

2) "Best and Brightest Part Two: Are Sciences and Engineering Graduate Programs Still Attracting the Best Students?"
http://www.cpst.org/web/site/bbcharts/bbcharts/bb2.htm

3) Talking about Leaving, Why Undergraduates Leave the Sciences, E. Seymore and N. Hewitt, Westview Press, 1997

Quality of Preparation **(IFQP)**

1) *Science and Engineering Indicators 2000*, pp. 5-19 to 5-22
http://www.nsf.gov/sbe/srs/seind00/start.htm

Reports & Information Resources, K-12 Preparation, ASEE
http://www.asee.org/k12smet_ed/resources.cfm

International Perspective **(IFIP)**

1) *Science and Engineering Indicators 2000*, pp. 4-16 to 4-26
http://www.nsf.gov/sbe/srs/seind00/start.htm

Statistical Profiles of Foreign Doctoral Recipients in Science and Engineering: Plans to Stay in the United States
http://www.nsf.gov/sbe/srs/nsf99304/htmstart.htm

"How Much Does the U.S. Rely on Immigrant Engineers?"
http://www.nsf.gov/sbe/srs/issuebrf/sib99327.htm

"Are the Foreign Born a Source of Strength for U.S. Science?," *Science*, August 20, 1999, pp.1213-1214.

Level of Satisfaction with PhD Studies **(IFLS)**

1) *The 2000 National Doctoral Program Survey*, NAGPS
http://survey.nagps.org/

2) Ph.D. Training Lacking In Career Preparation, Pew Charitable Trusts
http://www.pewtrusts.com/ideas/index.cfm?page=7&name=Grantee%20Press%20Releases&issue=22

3) *Employment Preferences and Outcomes of Recent Science and Engineering Doctorate Holders in the Labor Market*
http://www.nsf.gov/sbe/srs/issuebrf/nsf02304/tab2.xls

Best Practices **(IFBP)**

1) SWE Program Development Fund (descriptions of projects directed at increasing number of women in engineering)
http://www.swe.org/SWE/ProgDev/Projects/GrantProjectRep.htm

2) "The Meyerhoff Scholar Program: Producing High-Achieving Minority Students in Mathematics and Science," *Notices of the AMS*, January 2001, pp. 26-28.

3) ASEE Annual Meeting Sessions sponsored by the Graduate Studies Division
http://www.asee.org/conferences/default.cfm

BIOGRAPHIES

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