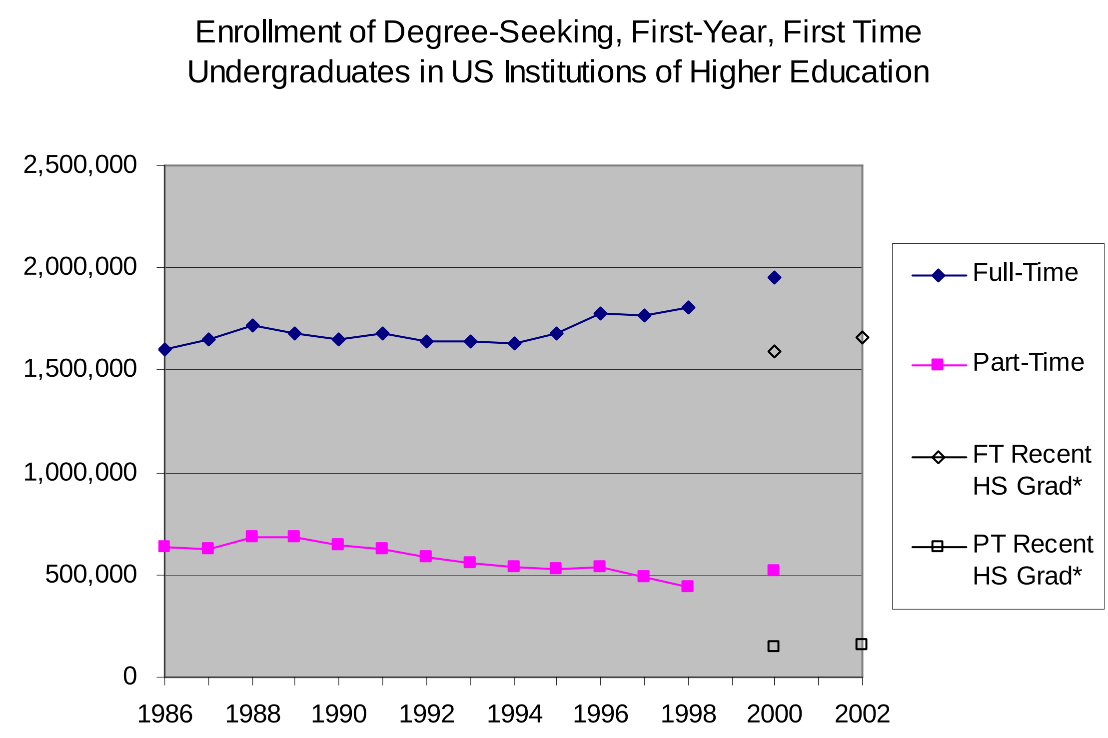
Assessing Changes in Student Interest in Engineering Careers Over the Last Decade
--Myles Boylan

This analysis addresses the following questions:

1. What changes have occurred in the interest of US students in seeking engineering undergraduate degrees from US institutions of higher education? Why do various quantitative indicators of student interest diverge in recent years?
2. What information do we have about the adequacy of K-12 preparation of students interested in engineering courses of study?

<u>Demographic Background</u>

The US is currently in a fairly stable demographic period in terms of population changes and the flow of new HS graduates into college. The number of 18 year-olds rose from a 30-year trough of 3.39 million in the fall of 1992 to 3.93 million in the fall of 1998. The number of first-time full-time undergraduates rose by an equivalent 15% during that same period, reaching 1.8 million. Since 1998 the increase in the 18 year-old population has been more gradual, reaching 4.0 million in 2000 (up 2% from 1998). There was a much faster rise in first-time full-time undergraduates over these 2 years of 9% (reaching 1.95 million). The number of 18 year-olds will reach 4.1 million in 2005 and then hit an expected peak of 4.3 million in 2007 (up another 7.5% over the year 2000).



Source: NCES data compiled through the NSF/SBE/SRS WebCaspar Database System.
*Recent HS Grad data is from the Current Population Survey, US Census Bureau

The total flow of high school graduates into college as full-time students has grown over the last few years primarily due to rising rates of immediate matriculation, which rose from 56% in the mid-1980s to 67% in 1997. There is evidence that this rate peaked in 1997 and has leveled out around 62% to 63%. However, because the US education system is complex, there are many pathways to college degree programs. About 18% of first-time, full-time undergraduates in 2000 were not recent high school graduates. A significant number of high school dropouts enter college through the pathway of earned General Education Development diplomas (GEDs), which are close substitutes for high school diplomas. For example, in academic year 2001 - 2002, 648,000 students earned GEDs and 67% of them were19 – 24 years old. There is also a considerable amount of delayed entry and re-entry into college by earlier cohorts of high school graduates. In 2001 - 2002, 1.65 million college freshmen were no older than 18, but an equal number were 19 – 24 years old, and an additional 1.1 million were 25 years old or older.

Attraction to Engineering Majors

The task of this analysis is to determine the propensity of these students to select engineering and engineering technology majors, and to assess how this has been changing over the last decade. There are data available from a variety of sources and they appear to be contradictory. However, these data are not perfectly suited to this task and thus the analysis is not straightforward. There are three types of data available to address student attraction to a discipline – plans & intentions data (collected up to the freshman year in college), enrollment data, and degree data.

Plans and Intentions

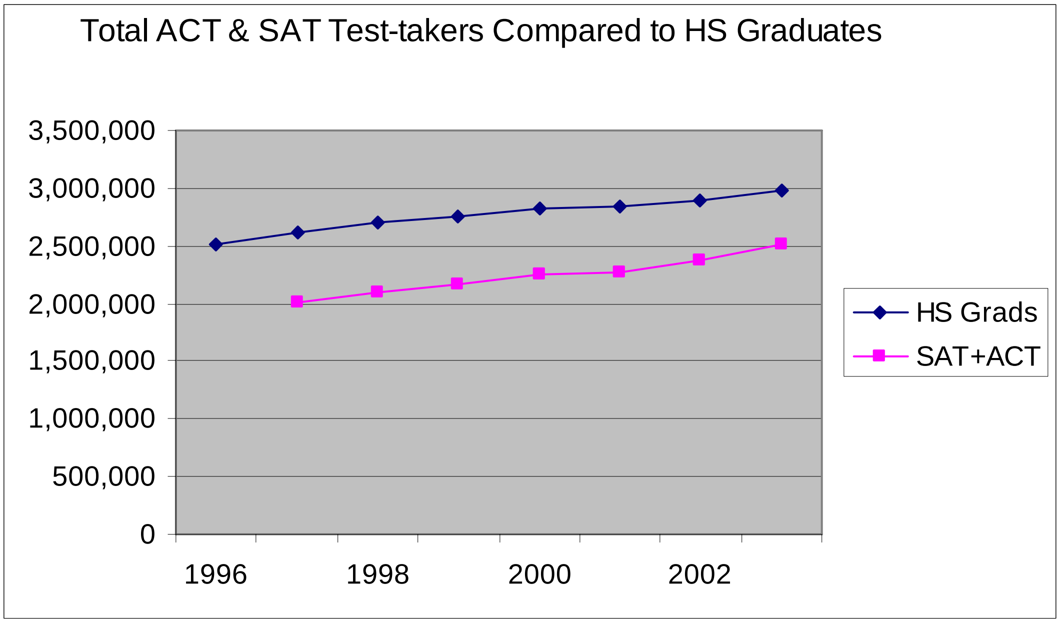
This analysis examines three sources of information about the interest of high school students in studying engineering in college:

1. The “high school profile” data on “planned educational majors” collected by ACT, Incorporated, the administrators of the American College Test given to prospective college students. These data go back at least 30 years. About 960,000 students took this test in 1997 and the number has grown to 1,175,000 in 2003.

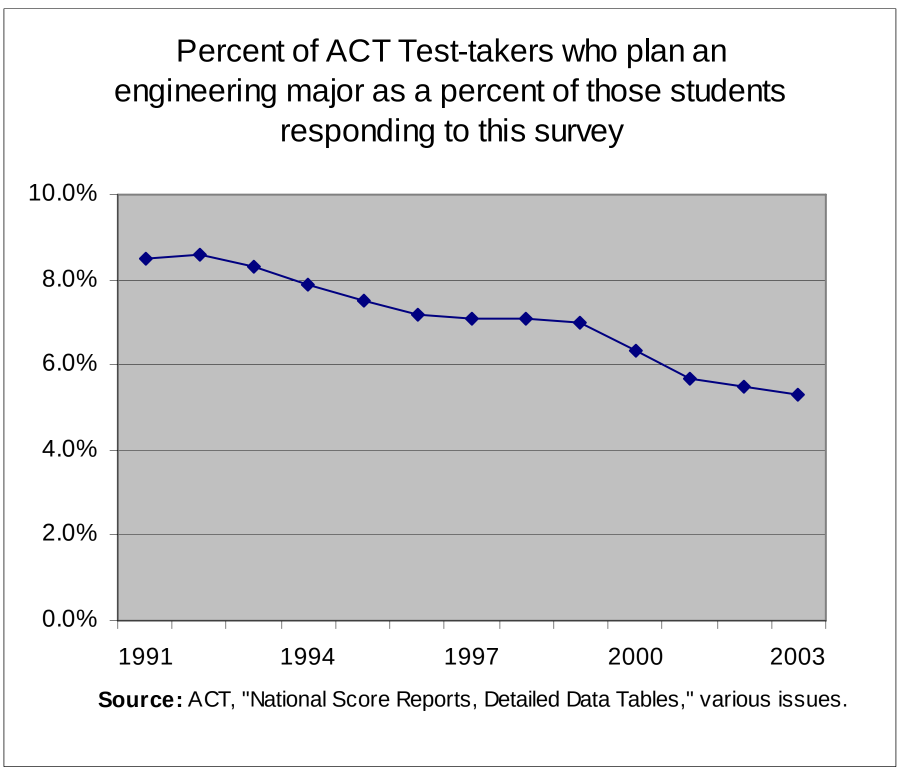
2. The “college plans (intended college major)” data collected by The College Board as part of the administration of the basic Scholastic Aptitude Test (SAT I). These data have also been collected for several decades. About 1,125,000 students took the SAT I in 1997 and the number has grown ton over 1,400,000 in 2003.

3. The “freshman intentions” data collected from approximately 400,000 college first-time freshman during their enrollment by the Higher Education Research Institute (HERI) at UCLA. These data are published annually in “The American Freshman: National Norms” (1966 to 2002). NSF publishes custom national tabulations for major disciplines in “Science Indicators,” a biennial publication. Annual percentages of students planning engineering majors during the 1970s and 1980s proved to be very good predictors of bachelor’s degrees awarded in engineering 3 years later: Eng Bach/Total Bach[t+3] = 2/3Eng Intentions[t].

The ACT and SAT jointly cover most entering college students. In 2000, 2.450 million first-time college students enrolled in college compared to 2.325 million students who took the ACT and SAT tests (although there is undoubtedly some overlap between these two groups). Evidently over 80% of HS graduates now take one of these tests, so the tests are potentially good sources of information.



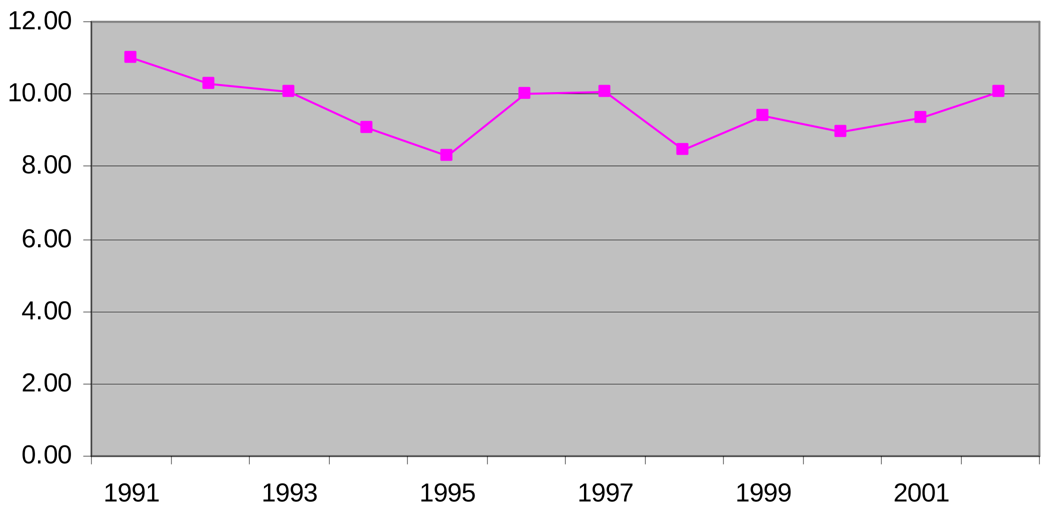
What do these data indicate about HS seniors and college freshman's plans to major in engineering? The most alarming data comes from ACT. These show a plunge in the



percentage planning to major in engineering (based on those of test takers who responded to the profile questionnaire) from 8.6% in 1992 to 5.3% in 2003. By any standard is a large decline. In fact it was these data that prompted me to begin this analysis.

In contrast, the "Freshman Intentions" data of the HERI do not show a decline of this magnitude, although these data are currently available only through the year 2000. (The next two years will become available in the near future after the National Science Board's "Science Indicators 2004" is released.) Ideally, HERI data should match the ACT data in the same year because ACT reports their data in the year of graduation and HERI reports data in the early fall of the first year of college enrollment. During 1991 – 2000 the ACT test-takers' interest in engineering declined from 8.5% to 6.4%. During the same period freshman intentions to major in engineering dropped from 11.0% to 9.0%. Thus the HERI numbers show the same general trend, but are considerably less monotonic. During 2000 – 2002, the ACT numbers continued to decline to 5.5% but HERI numbers rose to 10%, clearly divergent trends.

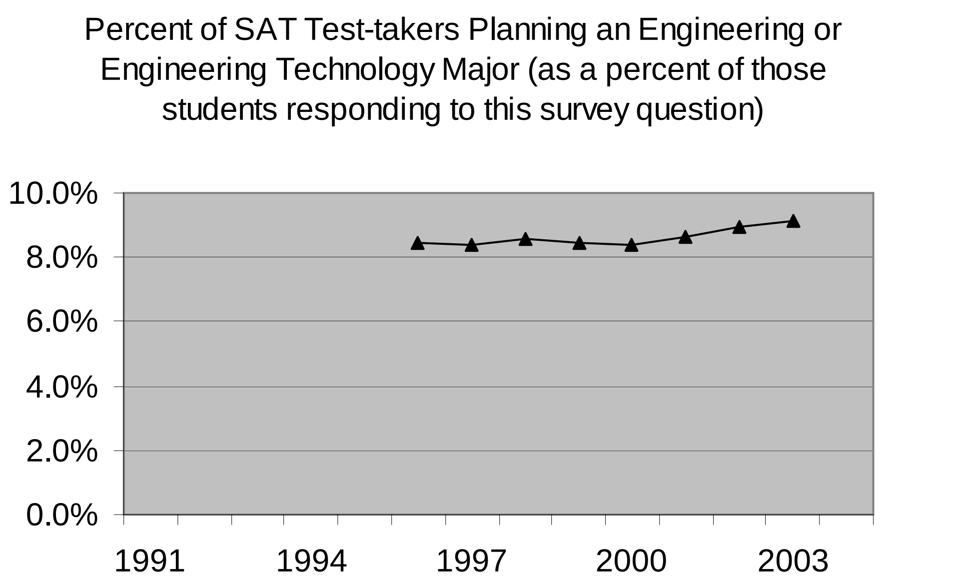
Percent of First-time Freshman planning to major in Engineering or Engineering Technology



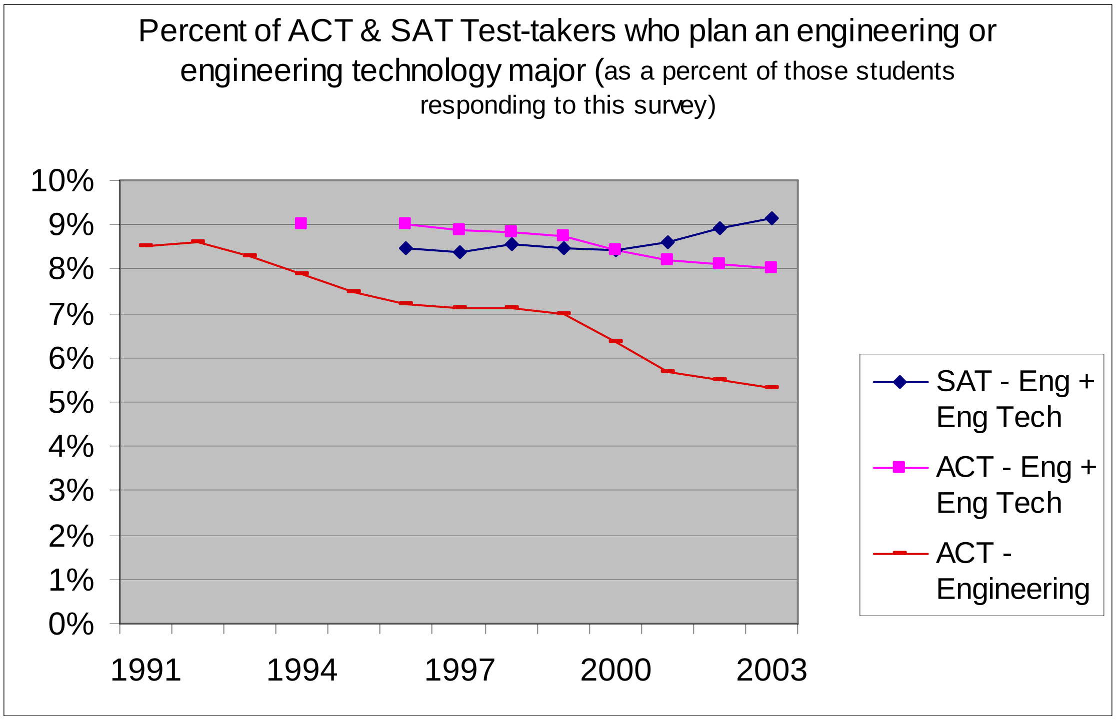
Source: NSF: Science Indicators 2002, Tables 2-11 and 2-12, based on special tabulations by the Higher Education Research Institute (HERI) at UCLA.

Why are the HERI data about 2.5 percentage points higher through 2000? There are a number of possible explanations. Most importantly, the collection of engineering disciplines that comprise "engineering" is not the same across these two series. The HERI data do not provide a separate category for engineering technologies and hence these are implicitly included in the 7 engineering categories available on the HERI survey. Second, the ACT data ignore a growing group of non-responders to the question about planned educational majors. (Most of this growth occurred after the year 2000. This is discussed in more depth later.) Third, neither HERI nor ACT data are drawn as national samples, so perfect congruence should not be expected. Finally, there is undoubtedly some winnowing that takes place as high school graduates enter college, with greater percentages of low scoring students not entering college right away or discovering that they do not qualify for admission into the school of engineering. Typically a higher percentage of students with high test scores plan to major in engineering.

The College Board data includes engineering technologies with engineering in measuring



Source: The College Board, "College Bound Seniors: A Profile of SAT Program Test Takers," various years.

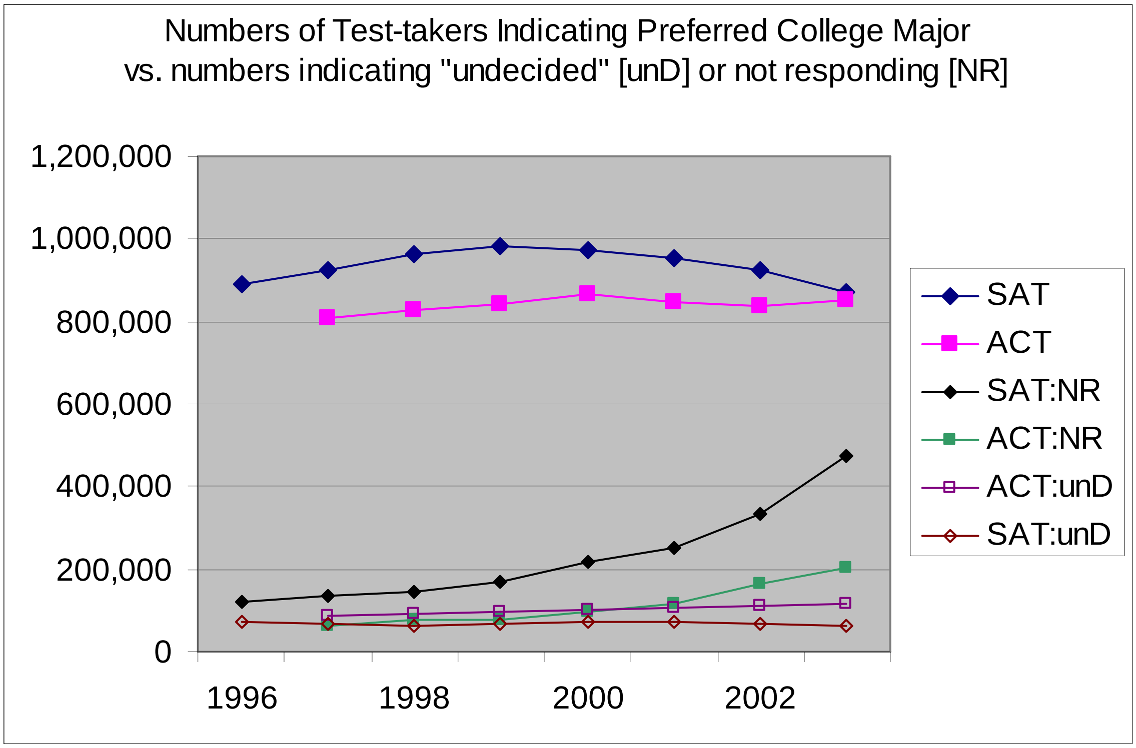


"intended college major." Their series show no change in interest during the 1997 – 2000 period and a rise from 8.4% to 9.15% during 2000 – 2003. In addition to this difference in disciplinary coverage, the same data issues associated with the other data must also be considered here. In particular, there was a very large increase in non- responders during the last four years. The discrepancy in disciplinary coverage can be solved by including ACT's data on student interest in engineering technologies. The above chart indicates that SAT and ACT data were actually in agreement in the year 2000. When engineering and engineering technology are considered jointly, the decline in interest among college-bound high school graduates in the ACT data is much less, dropping from 9% in the mid-1990s to 8% in 2003.

Nevertheless, ACT and SAT data show divergent trends and it is possible to explore some possible reasons for this divergence. This is a worthwhile exercise because the two sets of test-takers are largely non-overlapping sets, and because one variable might be divergent trends in average test scores of these two groups.

The ACT and SAT Student Profile Data

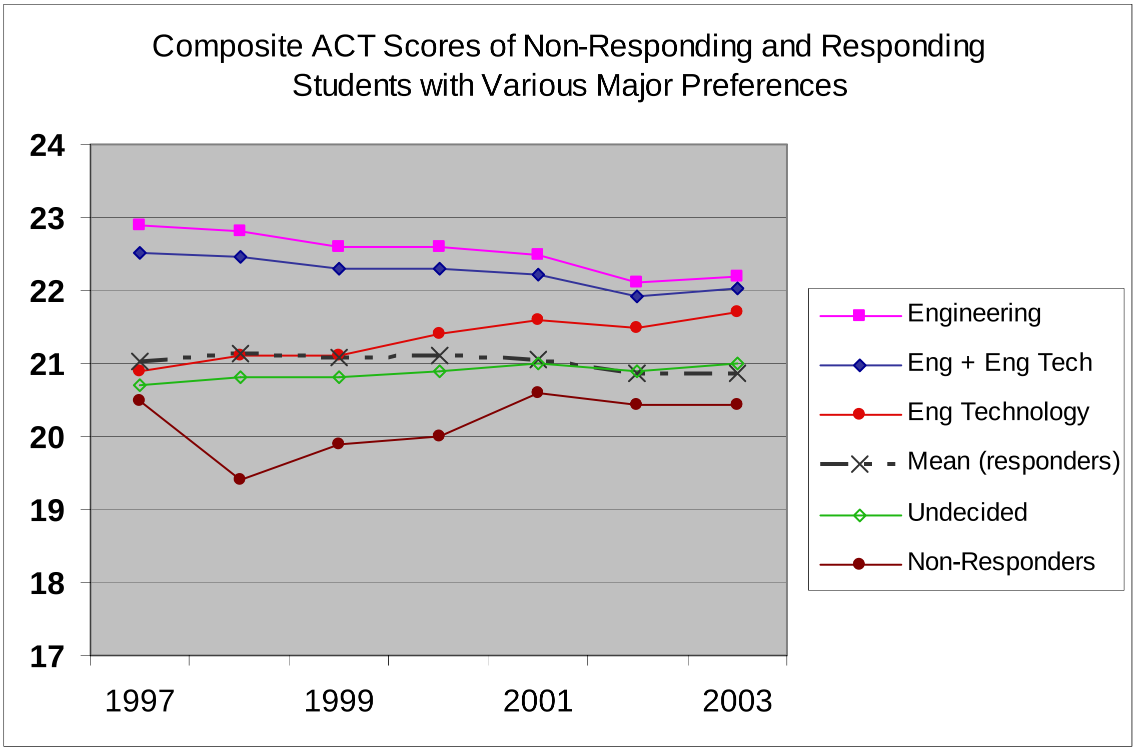
There are two key questions to address. One is whether there is any evidence that the growing fraction of test-takers who do not respond to questions about disciplinary preference (and other personal data) have biased the ACT's "planned educational majors" time series and the SAT's "intended college major" time series. The other is whether there are any trends in the average ACT composite scores and the SAT I combined mathematics and verbal scores for those indicating plans to major in engineering or engineering technology. These questions are at least partially related.



The trend towards non-response has been growing, particularly for the SAT test-takers. Because both the ACT and the College Board give students the option of indicating they have not yet developed a planned educational major, it is not necessary to consciously avoid responding in order to express uncertainty about the choice of a major field of study. In the chart above (examine the diamond-formatted lines) note that the number of responding students taking the SAT I peaked in 1999 and that there was a very large increase in the number of non-responders, but virtually no change in the number indicating they had not decided on a major field. Non-responders grew from 11% of test-takers in 1996 to 14% in 1999 and 34% in 2003.

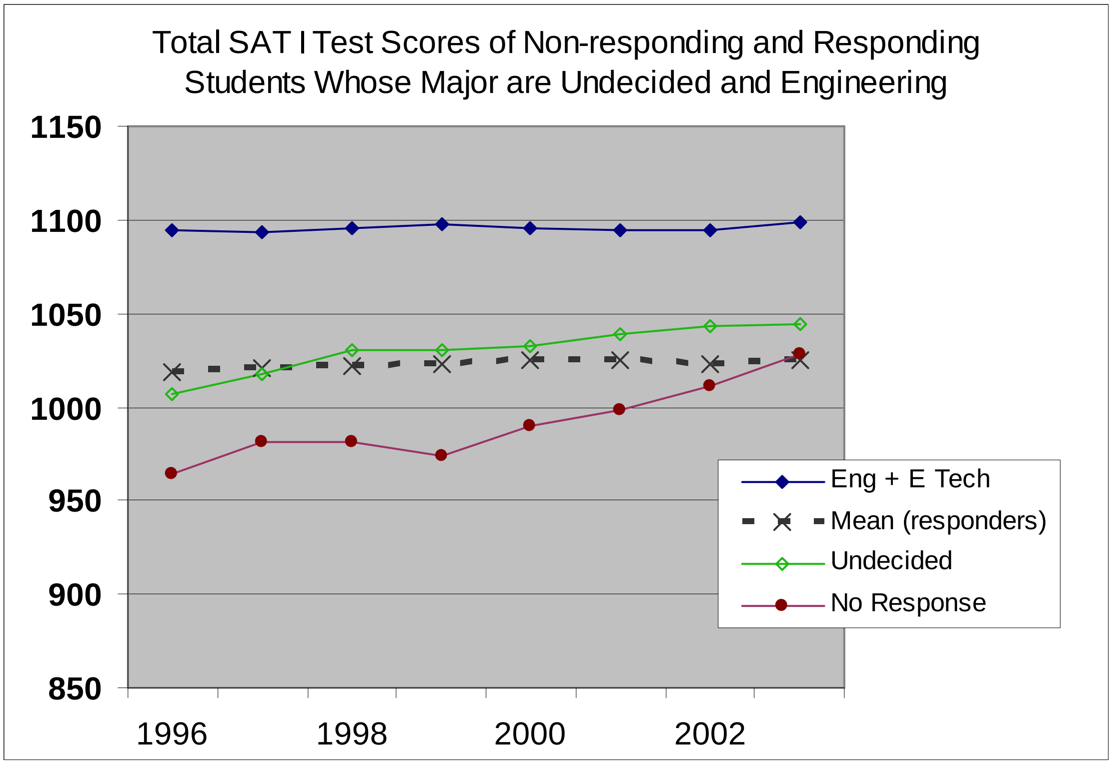
The ACT pattern of response and non-response was similar, but with a smaller growth in non-responders, who rose from 8% to 17% of the total test-takers during 1999 – 2003.

In determining whether these trends may have biased longitudinal changes, I examined the indirect evidence. Those students picking a major field (e.g. engineering) are drawn from the total pool of responders. Non-responders form a second pool that is a potential source of engineering majors. If the average test scores of the non-responders is far below the average test scores of responders, however, then one could infer that there were “slimmer pickings” from this second group. (Reaction to anticipated low test scores is a possible reason for non-response.) In order to make the appropriate comparisons, it was necessary to compute the average test scores of these two groups from other data that were supplied in the annual reports of the ACT and the College Board. The results are displayed in the next two charts. In the case of the ACT, note that the mean annual



composite test scores of responders changed very little during 1997 – 2003, dropping from slightly above to slightly below "21." The calculated mean annual test scores for non-responders dropped in the late 1990s, but during 2001-2003 returned to the 1997 estimated level of 20.5. The conclusion is that except for 1998 – 2000 there was not much difference in the responder and non-responder groups. Using percentiles, the mean composite test score of responders throughout the 1997-2003 period dropped only slightly from an estimated 57% to 56%. (The median composite test score is nearly a full point below the mean test score.) In contrast, the equivalent mean percentile scores for non-responders were an estimated 53% in 1997 and during 2001-2003, dipping to a low of 44% in 1998 (although the size of this dip could be partly the result of data errors).

The gap between the means of the responders and non-responders on the combined verbal and mathematics test scores on the SAT I was somewhat larger in the late 1990s



but progressively narrowed to zero in 2003. Using percentile measures, the mean test score of non-responders was estimated to be 40% in 1996 and 42% in 1999, rising steadily to 50% during 1999-2003. The mean percentile of responders was about 50% in every year. (There is not much difference in mean and median test scores on the SAT I.)

Trying several models of the relationship between test scores and the probability of preferring engineering, there was very little estimated bias in using the percentage of responders planning to major in engineering and engineering technology to characterize the entire population of test takers. The decline in the ACT percentage planning to major in engineering or engineering technology is slightly understated by probably no more than 1/10 of one percent as a consequence of the growth in the non-responder population. The rise in the corresponding SAT percentage is understated by probably no more than 2/10 of one percent as a consequence of the improvement in the mean score of the non-responders and the growth in this population.

<u>ACT Trends in Mean Scores of Students Preferring Engineering and Engineering Technology; Comparison to SAT</u>

The fact that the mean ACT score of students indicating a preference for engineering dropped steadily during 1997 – 2002 from 22.9 to 22.1 is somewhat disheartening but is actually not a large change. Further, it appears that part of this decline was due to well-prepared students shifting preferences from engineering to engineering technology.

Using percentile scores as the measure, the decline in mean test scores of students preferring engineering was from about 70% to 65%. The rise from 20.9 to 21.7 in the mean scores of students preferring engineering technology translates to a rise from about 56% to 63% in percentile equivalents. Because these two divergent trends occurred as student preferences were shifting from engineering to engineering technology, it appears that students qualified to choose engineering were increasingly choosing engineering technology instead.

The slight decline in the mean test scores of students preferring either engineering or engineering technology was from about 67% to 64% in percentile terms. This was still somewhat above the level of mean SAT percentile scores of students indicating a preference for engineering or engineering technology, which dropped from about 63% in the late 1990s to 61% in 2003.

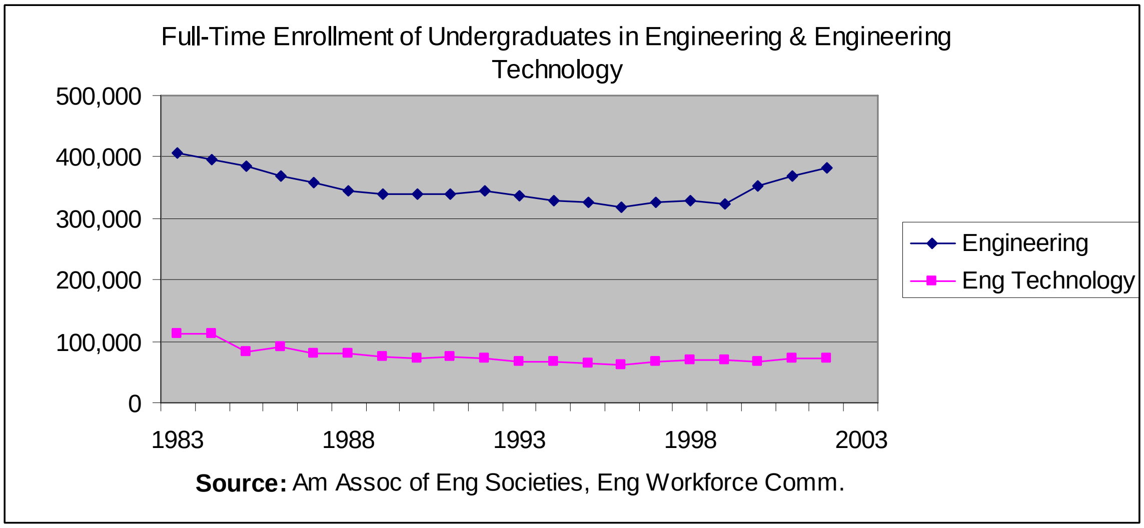
Enrollment Trends

Enrollment data reflect the interaction of student preferences of high school graduates seeking to enter college with the reality of affordability, college admissions decisions, and minimum standards for being allowed to major in engineering. These data are available directly from the Engineering Workforce Commission (EWC) of the American Association of Engineering Societies and from the American Society for Engineering Education.

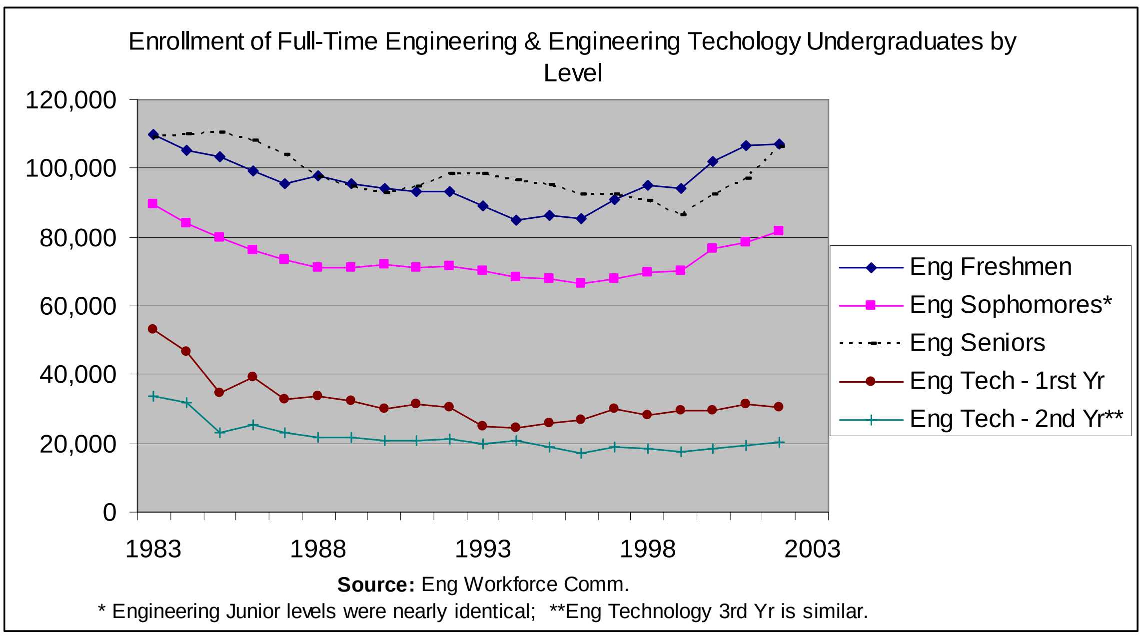
EWC data are published in NSF's "Science Indicators" and are otherwise available from the EWC for a subscription price. ASEE data are available for individual institutions from the ASEE website: www.ASEE.org/publications/Colleges. ASEE coverage of reporting institutions is a bit lower but data from both sources are largely in agreement about trends.

In addition, a synthetic data series on freshman enrollment in engineering can be constructed by multiplying the HERI data on the fraction of freshmen planning to major in engineering by the NCES data on first-time, full-time freshman enrollments in US colleges and universities. These synthetic numbers are in the same range as the EWC data.

The EWC data indicate a strong upturn in full-time undergraduate enrollment in engineering programs during 1999-2002 of 19% following a long period of slight decline (4%) during 1989-99. Full-time undergraduate enrollment in engineering technology rose by 17% during 1996-2002, following a long-term steady decline of 31% during 1986-1996. Part-time enrollment in each of these two fields has remained flat at 40K.



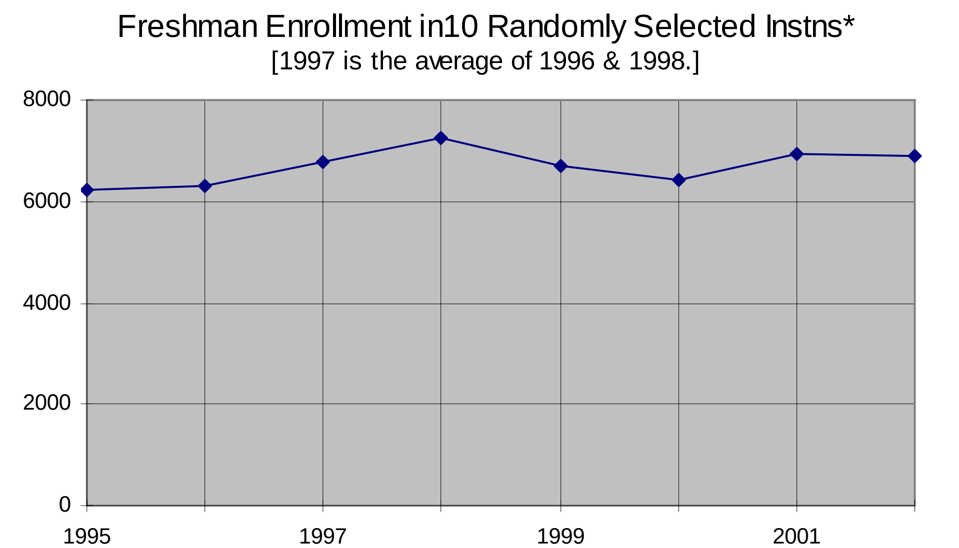
The leading edge of the resurgence in full-time undergraduate engineering enrollment has been the growth in full-time freshman enrollment, which began growing in 1997. It grew by 25% during 1996-2002, from 85K to 106K. It is possible that this overstates the growth in the national total because during these 6 years the number of reporting



institutions rose by 5% from 317 to 332. This raises the issue of institutional coverage in these data series; What fraction of all institutions with undergraduate engineering programs report data to the EWC? Is this fraction stable?

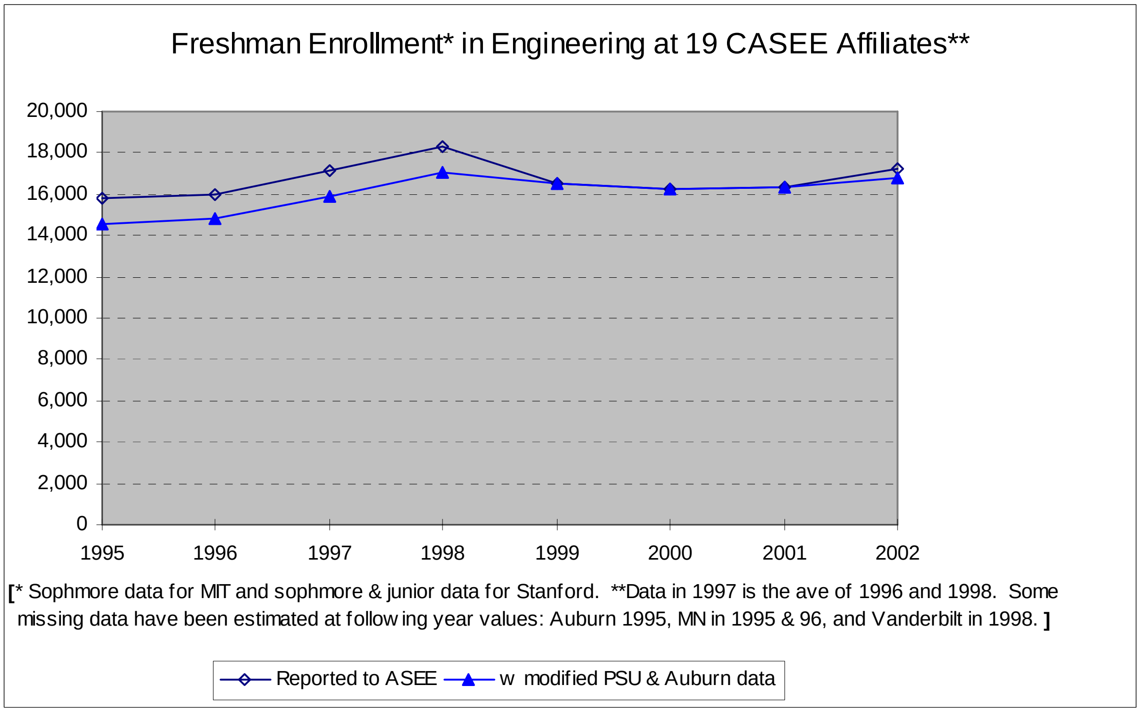
Another view on changes in engineering enrollment is obtained by examining the same set of institutions over time. I did this two ways for the 1995-2002 period, using ASEE data (which I could download from individual institutions). I randomly picked 10 institutions with large and small programs. I also examined changes in enrollment in the 19 CASEE affiliates with engineering programs. The SAT and ACT test scores of undergraduates in these programs tend to much higher than the mean scores of students taking ACT and SAT I tests who indicated they were planning to major in engineering or engineering technology.

Changes in Freshman Enrollment in a Random Group of 10 Institutions
The gains in enrollment were considerably less in this group. Enrollment grew by 6% during 1996-99 and another 3% from 1999-2002. Thus the gain during 1996-2002 was considerably less than the 25% measured by the EWC for the same period.



Source: ASEE. *They were Cal State - LA, UC-Davis, C-M U, CWRU (sophs), Co Schl of Mines, FL St + A&M, Purdue, TN, TX A&M, & Tufts.

Changes in Freshman Enrollment in the 19 CASEE Affiliates
In the process of examining these data, it became clear how total enrollment data reported by EWC or ASEE might contain some inaccuracies. There are a number of ways this can occur. First, there were 4 missing values from the 19 institutions and 7 years of data sought. (This is a 4/133 = 3% missing data rate). These missing values were crudely estimated by setting the missing values equal to the enrollment number reported the following year. Second, there were several institutions that do not allow freshman to declare engineering majors. Yet, they clearly have students who will earn engineering bachelors. This missing data problem was resolved by using data from the first year in which students are allowed to declare their major. Third, there was a clear change in the classification system used by Penn State in 1999, when engineering technology majors appeared to be separated from engineering majors for the first time. This resulted in a drop in reported freshman enrollment from the 2,400 range to the 1,200 range. I resolved this by halving the Penn State figures for 1995 – 1998. Finally, There appeared to be a change in the way Auburn classified freshman and sophomores in 2002. The freshman figure soared and the sophomore figure plummeted. I adjusted these numbers to maintain the historical (stable) relationship between freshman and sophomore enrollment levels at Auburn. This required reclassifying 421 “freshmen” as “sophomores” in 2002. (The freshman enrollment level still grew by 25% in 2002 after making this adjustment.) I have sent inquiries to both institutions asking for clarification.



Calculating the freshman enrollment levels in the CASEE affiliates <u>without</u> <u>adjusting</u> the Penn State and Auburn enrollment numbers, the measured growth during 1996 – 2002 is from 16K to 17.2K (7.5%). With the adjustments I made, the estimated growth was from 14.8K to 16.8K (13.5%). In either case, notice also that the entire net gain seems to have occurred in the 1995-98 period. Since 1998, there has been a 2% drop in freshman enrollment in the CASEE institutions. Thus, during 1998-2002 CASEE freshman enrollment dropped from 18% to under 16% of total freshman enrollment in engineering programs reported by the EWC. It may be worth further effort in examining ASEE and EWC data to determine in which institutions this growth occurred.

The CASEE Institutions

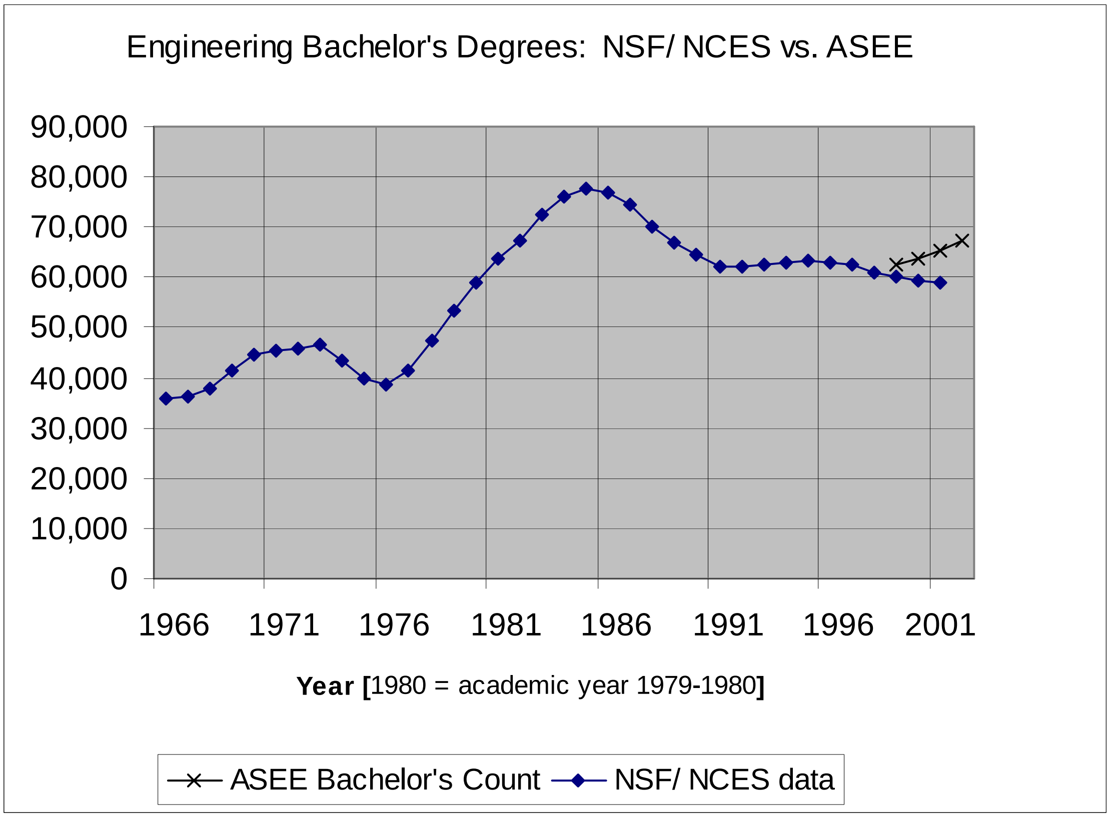
Arizona State University	
Auburn University	Purdue University
Colorado School of Mines	Rose-Hulman Institute of Technology
Cornell University	Stanford University
Georgia Institute of Technology	SUNY Stony Brook
Howard University	Texas A&M University
Iowa State University	University of Michigan
Massachusetts Institute of Technology	University of Minnesota
North Carolina State University	University of Texas
Pennsylvania State University	Vanderbilt University

<u>Changes in Bachelors Degrees Awarded in Engineering.</u>

A final indicator of changing interest in undergraduate engineering is the persistence of engineering students to complete their bachelor's in engineering. Studies have shown that events that influence HS students and college freshmen also influence other college students and recent drop-outs. Thus in the above chart indicating growth in the Freshman enrollment numbers there was a roughly similar pattern in the enrollment levels of sophomores, juniors, and seniors.

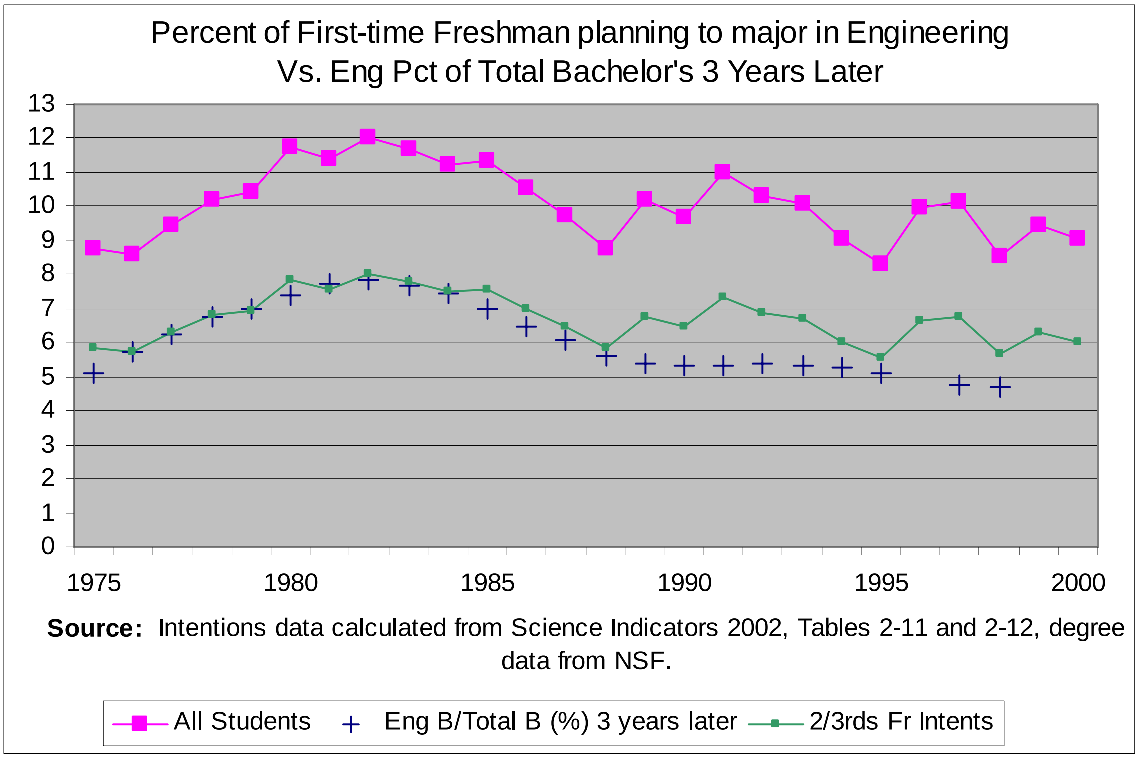
Degree data are collected both by the NCES, by the EWC, and by ASEE. The EWC and ASEE time profiles are quite similar although the EWC coverage of degree programs is somewhat higher. The NCES data are carefully vetted to ensure disciplinary congruence across all reporting institutions and to avoid missing values problems. This process insures their accuracy but hurts their timeliness.

Somewhat surprisingly, there seems to be a divergence in the NCES/ NSF and ASEE trends in degrees awarded in engineering in recent years. The NCES based data run



through 2001 and give no indication of an upturn in interest. The ASEE data run through 2002 and show a significant upturn of 8% during 1999-2002.

Tying Freshman Intentions to Bachelor's Degrees: What does the long-term trend tell us?
Earlier in this analysis, it was noted that historically the fraction of first-time freshman with intentions to major in engineering (HERI) have been good predictors of actual degrees earned during the 1970s and 1980s: Engineering Bach/Total Bach[t+3] = 2/3Eng Intentions[t]. The accuracy of this relationship has not been maintained.



This chart indicates that the relationship has degraded somewhat. In 1989 and later years, the construct of "2/3rds of freshman intentions" provides only an upper bound for the fraction of total bachelor's degrees awarded in engineering. Since 1991, a 5-year moving average of "2/3rds of freshman intentions" is about 1.5 percentage points higher than the ratio of engineering bachelor's to total bachelor's degrees three years later.

It is interesting to speculate on what this change in relationship might signify. It may indicate that it became more difficult to get into engineering programs during the 1990s. It may indicate a growing dissatisfaction with traditional teaching methods still employed in many engineering programs. Or it may signal growing student frustration with traditional engineering curricula where creative engineering work is not encountered until the junior and senior years. It may also represent the growing attraction of other majors which students discover once they are enrolled in higher education. Finally, it probably reflects a decline in the percentage of students who persist to the bachelor's degree without interruption.

Certainly it does not yet reflect much of the more recent improvements that have been occurring in engineering undergraduate programs, nurtured by grants from NSF and other programs. Students who graduated in 2001 were typically enrolled in engineering programs during 1996-2001 when these changes were beginning to take effect in the more progressive engineering schools.

Conclusions

The evidence about student interesting engineering studies and careers is quite mixed. It is not as negative as suggested in places in the recent ACT Policy Report "Maintaining a Strong Engineering Workforce" (by Richard Noeth, Ty Cruce, and Matt Harmston, ACT 2003). One passage in this report does match the information in the above graph:

"The percentage of potential engineering majors among various minority groups improved over the past twelve years, but the increase was due in large part to a decrease in the number of Caucasians who planned to major in engineering. In fact, the number of minority students planning to major in engineering has dropped. The actual number of African American and American Indian engineering majors was lower in 2002 than in 1991 (African Americans reached a low of 6,993 in 2002)." (page 9)

This accounting does not, however, adjust for the growing percentage of ACT test-takers who did not respond to questions about planned college majors. (This report is generally very informative and contains a wealth of information on both the academic preparation and interest of different demographic groups.)

Nor is the evidence as rosy as described in an online publication "Enrollment Records are Here – Degrees to Arrive Soon" (Copyright 2003 by Engineering Trends, Houghton, MI 49931):

"This report is aimed at providing an insight into what now appears to be an oncoming period of substantial degree growth at bachelor's, master's, and doctoral degree [levels]. New degree records in all three degrees appear highly probably in the near future."

To the extent that this prediction is correct, it will depend on rising enrollments generally to pull up the engineering numbers.