Five Year Plan
1986-1990

University of Pennsylvania

School of Engineering and Applied Science

To The University Community:

The following document is the third in a series of School five-year plans to be published For Comment. This draft has been considered by the Academic Planning and Budget Committee, as well as by the University administration, and it will be revised periodically by the School. Readers are urged to bear in mind the University tenets on future scale, which can be found in "Choosing Penn's Future."

Comments concerning this draft should be sent to Dean Joseph Bordogna at the School of Engineering and Applied Science, 107 Towne Building/6391.

—Sheldon Hackney, President *—Thomas Ehrlich, Provost*

Engineering and Applied Science Five Year Plan: 1986-1990

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Preface

In 1979 the Board of Overseers of the School of Engineering and Applied Science charged the dean to examine the School's programs and resources and to develop a comprehensive plan for its future as it entered the decade of the Eighties.

The request came as the University's five-year capital campaign, the Program for the Eighties, was approaching completion and at a time when the School had demonstrated success in achieving the program goals it had set in 1974 in anticipation of the campaign. Citing the increasingly competitive environment in which an engineering school in a private university was going to have to operate and expressing the desire to sustain the momentum gained during the Program for the Eighties, the Overseers asked that the School's goals be determined through a deliberate planning effort and that the plan be submitted for review to the University Trustees. Responding, the Faculty of Engineering and Applied Science examined the mission of the School, evaluated its programs, and worked to determine what course the School should follow.

In February 1980 the Board of Overseers was presented a preliminary version of the School's first comprehensive strategic plan which was subsequently refined to include detailed assessments of each departmental program. The Board reviewed the second draft of this plan at its February 1981 meeting and requested an incremental financial analysis to better evaluate four alternative strategies. Completed in May 1982, this extensive fiscal analysis was combined with academic objectives and led to a revised strategic plan published on 30 June 1983. This plan was developed with a focus on an "optimal" strategy selected by the overseers from among the four alternatives analyzed.

This present version of the strategic plan is the culmination of the School's planning experience, representing an integrated, coordinated and consistent plan for the future based on distinct intellectual competencies and benchmarks already achieved. It serves once again as the base for continuous study by all in the School, guided by the School's elected Faculty Council and Council's Planning Subcommittee.

The Plan presented here is an abridged version of the complete plan. In particular, among other deletions, the separate departmental component plans and all 26 appendices are not included.

School of Engineering and Applied Science
Five Year Plan: 1986-1990

Executive Summary

The University of Pennsylvania's School of Engineering and Applied Science (SEAS) is a contributor to the intellectual and financial base of the University and has received recognition for the quality of its education and research. Since 1975 undergraduate enrollments have tripled, full-time graduate enrollments have increased 50% and research has increased from $43,000 per faculty member annually to $123,000, a real-dollar growth of 42%. The School attracts the brightest students (freshman average combined SAT score of 1,310 in fall 1985, typical freshman ranking in the top 3% of high school graduating class) and ranks in the top ten among engineering schools nationally in per capita research. The productivity of the School in its various facets during the past decade has been extraordinary, as evidenced by the productivity profile summarized in the table shown.

The School is comprised of eight academic departments, each having undergraduate and graduate degree programs. Each department is administered by a chair who reports to the dean of the School. Presently, the standing faculty is 100 with 1,290 undergraduate students and 542 full-time equivalent (FTE) graduate students. Over the next five years, it is planned to increase the faculty to 125, undergraduate enrollment to 1,500 (the increment primarily dual degree with other Schools in the University), FTE graduate enrollment to 720, and per capita research to $170,000.

The strategic objective upon which these figures have been developed is to strengthen the core engineering disciplines within the School and, upon this base, to develop academic excellence and national leadership in specific fields where the School, *jointly with the University*, uniquely excels. Studies and operational success thus far have led the School to commit itself to comprehensively organized one-university programs in Bioengineering, Computer and Cognitive Sciences, Management and Technology, and Sensor Technologies, which the School believes cannot be easily duplicated elsewhere.

To accomplish these goals, a $50.0M resource development plan has been prepared. This plan provides $14.5M for faculty support, $6.5M for student support, $3.5M for opportunity funds, $10.5M for renovations and equipment, and $15.0M for construction to meet the School's current (28,000 square feet) and projected (110,000 square feet) space needs.

SEAS Productivity Profile: 1975-1985

	FY '75	FY '85	% Change
Faculty Size*	90	100	+11%
UG Enrollment	409	1,290	+215%
Graduate Full-Time			
MSE	160	294	+84%
PhD	134	146	+9%
Graduate Part-Time			
MSE	455	219	-52%
PhD	108	76	-30%
Graduate FTE	489	542	+11%
Student/Faculty Ratio	9.9	18.3	+85%
Total Research	$3,875,000	$12,315,000	+218%
		$6,134,000†	+58%
Research per capita	$43,100	$123,100	+185%
		$61,300†	+42%
Total Budget	$8,955,000	$29,159,000	+226%
		$14,550,000†	+62%
Degrees Awarded			
BSE	89	260	+192%
BAS	1	33	+3200%
MSE	108	176	+63%
PhD	40	39	-3%
CU Taught UG	2,888	5,556	+92%
CU Taught Grad	3,061	3,479	+14%
Total CU Taught	5,949	9,111	+53%
CU Taught per Capita	66.1	91.1	+38%

* Of the current faculty, 44 have been appointed within this period.
† 1975 dollars

Organization of the School

The School of Engineering and Applied Science currently is comprised of eight academic departments, each having undergraduate and graduate degree programs. Each department is administered by a chair, who reports to the dean of the School. Associate deans for Undergraduate Education and for Graduate Education and Research oversee their respective areas and likewise report to the dean. In the graduate area, degree programs are administered academically by nine graduate groups (eight named corresponding to the eight departments plus one in Transportation) whose members are appointed from among all faculty in the University.

Three of the School's eight departments comprise The Moore School of Electrical Engineering, with the chairs of these departments reporting on relevant educational (not fiscal) matters to the director of The Moore School (who is currently also the dean of the School of Engineering and Applied Science).

The School's Faculty Council is the faculty's official "voice" in the School's administration. Its six members, who are elected to Council by the faculty at large, meet regularly to review SEAS programs and plans and to maintain a continuous dialogue with the dean. The Council is formally the Long Range Planning Committee of the School.

Two research centers now operate within the School, both within the Department of Electrical Engineering: The Center for Chemical Electronics and the Valley Forge Research Center (the School's off-campus test site). The School also participates in two campus-wide research centers: the Center for Dental Bioengineering and the Laboratory for Research on the Structure of Matter.

Changes anticipated in this organization over the period of the plan include the establishment of two additional centers, one in Artificial Intelligence and the other in Sensor Technologies (which would subsume the Center for Chemical Electronics). Also, the School's Faculty Council is presently conducting a major study of two departments, Civil Engineering and Systems Engineering, which may result in organizational changes.

Current Assessment

The quantitative measures cited in the accompanying table and the qualitative measures to be discussed on the following pages indicate that the School is intellectually and fiscally well-prepared to enter a period of solidification and modest growth that will capitalize on Penn's potential for providing leadership in the emerging technologies that will dominate global industrial and economic advance for the rest of the century and beyond.

Important needs which must be addressed regardless of whether the School is to continue to improve or is merely to maintain the level and quality of its current operation include:

The need to increase the overall level of funding for graduate education, in particular, the requirement that first-year fellowships be available to attract top students to each of the graduate degree programs.

The need to provide faculty members with an environment and incentives that are conducive to scholarly research and teaching; specifically, to offer a level of compensation and quality of research facilities (laboratories, library and computing services) that will be competitive with those of their peers and not increasingly divergent from those in the industries that tend to attract top engineering graduates away from careers in academe.

The need to upgrade the School's teaching laboratories to the state-of-the-art and establish fresh laboratories in areas that are essential to the future of the academic program.

The need to strengthen the research effort through increased support from industry and other private sources to complement federal funding. By increased joint research with industry the School will be positioned better to focus attention on rejuvenating the nation's technological enterprise in the face of growing global competitiveness.

Faculty

There are currently 100 standing faculty members in Engineering and Applied Science, with 77% of that number holding tenure. Eleven of the faculty members occupy scholarly chairs.

All faculty members are expected to teach both undergraduate and graduate students and to conduct research. A policy of half time devoted to teaching and half to research is the guide, although primary emphasis is placed on the successful integration of these activities in order to maintain the academic program at the forefront of technological development.

A major concern of engineering schools across the country has been the need to improve the level of compensation for engineering faculty members in order to stem the flow of both present and potential educators to the more attractive offers being extended by some industries and some peer institutions. Penn has made an effort to resolve this problem over the past several years through a plan of marketplace salary adjustments. However, while some gain against inflation has been achieved, salaries of assistant and associate professors are presently slipping vis-a-vis peer engineering schools, particularly those at some public universities whose state legislatures are providing special support for engineering education.

Undergraduate Education

In fall 1984 semester, 1,290 students were enrolled in the School's two undergraduate degree programs: 1,042 as candidates for the Bachelor of Science in Engineering degree, 187 in the Applied Science program, and 61 freshmen enrolled on a "curriculum deferred" basis.

The curriculum deferred option, which was introduced as a recruiting strategy in the fall of 1977, has proved to be an effective way of attracting students who are not prepared to declare their engineering majors on being admitted to the School. The School is well prepared to handle these students because of the similarity of engineering and applied science curricula in the freshman year (essentially a liberal arts year), coupled with the customized nature of the advising program.

Current data regarding the undergraduate curricula in Engineering and Applied Science are summarized below.

SEAS Undergraduate Curriculum 1984-1985	Degrees Awarded 1984-85*	Total Enrolled 1984-85†	Student/ Faculty Ratio
Bachelor of Science in Engineering			
Bioengineering	27	137	11.4
Chemical Engineering	37	137	10.5
Civil Engineering	7	41	4.6
Computer Science and Engineering	65	228	13.4
Electrical Engineering	66	280	14.7
Materials Science and Engineering	4	15	1.2
Mechanical Engineering and Applied Mechanics	39	137	11.4
Systems Science and Engineering	15	67	13.4
Curriculum Deferred	-	61	#
	260	1,103	11.0
Bachelor of Applied Science	33	187	#
Total, SEAS Undergraduate Program	**293**	**1,290**	**12.9#**

* Includes totals for August, December 1984 and May 1985.

† For fall term 1984.

Applied Science students and freshman Engineering student selecting the "curriculum deferred" option are not assigned within a departmental program; each is instead assigned an SEAS faculty advisor based on his or her program interests. Thus these students add to the overall teaching and advising load for each department—as reflected in the student/faculty ratio for all SEAS undergraduates.

The above data indicate a wide disparity in student/faculty ratio among the various *undergraduate* curricula. It is useful to look at trends in these enrollments to see where faculty adjustments are necessary to meet undergraduate teaching demand. Trends can be illustrated by dividing the various curricula into two groups: the first, having relatively low enrollments, includes Civil Engineering, Materials Science and Engineering, and Systems Science and Engineering; the second, with higher enrollments, consists of Bioengineering, Chemical Engineering, Computer Science and Engineering, Electrical Engineering, and Mechanical Engineering and Applied Mechanics. With respect to the first grouping, trends since 1971 indicate that enrollments in Civil Engineering have dropped (even though construction remains the nation's largest industry, a perplexing dilemma); enrollments in Materials Science and Engineering are currently low, as they have been at Penn perennially; and, although enrollments in Systems Science and Engineering are low, they have been increasing dramatically since 1974. For the second grouping, enrollments in Electrical Engineering are increasing at a rapid, perhaps alarming rate, while those in Computer Science and Engineering have peaked and have actually decreased for the first time this year (it is expected, however, that this recent trend will be reversed again as the new Bachelor of Applied Science in Computer Science Program becomes well known and as the faculty responsible for this area increases in size to dampen the large student/faculty ratio).

Planned growth in undergraduate enrollment in recent years occurred partly as a result of the introduction of the Applied Science degree program in the fall of 1974. Today, Applied Science students comprise 14% of the undergraduate student body, with 80% of these students enrolled in the dual-degree Management and Technology Program that is jointly offered with the University's Wharton School. However, the most significant growth has occurred in the undergraduate engineering curricula, which have increased their enrollments by more than 250% during the same period (with a simultaneous improvement in quality and while national engineering enrollments increased half as much).

For the freshman class entering in the 1985 fall term, the School had an applicant-to-matriculant ratio of over 6.5 to 1, which compares favorably to the 4 to 1 norm for high-quality engineering schools across the country. The combined average SAT scores for freshmen entering SEAS this fall (1,310) is 40 points higher than that for the School's 1974-75 entering freshmen class. The typical SEAS freshman now stands in the top 3% of his or her high school graduating class.

Graduate Education

Graduate degree programs leading to the Master of Science in Engineering and the Doctor of Philosophy are offered in each of the School's eight departmentally-related graduate groups. In addition, the School offers a Master of Science degree program in Transportation. The Transportation program is administered by its own Graduate Group Committee comprised of faculty from SEAS, the School of Arts and Sciences, the Graduate School of Fine Arts, and the Wharton School and is under the fiscal guidance of the Civil Engineering Department. (A PhD degree program in Transportation is currently under development.) Students enroll in these degree programs on a full or part-time basis, with the majority of full-time graduate students receiving tuition and stipend support.

Enrollments in the School's graduate degree programs for the 1984-85 academic year are shown below.

SEAS Graduate Curriculum 1984-85	MS		MSE		PhD		Student/ Faculty
	FT	PT	FT	PT	FT	PT	Ratio*
Bioengineering			39	5	21	9	5.4
Chemical Engineering			52	14	14	2	5.5
Civil Engineering			21	7	5	1	3.2
Computer and Information Science			89	85	38	20	9.6
Electrical Engineering			27	40	23	5	3.4
Materials Science and Engineering			20	2	21	6	3.4
Mechanical Engineering and Applied Mechanics			24	26	11	13	4.0
Systems Engineering			18	39	13	20	10.2
Transportation	4	1					
Subtotal			290	218	146	76	
Total	**5**		**508**		**222**		**5.4***

* The SEAS graduate student/faculty ratio is shown on a full-time equivalent basis (computed as 1 part-time student equals 0.346 full-time student). Ratios shown within graduate group programs are based on the number of standing faculty in each related SEAS department.

With a current enrollment of 513 students in the master's program, the School has not yet regained the peak level of 615 MSE students enrolled in 1974-75, after dipping to a low of 430 students in 1978-79. The significant factor, however, is that today more than half of the present number consists of full-time students, while in 1974 only a quarter of the master's students attended on a full-time basis.

Enrollment in the School's PhD program has ranged between 200 and 225 students a year since reaching a low of 178 in 1975-76 (following the termination in 1972 of the Ford Foundation grant which had provided substantial support for graduate education, especially first-year fellowships). Again, as in the master's program, it is important to note that today, with 66% of the doctoral candidates attending on a full-time basis, the School has achieved its highest full-time to part-time ratio in the PhD program in recent history. For the School to have sustained its PhD enrollment and at the same time increased its percentage of full-time students within the program is worthy of note during a period when national enrollments in doctoral engineering programs were declining.

Minority Programs

The School has had a long-term interest in seeking out and including members of minority groups in its programs. At the undergraduate level it has formally participated since 1973 in the national effort to increase the number of minority engineering graduates at least to a level equal to their representation in the overall population of the nation. In this the school has achieved success to the extent that the percentage of enrolled minorities is twice the national average. Additionally, the school has effected leadership in the establishment, in its geographic area of Philadelphia, of the Regional Introduction for Minorities to Engineering (PRIME, Inc.) program, a consortium of universities, school districts, corporations, government entities, parent and community groups, and others to provide focused, pre-college preparation for minority citizens. This program identifies potential minority engineering candidates at the seventh grade level and provides substantive and continuous educational experiences through the twelfth grade. These students are identified in collaboration with school counselors, industry representatives, science, mathematics and communication teachers and are enrolled in PRIME classes during the academic year that are rostered for a minimum of two periods per week. Each participating PRIME school is matched with the resources and expertise of a member company or government agency. Many PRIME students also participate in an intensive summer program, the PRIME University Program (PUP). This program has served as an example for the development of similar consortia nationally and presently has 2,500 students involved locally.

Ethnic/racial minorities of U.S.A. citizenship currently comprise 9.6% of the enrollment compared with 14 years ago when the minority enrollment was half that percentage within a total student enrollment merely one-third today's size. Thus, the records show that recruitment and admission are understood and practiced vigorously; the effort in recent years is to improve retention.

With respect to retention, SEAS initiated some 10 years ago a pre-freshman year orientation and academic program. This program is designed to introduce incoming freshman students to the university environment, to enhance their analytical and communication skills prior to freshman year matriculation, and to learn computer techniques. Following the pre-freshman program, commencing with the first day of class in the freshman year and extending through the entire curriculum to graduation, students' progress is closely monitored by frequent review of their academic documents by faculty advisors and also by the Assistant to the Dean for Minority Programs. A review of the retention record since 1971 reveals that in the 11-year period between September 1971 to September 1982, the overall retention rate of United States' nationals of minority status enrolled in SEAS at Penn has been an impressive 79%, placing Penn among the leaders in this important national effort.

Whereas the undergraduate pool of minority engineering baccalaureates has grown handsomely during the past decade, practically all graduates have entered industry. This is primarily due to the lucrative salary compensation available in industry (three to four times the stipend a graduate student can expect while studying for a graduate degree), and the inability of the professoriate to convince the best graduates to attend graduate school. These reasons hold also for majority graduates, with the result that the overall pool of doctoral graduates to fill both industrial and academic posts has been waning and, in fact, is presently a national problem of significant magnitude.

With regard to the representation of women in the engineering profession the School is performing percentage-wise at twice the national average in student enrollment and three times the national average in faculty presence. At the undergraduate level, the contrast compared to the early '70's is exciting. In fall 1972 there were 17 women enrolled (4%); in the fall of '84 there were 269 women enrolled, representing more than 20% of the overall undergraduate enrollment (which had tripled in size during the same period). At the graduate level, women comprise 18.5% of the enrollment, up from 14% in 1979-80; it is perhaps significant that this increase has come primarily in the PhD program where 13% of the students are women; five years ago this figure was 2½%. Six percent of the SEAS faculty are women, which compares favorably with the national average for engineering schools of 2%. This has been accomplished through the success of a focused recruiting program. This same approach has not worked, however, in attracting black faculty to the School. The number of qualified black candidates is miniscule, and those who do become available are frequently attracted to higher paying jobs in industry—along with many non-black faculty candidates, as noted ear-

Quantitative Changes in SEAS from 1975 to Present

	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
Faculty Size	90	88	85	85	88	92	95	98	95	98	100
Degress Awarded											
BSE	89	84	88	113	140	191	174	219	243	243	260
BAS	1	3	8	8	9	17	18	21	38	28	33
MSE*	108	133	133	129	140	156	119	165	139	177	176
PhD	40	39	40	37	30	35	34	35	29	35	39
Student Enrollment											
Undergraduate: BSE	399	498	636	712	807	904	1,029	1,088	1,054	1,103	1,042
BAS	10	34	38	50	85	123	161	169	174	166	187
Curric. Deferred				39	74	93	59	59	73	72	61
Total	409	532	674	801	966	1,120	1,249	1,316	1,301	1,341	1,290
Graduate											
Full-time: MSE	160	173	157	154	198	233	244	280	319	272	294
PhD	134	100	102	99	105	102	126	133	125	159	146
Part-time: MSE	455	425	307	279	248	277	296	275	278	225	219
PhD	108	78	121	123	115	98	103	93	85	79	76
Full-time Equivalent†	489	447	407	392	429	465	508	540	570	536	542
Student/Faculty Ratio											
Undergraduate	4.5	6.0	7.9	9.4	10.9	12.2	13.1	13.4	13.7	13.7	12.9
Graduate	5.4	5.1	4.8	4.6	4.9	5.0	5.3	5.5	6.0	5.5	5.4
Overall	9.9	11.1	12.7	14.0	15.8	17.2	18.4	18.9	19.7	19.21	8.3
Research Activity											
Total Contracts and Grants	3,875,000	4,513,000	5,043,000	5,427,000	6,041,000	6,759,000	8,256,000	8,201,000	9,088,000	9,688,000	12,315,000
Per Capita#	43,100	50,100	59,300	63,800	67,100	71,900	85,100	82,000	95,700	98,900	123,100

* Includes Energy Engineering students not shown in departmental tallies. This program terminated in 1984-85.
† Total graduate enrollment, including the full-time equivalent of the part-time graduate enrollment (1 PT=0.346 FT graduate student).
\# Includes two research professors in 1976 and in years 1979 through 1982.

lier. The School, however, expects to make its first native Puerto Rican appointment to the faculty in July 1985.

In summary, there is strong commitment by the administration and faculty to the goal of increasing the presence of ethnic/racial minorities and women in the School to parity with their presence in the general population. Progress toward reaching this goal has been relatively impressive in undergraduate enrollment for both racial/ethnic minorities and women, and at the graduate and faculty levels for women. However, increasing the racial/ethnic minority presence in graduate programs and faculty remains a serious concern. This concern is being addressed through a more focused and vigorous recruiting program and, in the case of faculty, through increased attention on expanding the pool of doctoral candidates and communicating to them the benefits and rewards of an academic career.

Research

Penn's research enterprise in engineering is distinguished among engineering schools nationally in terms of both the quality and volume of its research. The program is carried out by a faculty that also bears extensive teaching commitments in the School's undergraduate and graduate programs. (In the undergraduate program, 95% of all courses are taught by standing faculty.) Despite the fact that the School has no "research faculty," which is unique among peer engineering schools, SEAS today has one of the highest levels of per capita research in the country and, in fact, ranks among the top ten.

The School is committed to the principle of every faculty member sharing equally in the research and teaching programs. In general, faculty members are expected to devote half of their time to teaching and half to research. During 1984-85, there was a total of 226 active projects with gross dollar support at a level of $23.5M. The faculty submitted a total of 220 new research proposals during the same year totaling $23.8M and, of the 216 support decisions reached during 1984-85, 110 resulted in awards, for a success rate of 51% and a dollar award success rate of 60%. These success rates are well beyond the norm and provide the confidence on which this strategic plan is based.

In 1975 the School's research budget was approximately $4 million for a faculty of 90 members. Over the next five years the program continued at about the same level, with the budget increasing to $6½ million for a faculty of comparable size in 1980. It should be noted that much of the School's effort during this period was focused on improving the academic programs and recruiting greater numbers of full-time students to both undergraduate and graduate degree programs. With the approach of the 1980's, however, and having made substantial gains in both the quality and number of students enrolled in Engineering and Applied Science, the School began to place emphasis on attracting more sponsored research.

The results of this renewed focus on the School's research enterprise were dramatically evident in 1980-81 when the School's research budget in one year increased 22% to $8½ million, reflecting an 18¼% increase in per capita research (which that year grew to more than $85,000 per faculty member). These gains were sustained through 1983-84 and the results for the current year (1984-85) indicate the School did $12,317,000 worth of sponsored research, further increasing the per capita level of research to $123,100. This per capita performance maintained the School among the top ten nationally. The School has sustained its top-ten ranking through the first five years of the 1980's and expects to continue this achievement for the foreseeable future.

A summary of the growth in research enterprise from 1975-85 is given graphically in Fig. 1. Overall, this performance represents 58% real growth for the decade and an impressive 24% real growth over the last year.

Facilities

The School currently occupies approximately 184,000 square feet of space within the University. The majority of this space, approximately 135,000 square feet, is devoted to SEAS laboratories and faculty, graduate student, and supportive staff offices. The balance is assigned to "general administration" within the University's facilities system—this space being comprised of classrooms, libraries, lounge, storage and central administrative space assigned to the Dean's Office.

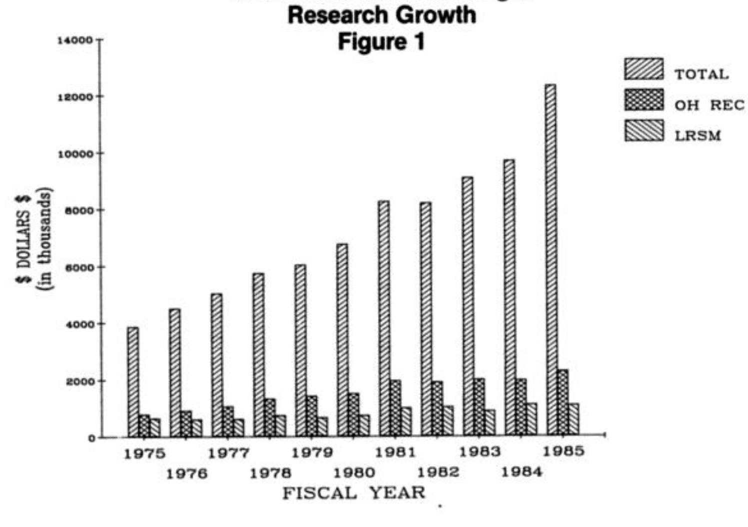
It has been conservatively estimated through three separate studies that SEAS currently faces an immediate space shortage exceeding 28,000 square feet. Further, to realize the objectives of the five-year plan, an estimated 110,000 square feet additional space (over existing) will be required. Using a factor of 1.6 to translate net into gross areas, it is projected that new space of approximately 175,000 square feet is needed. The importance of this space to the plan has been exemplified by making it the focal point of the entire five-year development campaign. The University has agreed with this assessment and has committed Hayden Hall, a building built in 1896 as a Dental School and adjacent to the Towne Building, for SEAS use. Partial occupancy of this building will commence in August 1985 and it is expected that complete occupancy will take place in 1987. The space is slated for Bioengineering and the School's Educational Resources Center. In addition, the facilities plan contains a proposal for the construction of a new wing, as well as plans for increasing the total square footage available within its existing space.

SEAS is physically located in three buildings on the University's campus: the Towne Building, built in 1906; the Moore School, whose original structure was built in 1909, with the additions in 1959 of the Pender Laboratory and in 1965 of a Graduate Research Wing; and the Laboratory for Research on the Structure of Matter (LRSM), built in 1963. The LRSM space occupied by SEAS is used to house the School's Department of Materials Science and Engineering, which shares extensively in the LRSM interdisciplinary program. In addition, SEAS currently has the use of space in what was formerly the Edison Electric Institute, now known as the Edison Building and located adjacent to the LRSM on Walnut Street. From the time of their original construction, these campus facilities have undergone no major renovations, with the only significant upgrading of electrical or other systems being accomplished in conjunction with isolated renovation projects involving a single laboratory, office or other facility. The result by the mid-1970's was that the School's facilities were generally outdated and in serious need of upgrading, a problem common to most engineering schools and, indeed, most science departments.

Since 1975 the School has spent approximately $10 million on facilities improvements. Roughly half of that amount was obtained through the capital campaign cited above; the remainder of these funds has come from the School's operational funds, which have been used either to make up the short-fall on projects lacking full funding (particularly projects to support a successful commitment to funded research) or to accomplish essential renovations for which an outside source of funds could not be found. In limited areas funds have been obtained through special project grants but "equipment grants," as noted earlier, have generally not been available.

The remaining facilities improvements that the School feels it must accomplish within the five-year range of this plan, including the one-University Computer and Cognitive Sciences, Bioengineering, and Sensor Technologies programs, total some $25 million, minimally. The School recognizes that this number is large; but given the neglect of these

SEAS Quantitative Changes
Research Growth
Figure 1



needs over a period of years, it considers the figure to be realistic and in fact conservative. Engineering schools across the country have undertaken programs to upgrade or augment their facilities, and Penn with a $25 million program falls at the lower end of the scale of these investments. (An ongoing detailed survey on this issue has been conducted during the past several years and can be found in Appendix 6 of the unabridged Plan.)

Peer Comparison

The School routinely compares its programs and performance with engineering schools across the country. With regard to such quantitative indicators as faculty size, research volume, salaries, and enrollments, this information is readily available and these comparisons easily made. However, qualitative indicators such as the research performance of the faculty or the quality of students enrolling in a school's degree program are difficult to identify in measures that are meaningful, and the means are limited for gathering these data on a common basis among the schools. It is nevertheless important that such comparisons be an integral part of the school's day-to-day operation and long-range planning; thus the School has selected a number of measures for comparison, including those criteria which are commonly cited in national rankings of engineering programs.

Ten engineering schools (including Penn) make up the peer group with whom SEAS believes it is in direct competition:

University of California, Berkeley
Carnegie-Mellon University
Columbia University
Cornell University
Massachusetts Institute of Technology
University of Michigan
Princeton University
Stanford University
Washington University—St. Louis

Likewise ten schools that have certain program areas or departments that can be considered a peer of SEAS, but overall do not share the across-the-board comparison with SEAS have been designated the "related" group:

California Institute of Technology
University of California, Los Angeles
Case Western Reserve University
Georgia Institute of Technology
University of Illinois, Urbana
University of Minnesota
Northwestern University
Rensselaer Polytechnic Institute
University of Texas, Austin
University of Wisconsin

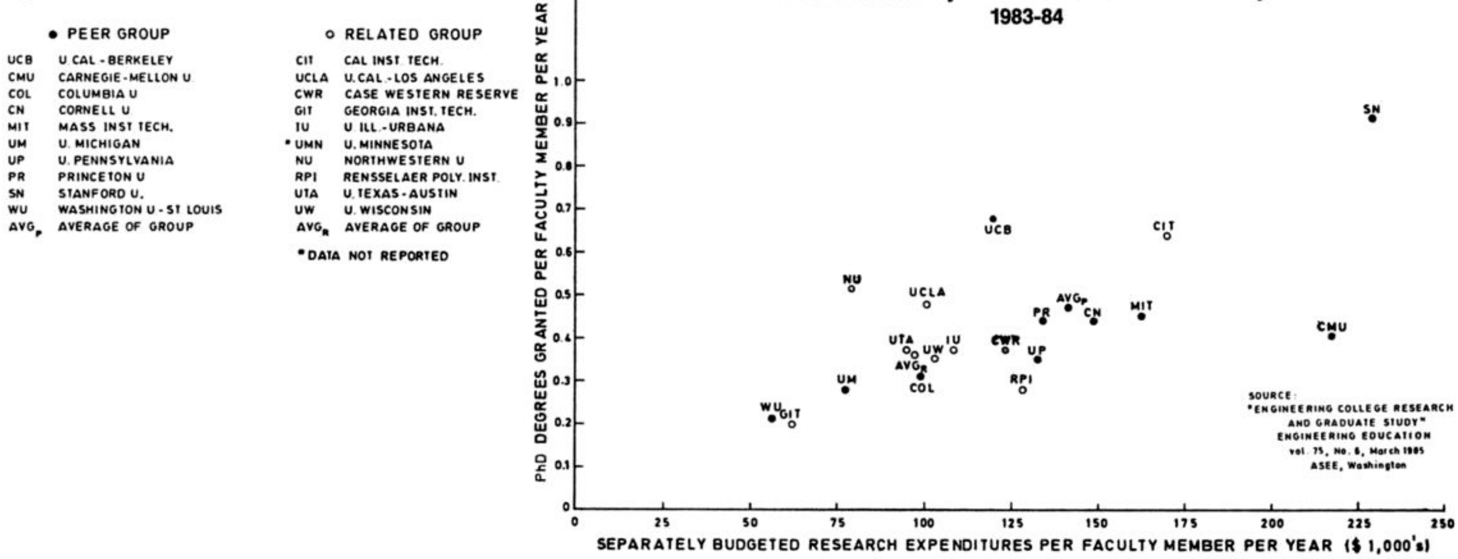
Current comparisons among the peer and related groups are summarized in the table below. Fig. 2 illustrates research and PhD comparison graphically. The primary source for these data is the journal, *Engineering Education*, published by the American Society for Engineering Education. Additional information (mean SAT scores for the entering freshman class) has been obtained through direct contact with the schools and is included in the comparison.

SEAS Comparison with Peer and Related Engineering Schools
(Derived from 1983-84 data reported in *Engineering Education*)

	Undergraduates		Graduate Programs			Research
School	S/F Ratio* (BSE)	Mean SAT's† (Fresh)	S/F Ratio*	PhD Degrees/ Fac. Memb.	MSE Degrees/ Fac. Memb.	Faculty Per Capita Research
Pennsylvania	11.0	1300	4.3	.36	1.8	$132,000#
Peer Group						
Cal, Berkeley	12.2	1297	7.1	.68	2.2	$122,000
Carnegie-Mellon	12.8	1290	5.4	.41	1.1	$217,000
Columbia	10.6	1280	6.8	.31	2.8	$99,000
Cornell	11.8	1291	4.5	.44	1.9	$149,000
MIT	8.1	NA	6.1	.45	1.7	$162,000
Michigan	16.1	1250§	5.6	.28	2.2	$76,000
Princeton	11.4	1324	3.6	.44	0.8	$133,000
Stanford	8.6	NA	10.2	.91	4.7	$229,000
Wash. U., St. Louis	13.9	1310	5.5	.21	1.7	$56,000
Average	11.7	1292	6.1	.46	2.1	$138,000
Related Group						
Cal Tech	4.6	1380	5.4	.64	1.3	$171,000
UCLA	11.8	NA	7.6	.48	1.8	$101,000
Case Western	31.8	1194	6.1	.37	1.2	$124,000
Georgia Tech	22.0	1182	4.2	.20	1.6	$63,000
Illinois, Urbana	13.2	NA	1.5	.37	1.1	$109,000
Minnesota	24.4	1159§	NA	NA	NA	$54,000
Northwestern	10.5	1280	6.1	.51	1.4	$79,000
Rensselaer	16.6	1266	6.5	.28	2.1	$128,000
Texas, Austin	32.0	1133	8.1	.37	1.8	$95,000
Wisconsin	22.7	NA	5.2	.35	1.4	$104,000
Average	19.0	1228	5.6	.40	1.5	$103,000*

* Student/faculty ratio, based on full-time enrollments only.
† SAT scores obtained from admissions offices of schools listed for fall 1985 unless noted otherwise. Detailed information is available in the SEAS Undergraduate Office.
# Includes total LRSM research for 1983-84.
§ 1984 Mean SAT's
NA—Not available

Figure 2



The Planning Effort

In April of 1979, as the University's capital campaign, "Program for the Eighties," was drawing to a close, the Board of Overseers for Engineering and Applied Science asked the School to look beyond the scope of its existing development program and prepare a detailed plan of operation for the 1980's.

The Overseers' request in 1979 for a long-range plan came at a critical time for the School. Enrollment in the Bachelor of Science in Engineering curricula had more than doubled in the years since the Board was formed in 1975; and the Bachelor of Applied Science program, which was implemented during the 1974-75 academic year, had proved to be a successful degree option with increasing numbers of students seeking entry into the program. Full-time graduate enrollments had begun to increase, as planned, and the School was preparing to focus on the expansion of its research program. The School was operating within a balanced budget, its accumulated debt had been paid off, and the plan for eliminating the long-term accumulated deficit of The Moore School was proceeding as scheduled (this deficit was ultimately eliminated in Fiscal Year 1982). Having reached this point, the faculty was facing a new set of questions about the scope of the School's operation and its potential for development:

- Where should the limit be set for growth in the undergraduate program? What percentage of the undergraduate enrollment should be made up of Applied Science students?
- How large should the full-time graduate program be in relation to faculty size, and where would the School obtain support for the increasing numbers of students it was attracting?
- What areas should the School pursue in the development of its research program? How could the overall research effort be linked more effectively with industry and with other areas of the University in interdisciplinary cooperation?
- How would the School make the improvements in the physical plant that were by this time essential to the continued operation of the program?
- What was the optimum size of the Engineering and Applied Science faculty? Did the School have the critical mass necessary to compete with its peers and to pursue its plans for development?

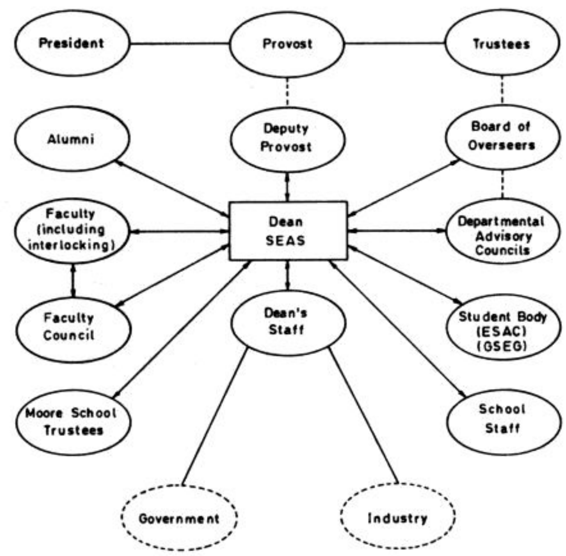
The gains made by the School from the time Penn's four separate engineering schools were consolidated in 1972 up to 1979 were the result of an aggressive, but ad hoc approach to solidifying the School's position within the University at a time when its continued existence was in question. The approach had succeeded; but as these new questions arose in the face of this success, the School lacked a rational and consistent means for evaluating its programs and projecting its course for the future. Thus it was in 1979 that the School formally addressed the requirement for developing a long-range plan.

Throughout this six-year period, much effort has been devoted to developing the planning process as well as to generating and annually updating the plan itself. As a result, when the University administration announced its intention in 1982 of focusing on long-range planning, the School was well prepared to assume its role in what is now a University-wide process.

The components of the SEAS planning team and their relation to the central University planning process are summarized in the diagram below.

Today the School has in place the means for proposing and evaluating educational innovations and research ventures in a manner that will insure for Engineering and Applied Science at the University of Pennsylvania: the proper allocation of the School's limited resources; conscious and planned adaptation to the continuously changing opportunities and constraints faced by this and other engineering schools; the promotion and development of program strengths, coupled with the amelioration of weaknesses; and the accomplishment of this within a framework of fiscal stability and responsibility.

Planning Team
An Iterative and Interactive Process



The Plan

The challenges presented to an engineering school in the mid-1980's are great. Never before have the opportunities for technological advance been so abundant or diverse in scope. Never before has the responsibility to provide future leaders with an understanding of the role technology plays in our lives been so vital to the future well-being of our society. To meet these challenges in an era of limited resources—and to excel in the effort—requires an approach that is at the same time bold yet realistic. Through the program of strategic planning it initiated six years ago, the University of Pennsylvania's School of Engineering and Applied Science has prepared to meet these challenges. The following presents a five-year strategic plan that is both ambitious in the scope of the proposed program, yet realistic in terms of the School's prospects for achieving its goals.

Objective

To achieve its potential, and in so doing to enhance the quality of the University of Pennsylvania, the School of Engineering and Applied Science has adopted the following objective:

> To strengthen the disciplinary core program within the School and to develop academic excellence and national leadership in specific fields where the School, jointly with the University, uniquely excels.

As an engineering school located within the University of Pennsylvania, SEAS has at hand the resources and a cooperative interdisciplinary environment that seem unequaled among other engineering schools. The School is proud of its tradition of quality academic programs, pioneering research, and achievements at the interfaces of disciplines, and notes that much of this success has involved joint associations with other disciplines within the University. But it is the now realizable potential to fully integrate the Engineering and Applied Science programs throughout the University that distinguishes the School from its peers.

Were this integration to be allowed to take place without boundaries and a carefully charted course for development, the result would unquestionably be a dilution of the School's constrained resources among numerous uncoordinated activities throughout the University—to the detriment of all and the jeopardy of the distinction the School and the University now enjoy among their peers. It was therefore essential that the School, in setting its objective, identify those program areas in which it should focus, i.e., those areas in which the School and the University have both the resource base and the faculty commitment upon which to build major interdisciplinary programs or "thrust" areas.

Thus it is that the School has developed a five-year plan to *strengthen its core disciplines,* correcting existing weaknesses and enhancing the overall program, in conjunction with its associated plans *to develop University-wide efforts in Bioengineering, Computer and Cognitive Sciences, Management and Technology and Sensor Technologies.*

Key Issues and Assumptions

A number of factors can seriously affect the School's plan to achieve its objective, and these matters have required close examination in the preparation of the plan. The current assessment of these factors and the way they might influence the School's course are presented below.

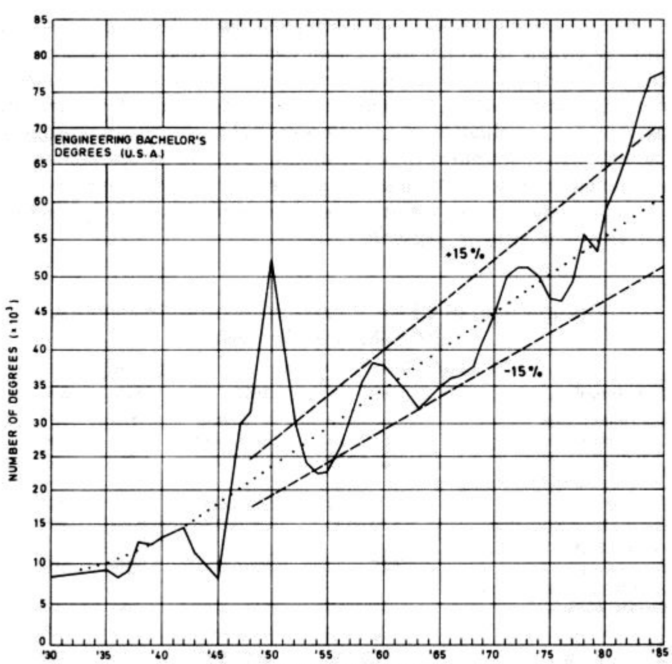
The Future of Engineering Education

The change in patterns of federal funding of research, coupled with growing industrial support of advanced technology programs in academe, is creating a focus on educational programs at those schools with the most extensive existing resources and the broadest opportunities for interdisciplinary research. This will cause funding to tend to be directed to those schools where the quality of research is already high and program interests parallel industrial interests and national needs, particularly with regard to large-scale systems synthesis in engineering research. The result of this shift is likely to be a concentration of resources among a small number of outstanding schools, whose distinction from the larger number of remaining schools will become increasingly sharp. SEAS is in an excellent position to attract significant research and program funding from both government and industry and, by virtue of the diverse resource base it has at hand within the University, it can emerge from this process as one of the leading engineering schools of the future.

Trends in Undergraduate Engineering Enrollments

While demographic data reveal that the total number of students reaching college age each year will continue to decline during the rest of the eighties and through the early nineties, engineering should become an increasingly more attractive career option for high school students because of the long-term, broadbased demand for engineers and society's heightened focus on technology. Furthermore, though cyclical patterns of engineering enrollments will likely continue, they historically fluctuate about an ever-increasing mean (see Fig. 3). Thus, with continued *vigorous* recruiting SEAS should be able to compete successfully for its share of the market in its engineering curricula, and its applied science and dual-degree programs will offer an important balance that will contribute to the School's success in attracting highly talented students with a diversity of career interests.

Engineering Bachelor's Degrees (U.S.A.)
Figure 3



Trends in Graduate Engineering Enrollments

Attracting well-qualified applicants to graduate engineering programs will be perpetually difficult as long as baccalaureate graduates continue to command salaries in industry equivalent to those offered doctoral engineering graduates entering academic careers and as long as those salaries exceed, by a factor of three to four, the stipends offered doctoral graduate students. In the face of this national problem, the School remains committed to operating a strong graduate engineering program and recognizes that it must *vigorously* compete to attract the best possible applicants and be prepared to offer them competitive fellowships, especially for the first year of study. In some departments which have recruited vigorously and continuously (e.g., chemical engineering), the School has experienced great success in this competition with industrial demand, especially with regard to matriculating U.S. nationals; thus, the challenge is to apply techniques learned here to the other graduate programs, a process begun in 1983 and which is now beginning to bear fruit in several departments.

Faculty Compensation and Supportive Facilities

In a related issue, the widening disparity between engineering professorial salaries and, even more so, available laboratory and office facilities compared with those of research PhD's in industry, presents a critical problem to engineering education in general. SEAS appears to be keeping pace with its peers in full professor's salaries but is slipping in assistant and associate professor salaries. The pool of qualified applicants for junior faculty positions has been dwindling in recent years and statistics indicate it will continue to do so for some time: there are 2,500 open faculty positions in engineering presently across the nation and only 3,000 engineering doctorates are being graduated per annum, over two-thirds of whom enter industry or, in the case of foreign nationals, return to their native land. A major additional dilemma is the difficulty academe experiences in sustaining and improving its facilities compared with private industry. Engineering facilities in both academe and industry are increasingly capital intensive and, though industry has been generous with its support to universities during a period of federal government malaise in funding laboratory improvement, academic facilities are not what they should be as a base for first class education and research.

Trends in Research Funding

The School is in an excellent position to compete for industrial support of its research and graduate programs. This position will be enhanced by the increasing involvement of the faculty in interdisciplinary research programs, whether on an individual basis or as part of University-wide thrusts. The faculty's success in recent years in raising its per capita level of research primarily from government sources to one of the highest among this country's engineering schools has been solid preparation for the five-year period of research growth projected in the plan.

The School's Role within the University

The School is a significant component of the University of Pennsylvania by virtue of the quality of students it attracts to its programs, the level of research activity it maintains, the resulting income it generates for the University through tuition and overhead charged on research contracts, and the broad-based intellectual contributions it makes to the University. The School accepts that fiscal viability and scholarly quality are inextricably related and that all major adjustments to existing programs or additions of new programs must consider this pairing of factors. Moreover, it believes that its fiscal performance over the period of the last 10 years attests to its ability to proceed with its plan on a responsible basis.

Regional Cooperation

With the demand for improved technology extending into virtually every area of society and with the resources with which to develop that technology becoming increasingly strained, it is imperative that the School capitalize on the opportunities it has for cooperative ventures involving local industry, government, and other academic institutions. The recent success of attracting support from the Commonwealth's Ben Franklin Partnership program to create the Advanced Technology Center of Southeastern Pennsylvania (ATC/SEP) is testament to the School's potential for successful leadership in regional technological activities.

Ability of SEAS to Raise Capital Funds

The School's experience during the Program for the Eighties, 1975-80, helped it to develop a level of sophistication in fund raising. In the years since that capital campaign, the School has focused attention on upgrading its internal development resources to complement the University's development staff in preparation for the effort that will be necessary to raise the funding required over the next five years. The result thus far has been a detailed Development Plan that was approved by the Trustees in October 1984 and a doubling of gift income from FY 1983-84 to FY 1984-85.

Goals

To achieve its objective, the School has identified a set of goals or "targets" over the course of its plan. These goals, expressed in size of faculty, numbers of students, and level of research activity, were set first at the departmental level based on the assessment of how each program should and could progress over the five-year period. The filtered sum of these goals for the eight departments provides a profile of the School in 1990 which is compared with that of the School today in the table below.

It should be noted that the targets projected for SEAS are those which the School considers necessary to reach its optimum scale of operation. While scheduled over a five-year period, it is of more importance that the changes occur in a coordinated and responsible fashion. Thus the *pattern* of change takes precedence over its timing, and the plan will be extended over a longer period if necessary.

Faculty Size

In the past decade, the faculty has corrected a number of program weaknesses and has been innovative in developing successful new cross-School academic program areas such as the Applied Science, Management and Technology, and Computer and Cognitive Sciences Programs. The spirit and drive that the faculty brought to these tasks are at their peak in the face of the gains that have been made. Referring to the two-part objective presented, this means the current faculty is adequately prepared to maintain the disciplinary core program of Engineering and Applied Science at the University of Pennsylvania.

With a projected faculty of 125, SEAS will still be among the smaller prominent engineering faculties in the country, but this size will allow the School to bring expertise to the faculty in specific areas where it is lacking currently and where it will be needed in order to mount the major interdisciplinary programs in Bioengineering, Computer and Cognitive Sciences, Management and Technology, and Sensing.

Student Enrollments

Regarding student/faculty ratios, an increase in faculty size permits some growth in enrollments in the School's degree programs where it is prudent to do so. But it also permits the School to correct existing problems in this area. The enrollment targets for the School are presented in the table below and provide a test of these enrollment projections against current enrollments using the student-to-faculty ratio as the means for comparison.

Comparison of SEAS Student/Faculty Ratio

1985 to 1990 (fall semester of years noted)

Department	Undergraduate* 1985	Undergraduate* 1990	Graduate† 1985	Graduate† 1990	Overall 1985	Overall 1990
Bioengineering	12.7	11.6	5.4	5.2	18.1	16.8
Chemical Engineering	11.3	12.0	5.5	5.4	16.8	17.4
Civil Engineering	7.3	7.9	3.2	5.2	10.5	13.1
Computer and Infor. Science	16.2	13.9	9.6	8.0	25.8	21.9
Electrical Engineering	15.9	12.5	3.4	4.4	19.3	16.9
Materials Science and Engineering	1.8	3.0	3.4	4.1	5.2	7.1
Mechanical Engin. and Appl. Mechanics	12.5	11.8	4.0	4.7	16.5	16.5
Systems Engineering	22.4	19.0	10.2	8.7	32.6	27.7
SEAS Overall#	**12.9**	**12.0**	**5.4**	**5.7**	**18.3**	**17.7**

* Includes BAS advising load within the department.
† Shown on a full-time equivalent basis (1 PT=0.346 FT)
# Excludes 1 part-time and 4 full-time MSE students in Transportation.

Research Funding

The remaining goals for Engineering and Applied Science have to do with the extent to which the School can be expected to increase its research enterprise. With a level of per capita research among the highest of engineering faculties throughout the country, the School has been cautious in its evaluation of growth potential in the research program. The Faculty is committed to not establishing a separate research faculty and therefore must accept that any growth in per capita research will be accomplished by a faculty whose other commitments are likely to remain as extensive as they are presently.

Long-Range Goals for Change: Comparison with Current Profile

1984*	1985*		1990*
98	100	**Faculty Size**	125
		Student Enrollment	
		Undergraduate	
1,103	1,042	Engineering (BSE)	1,140
166	187	Applied Science	285
72	61	Curriculum Deferred	75
1,341	1,290	Total Undergraduate	1,500
		Graduate	
272	294	Full-Time: (MSE)	297
159	146	(PhD)	271
225	219	Part-Time: (MSE)	308
79	76	(PhD)	122
536	542	Full-Time Equivalent	717
		Student/Faculty Ratio	
13.7	12.9	Undergraduate	12.0
5.5	5.4	Graduate	5.7
19.2	18.3	Overall	17.7
		Research Activity	
$9,688,000	$12,315,000	Total Contracts and Grants	$21,515,000
$98,900	$123,100	Per Capita	$172,000

* Fall semester for year noted

Comparison of SEAS Research Income Projections FY 1985 and FY 1990

Department	Per Capita Research Income 1985	Per Capita Research Income 1990	% of SEAS Total 1985	% of SEAS Total 1990
Bioengineering	$94,500	$180,000	9%	12%
Chemical Engineering	$60,100	$150,000	6%	10%
Civil Engineering	$24,900	$100,000	2%	5%
Computer and Information Science	$235,800	$220,000	33%	25%
Electrical Engineering	$109,200	$175,000	17%	20%
Materials Science and Engineering	$235,200	$240,000	25%	16%
Mechanical Engin. and Applied Mechanics	$71,200	$120,000	7%	8%
Systems Engineering	$36,000	$100,000	1%	4%
SEAS Overall	**$123,100**	**$172,000**	**100%**	**100%**

Strategy

To reach the optimum level of operation put forth in this plan, the School will have to pursue a deliberate course of action designed to meet the target goals outlined in the previous section. As noted earlier, certain factors, and indeed constraints, can seriously affect the School's ability to achieve its objective, and the School has had to incorporate these considerations into its plan. Given this as background, the School has designed a strategy for accomplishing the targets it proposes in a coordinated and realistic fashion. This strategy is summarized below.

Faculty Development

The School seeks the University's cooperation and support for a program of planned faculty growth in specific areas of long-range importance to the University. While the School could maintain its current core level of operation and continue to be an asset to the University, it is the plan to integrate Engineering and Applied Science with disciplines throughout the University that will mark the greatest return to the University on its investment in SEAS.

Students and Degree Programs

The groundwork for developing degree programs and study options was completed with the implementation of the Applied Science degree in 1974 and the successful development of the management and technology dual-degree option with the Wharton School. The task now is one of refining these programs and, more specifically, of developing additional dual-degree options with other programs in the University—this in conjunction with the School's commitment to focusing on interdisciplinary cooperation in this next major period of change. In 1984, for example, a new dual-degree program with the School of Arts and Sciences in Computer and Cognitive Sciences was created. This program promises to be the leading one in the nation, if not the world.

The School plans to increase the baccalaureate program in Engineering slightly, with care taken to allow this growth in programs of developing interest to society (e.g., Bioengineering, Systems Science and Engineering). The Applied Science degree program will be allowed to grow significantly (an increase of 60% is projected) since it is a practical and popular alternative to the traditional liberal arts education and it attracts a talented group of applicants each year. The School considers an 80/20 percent balance between the engineering and applied science programs to be an appropriate goal for the School—one that will ensure the diversity of the student body, which is one of the School's (and the University's) strongest assets.

At the graduate level the School has increased the number of full-time students enrolled in its programs, and it will work to continue that trend with emphasis on the doctoral program. The doctoral program is directly linked with the School's research program, and for this reason will derive benefit from the increased focus on interdisciplinary programs. Above all in the graduate program, it is imperative that the School obtain funding for first-year fellowships for PhD candidates. Regardless of the excellence of the program, and despite recent gains in attracting well-qualified applicants to the doctoral program, the School cannot hope to compete for the top applicants if it is not prepared to offer them competitive fellowship packages upon their acceptance to the program.

Research Program

The strategy already in effect in Engineering and Applied Science has been extremely successful in increasing the School's research base. Briefly summarized here, the approach has been: to add junior faculty members in key areas of program focus; to promote the full utilization of existing faculty talent; and to invest in the resources of a department where a particular program shows promise.

The significant addition to this strategy is the aggressive concentration on extending interdisciplinary involvement throughout the University, both in the thrust areas of Bioengineering, Computer and Cognitive Sciences, Management and Technology, and Sensing and in other areas as well.

Facilities Development

The School will continue its program of carrying out those renovations for which it is able to locate funding, and making additional improvements with available operational funds where these renovations are essential and cannot wait for outside funding. This program, however, will have to be intensified and coupled with the ongoing campaign to raise capital funding if the School is to accomplish in the next five years a significant portion of the projects identified in the accompanying table.

Regarding the amount of space available to SEAS, the School, as noted above, fully utilizes the space it now occupies, with many programs operating in less space than is appropriate for these activities. For the program to expand as it should, additional space will be required. In April 1983 the University decided that Hayden Hall should be utilized by SEAS for additional space (36,000 square feet). Hayden Hall is situated adjacent to the Towne Building and thus is an ideal addition. It will be renovated to house Bioengineering and the SEAS Educational Resources Center.

The School also plans to add a substantial wing at the west end of Towne and Moore to accommodate the growth in Computer and Information Science and provide research laboratory facilities for all programs.

Equipment Sustenance

It is recognized that the development of new research, the attainment of increased research funding, and the attraction of outstanding faculty and graduate students depends on the availability of modern instrumentation and equipment as well as adequate space. Support for this critical need is being actively sought through industry and through government legislation at both local and national levels. As one example, through the efforts of the Pennsylvania Society of Professional Engineers and the deans of engineering in the Commonwealth of Pennsylvania, an engineering schools equipment bill was legislated and funded in 1984. Equipment sustenance is also recognized in the development plan as a priority item.

Financial Overview

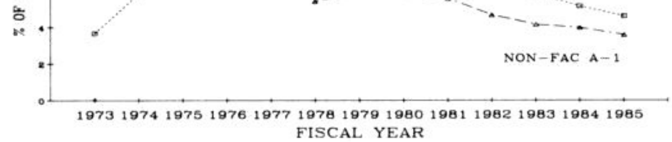
Since 1975 when the School closed with a budget deficit of $404,000, SEAS has successfully linked academic excellence with fiscal responsibility. Today that deficit, as well as the long-standing Moore School debt of $1,218,000, have been repaid by the School. Over the same period undergraduate enrollments have tripled and graduate full-time enrollments are up 50%, average SAT scores have increased 40 points, and research volume has increased 58% in real dollars. This dramatic growth has been accomplished with only a 10% increase in faculty size (90 vs. 100). Further, administrative and support numbers have remained essentially flat over the last five years while a steady decline in non-faculty administrative and technical (A-1) and secretarial/clerical/technical (A-3) compensation as a percentage of unrestricted funds has been effected (see Fig. 4).

SEAS revenues and expenditures by source are illustrated in the pie charts shown. Closing data for fiscal year 1984-85 were selected.

Although sound fiscal and academic planning have been successful in bringing national recognition and fiscal stability to the School, three

School of Engineering and Applied Science
A-1 and A-3 Salaries
As a Percent of Unrestricted Direct Expense

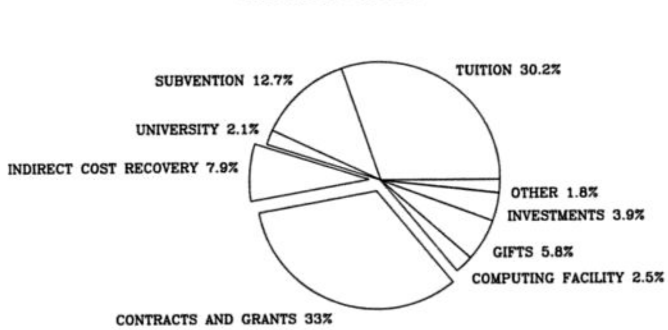
Figure 4



School of Engineering and Applied Science
Fiscal 1985 Budget Closing
(dollars in thousands)

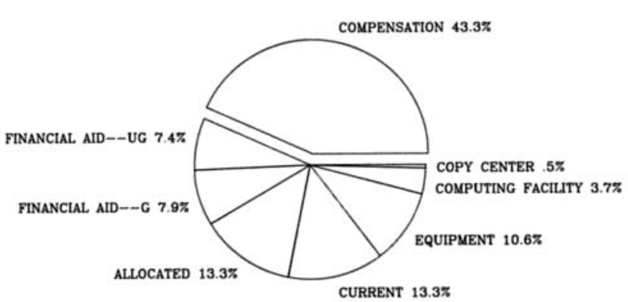
Revenues		Expenses	
Unrestricted			
Tuition—Undergraduate	$5,460	Compensation	$6,691
Graduate	3,357	Current Expense	1,828
Indirect Cost Recovery/Grants	2,172	Financial Aid	
		Undergraduate	1,420
Indirect Cost Recovery/Other	125	Graduate	1,373
Investments/Bank	441	Equipment	163
Gifts	99	Allocated Costs	3,892
Subvention	3,713		
Sub-total	**$15,367**	**Sub-total**	**$15,367**
Restricted			
Contracts and Grants	$9,629	Compensation	$5,933
Gifts	1,584	Equipment	2,917
Investments	703	Current Expense	2,064
Computing Facility	738	Computing Facility	1,075
University Special Subvention	600	Financial Aid	
		Undergraduate	728
Other	538	Graduate	936
		Copy Center	139
Sub-total	**$13,792**	**Sub-total**	**$13,792**
Total	**$29,159**	**Total**	**$29,159**

School of Engineering and Applied Science
Revenues FY 1984-85



$29,159,000

School of Engineering and Applied Science
Expenses FY 1984-85



$29,159,000

problems remain that threaten the continued success of the five-year plan: undergraduate course units credited fiscally to the School, graduate student support, and the Moore School Computing Facility budget.

By design, undergraduate engineering and applied science students take more than half their course units from other schools of the University. For FY 83-84, for example, the course-unit flow was 57% out, 43% in, an accomplishment unmatchedby any other School at Penn; at the end of FY 84-85 this measure improved even more significantly to 61% out, 39% in. While this may represent an educational achievement, these percentages correspond to a negative cash flow for the School with respect to responsibility center budgeting. Looking at this situation on a one-University fiscal level, the net FY 84-85 undergraduate course-unit contribution to the University is the highest in the School's history, representing over $4,000,000 at the current course unit value. However, because of existing allocation algorithms, the School experienced a FY 84-85 shortfall of $600,000 in its budgeted tuition income. This dilemma of SEAS pressing its students to enjoy the intellectual breadth of the campus while suffering fiscally due to countervailing tuition allocation algorithms needs to be resolved more directly than simply via subvention.

Removing graduate student tuition support from the employee benefit pool as a result of OMB Circular A-21 in FY 1981-82 severely taxed the School's financial base and required drastic changes in academic planning. Even with the University contribution of one-half tuition when the other half is charged to contracts and grants there was a loss of over $900,000 in restricted SEAS funds. This loss of operational funds, which might otherwise have been used for laboratory and equipment needs, comes at a time when the School's competition is investing heavily in their physical plant (Appendix 6). This dilemma may continue to undermine the five-year plan.

The final major concern is the computing facility where the School has been facing an operating deficit of approximately $350,000 annually. In an attempt to resolve this perennial negative cash flow, the computing facility will be reorganized next year into a more pervasive "Computing and Educational Technology Services" (CETS) operation. Simultaneously, the institution of an Educational Technology Fee to support the pervasively growing computer-communications system in the School is under study. At a proposed $100 per semester per full-time student (undergraduate and graduate) this fee could help close the yearly deficit for *academic* computing services.

Budget Projection

In defining its program for the future, the School first proposed several alternatives that would accommodate a range of changing economic circumstances. The fiscal viability of each of these alternatives or scenarios was then examined by the School through an incremental analysis of its goals. The results of the analysis indicated that—with the important exception of the student aid obligation to be borne by the School—it was clearly in the interest of the School and the University to permit a scale-up of the academic and research programs.

Having thus determined the academic course for SEAS over the next several years, the School has projected the operational budgets (p. XV) for the next five years and the capital budget (p. XVI) required to augment the resource base over the same period of time. While operational budgets are difficult to project within the University budgeting system because the University's central administration determines the subvention on the revenue side of the budget and the indirect cost assessment on the expense side, nonetheless, in consultation with the central administration, these projections have been made on as realistic a basis as possible by applying conservative assumptions throughout the projection.

The School's preliminary capital budget, or resource development plan, targets the School's funding needs in four major areas of resource requirements:

Faculty support	$14,500,000
Student support	6,500,000
Opportunity funds	3,500,000
Capital projects	
Renovations and equipment	10,500,000
New construction	15,000,000
	$50,000,000

Meeting the School's space requirements is essential to the success of the five-year plan. This, combined with the serious need for laboratory equipment and renovations, represents over 50% of the SEAS development budget. Viewed from this perspective a plan to raise approximately $24 million to support (preferably to endow) chaired professorships, first-year graduate fellowships, and opportunity funds over five years could be considered reasonable if not conservative.

Major Interdisciplinary Programs

Bioengineering

The future of medical diagnosis, treatment, and research is one of increasing dependence on technological development and application. Penn, which has a tradition of cooperation among its biomedical engineering programs and medical and biological sciences, has the potential for coordinating and enhancing its existing resources to build a bioengineering program that will meet the diverse and expanding needs of the University's biomedical disciplines. Were it to develop such a program using the unique opportunities for interdisciplinary cooperation present at Penn, the University would unquestionably become one of the country's leading centers for bioengineering teaching and research.

Penn currently lacks the means for coordinating these activities on a University-wide basis, and it lacks as well a focal point for industrial contact and involvement in the numerous bioengineering-related activities that are ongoing within the University. While the Department of Bioengineering does not yet have the resources to assume such a role, its existing resources being committed presently to its primary responsibility of ensuring the scholarly integrity of the academic program in bioengineering, its strategic plan is to develop the enterprise that can serve as the focal point for bioengineering research and training campus-wide. The objectives of the plan are fourfold:

- To enhance and expand the University's existing base of bioengineering resources.
- To provide greater opportunity for participation in the bioengineering research and training program across the University, building stronger interdisciplinary relationships in areas of common focus within the program.
- To build on the process already begun to infuse high technological skills into the curricula of the University's medical and health care programs.
- To provide the faculty of the University with the ability to introduce their bio-developments into commercial markets.

The principal areas of academic focus for the plan include the study of aging, biomechanics of trauma, orthopaedic bioengineering, respiratory bioengineering, bioengineering of visual impairment, cardiovascular computer-aided research, and computer-aided mechanical physiology.

Computer and Cognitive Sciences

The plan to build computer science at the University of Pennsylvania into a program of preeminence extends from enhancement of the core program in Computer and Information Science to supporting the broad-based integration of computer science throughout the University to focusing with special intensity on research in Cognitive Science. Specific goals include:

- To enhance the core program in computer science, specifically in the areas of man-machine interaction, environment-machine interaction, artificial intelligence, theory of computation and software engineering, and computer architecture.
- To expand the interdisciplinary research of the Department of Computer and Information Science in those areas Penn is uniquely qualified to develop, including those in the cognitive sciences, expert systems, image interpretation, and robotics.
- To broaden the academic base in computer science at Penn in order to encourage computer-related instruction in disciplines throughout the University.
- To intensify the development of the computer as a tool by focusing on research in computer-aided design, computer graphics, and speech synthesis.

In support of this campus-wide effort, the Department of Computer and Information Science has already secured funding from NSF for flexible communication with computers and computer interaction in three dimensions ($3.8M); funds for artificial intelligence from the Army Research Office ($7.7M); three individual grants from NSF ($2.0M); the Air Force ($1.1M) for computer vision and natural language interaction; the Defense Advanced Research Project Agency (DARPA) ($3.0M) for natural language processing; and miscellaneous support ($0.4M) for artificial intelligence.

Management and Technology

In having the world's oldest and arguably the most prestigious business school located on the same campus with a leading engineering school, Penn is capable of offering a range of programs that blend the principles of management and good business practice with the fundamentals of engineering and practical applications of technology.

In 1976 the University took the first major step in this area when it formally announced the undergraduate dual-degree option in Management and Technology. Under this program students at Penn earn a Bachelor of Science in Economics (BSEcon) degree from the Wharton School and either the Bachelor of Applied Science (BAS) or Bachelor of Science in Engineering (BSE) degree from the School of Engineering and Applied Science.

The BSEcon/BAS option is designed for students who wish to add a strong background in technology to their preparation for careers in the business or commercial sector, while the BSEcon/BSE option allows engineering students to acquire as undergraduates the business and management background that will be essential in their careers. These options have proved to be extremely popular in the years since first offered, attracting the brightest and most diverse group of applicants of any undergraduate program offered by the University.

In contrast to the very successful implementation of the undergraduate program, the graduate program and research potential of the Management and Technology Program are still in the initial stages of development. An MBA/MSE program, instituted several years ago attracts about 20 superb students annually, but it lacks sharpness of purpose. Presently, a faculty study group is assessing the notion of developing a major focus for this program in manufacturing systems engineering, a pervasive societal need which spans all engineering disciplines.

This area, like the other major interdisciplinary components of the plan, will require an infusion of resources to augment the existing resource base. The scope of these needs is currently being determined in conjunction with the preparation of a detailed plan for development of the Management and Technology Program.

Sensor Technologies

Because of the rapid changes occurring in the microminiaturization of high speed computers and the parallel need for more effective linkages between these systems and their environment, an international race is taking place to develop both the underlying scientific knowledge and the manufacturing capability to produce new, microelectronic-based sensors. The stakes are very high, involving new products, new jobs generated by manufacturing these new products, and new wealth that will be generated by this industrial activity. The University of Pennsylvania has become one of the world's major research centers in this vitally important field.

The importance of these new microelectronic-based sensors and their systems application is being recognized across the entire spectrum of industry as companies large and small seek ways to improve productivity, increase quality and performance, and control costs in the face of tenacious international competition. Advanced sensors and sensor technologies will permit companies to measure the behavior and properties of raw materials, monitor and adjust the details of manufacturing processes, and control the quality of finished products with a degree of speed and accuracy never before possible. While such new sensor systems are vital to high technology manufacturing processes such as microelectronics, perhaps their greatest impact will come as a result of their application in the technological revitalization of core industries such as raw materials extraction and processing, basic manufacturing industries, and petrochemicals.

The University of Pennsylvania's research on sensors is centered in the School of Engineering and Applied Science. In 1979 the School established its Center for Chemical Electronics in response to demand for chemical sensors for both medicine and the geochemical industry. In the intervening years, growing demand for information on all types of microelectronic-based sensors has expanded the level of activity significantly. At the present time, 15 faculty from five departments within the engineering school as well as faculty drawn from medicine and the sciences are engaged in research on the development and application of a broad range of advanced sensors and associated response systems for bioscience and industry. The School plans to add several new faculty members over the next several years across several departments to further strengthen this research activity.

The sensor focus has also played a major role in the research and industrial outreach activities sponsored by the Ben Franklin Partnership's Advanced Technology Center for Southeastern Pennsylvania. As indicated above the development of advanced sensors holds important promise for the revitalization of existing core industries within the Commonwealth. For example, research and development projects are currently underway which focus on sensors which will permit greater control in the manufacture of high quality steels, improved performance of thrust bearings, and continuous monitoring and adjustment of petrochemical processing.

The School has a current sponsored research budget of $12 million per year, approximately $1 million of which is for sensor related projects. The industrial component of this research support is increasing rapidly, and it is expected that expansion of the School's sensor activity will further accelerate that growth.

Computing and Educational Technology

The creation at the University's Moore School in 1944-46 of ENIAC, the world's first large-scale, all-electronic, general purpose, digital computer, set the stage for an era of global change in ways the human race communicates and processes information. Many believe that the period from 1946 to the century's end will be the formative stages of civilization's transit from the Industrial Revolution to the "Age of Information."

For Penn Engineering and Applied Science this changing societal scene demands careful attention to how we educate and do our research. In fact, of course, there is no choice here: the pace of change is forcing a response. Thus, much thought and consequent planning must be placed on how new technologies can be applied to education's benefit.

This exercise is a challenge of major proportion. At present, the School is coming off two decades of dedication to main-frame computing as a core operational base along with some modestly successful attempts at orienting its educational procedures around computing efficiencies. As in most leading institutions, the past ten years have seen a serious attempt at distributing computing technology from its mainframe core to a profusion of rather self-contained computing workstations. And, more recently, intense attention is being paid to developing computer-communications networks to permit "connections to learn," i.e., the ability for all to communicate or transfer educational information among each other most productively . . . the process started formally by Plato in the Groves of Academe over two millenia ago.

The School's Computer Advisory Committee has submitted a plan to the dean which suggests procedures for modifying the School's "computing plant" to set a new base from which, following a year or two of experiment, more extensive decisions on change can be made. These suggestions include: terminating the School's present mainframe operation, and participating in the School of Arts and Sciences' mainframe operation, connecting to the now-available NSF-funded supercomputer consortium, developing PC-workstation "classrooms," organizing selective use of minicomputers supporting multiple work stations for targeted institutional and research purposes, reconstituting the School's educational and research laboratories for computerized instrumentation and analysis, and constructing school-wide computer-communications networks. Much of this is now underway.

Educational Resources Center

The Educational Resources Center to be created and housed in newly renovated space in Hayden Hall represents an evolutionary step beyond the traditional concept of a university library for science and engineering. The Center will contain most of the present collections of the Towne and Moore Libraries, but it will also take maximum advantage of computerized facilities for information retrieval and storage of reference and archival materials on microfilm, microfiche and optical discs, and it will also contain viewing facilities for videotaped instruction.

The large third-floor vaulted-ceiling hall of Hayden will be laid out so that the central part will contain at least two tiers of shelved books and journals. Some will be in normal open shelves and others will be in mechanically-operated high-density compact shelving. The latter will conserve space while allowing immediate and easy access. Surrounding this central core on the windowed sides of the hall will be furniture for individual reading and work with library materials, seating at least 200. Apart from this hall will be provided closed rooms for groups working together with Center resources, and for individuals working with videotaped materials. Facilities will be installed for interactive computer-assisted instruction to take advantage of developments in computer graphics and expert systems.

The traditional card catalog will be computerized as part of the current University-wide effort now in progress. The catalog will be accessible from terminals in the Center and from computers in departments, faculty offices and student and faculty residences. This network will have access to the Research Library Information Network (RLIN), which presently consists of more than thirty major research university libraries and is growing. The data base of the whole RLIN will be searchable by author, title, key words, and combinations of all three. Also accessible from the various stations on campus will be the information indexes to which we subscribe; at present this comprises over 200 data bases.

Circulation of books will be computerized, and check-out will be done using a general-purpose University-wide ID card (soon to be instituted) and machine-readable labels on books.

As reference materials become available on optical disc, which the Engineering Index now is, for example, this storage mode will be used to take the place of bound volumes, thereby conserving space and enhancing access and reference searches. Whenever feasible, back-issues of archival journals will be stored on disc, microfilm, or microfiche, with equipment available in the Center to make hard copy when it is required.

SEAS Financial Profile — 1975-1990 (dollars in thousands)

	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
REVENUE																
Direct Revenue																
Tuition																
Undergrad	1,030	1,002	1,113	1,369	1,775	2,198	2,793	3,643	4,363	4,994	5,460	5,649	6,270	6,461	6,648	6,876
Grad	1,161	1,260	1,143	1,253	1,426	1,662	2,159	2,198	2,779	3,066	3,357	3,826	4,140	4,506	4,932	5,027
Financial Aid	156	127	693	603	689	874	996	958	1,665							
Endowment (Investments)																
Allocated	133	104	144	170	161	118	250	496	722	836	703	773	851	936	1,029	1,132
General	234	269	309	324	340	392	377	423	407	457	441	467	496	525	557	590
Gifts	114	132	236	192	302	553	466	1,214	1,226	1,827	1,683	1,919	2,187	2,493	2,843	3,240
Research (Contracts/Grants)																
SEAS	2,266	2,648	2,889	3,226	3,506	3,937	4,488	4,504	4,792	5,879	8,526	9,173	9,865	10,654	11,807	12,776
SEAS Portion of LRSM	658	618	623	754	673	751	1,014	1,042	903	1,123	1,103	1,103	1,103	1,173	1,173	1,173
Overhead Recovery	801	927	1,069	1,336	1,432	1,518	1,964	1,918	2,004	1,982	2,297	2,466	2,852	3,075	3,375	3,627
Other Revenue	247	139	67	206	218	231	202	228	482	1,016	1,772	1,677	1,454	1,359	1,680	1,665
Total Direct Revenue	**6,800**	**7,226**	**8,286**	**9,433**	**10,522**	**12,234**	**14,709**	**16,624**	**19,343**	**21,180**	**25,342**	**27,064**	**29,217**	**31,183**	**34,043**	**36,107**
Subvention	1,751	2,195	2,067	2,189	2,300	2,364	2,413	2,804	3,064	2,901	3,713	3,862	4,016	4,177	4,344	4,517
Total Revenue	**8,551**	**9,421**	**10,353**	**11,622**	**12,822**	**14,588**	**17,122**	**19,428**	**22,407**	**24,081**	**29,055**	**30,915**	**33,233**	**35,360**	**38,387**	**40,624**
EXPENSE																
Direct Expense																
Compensation																
Unrestricted—Faculty	1,891	1,956	2,130	2,448	2,653	3,006	3,388	4,093	4,510	4,937	4,959	5,854	6,177	6,545	7,116	7,555
—Staff	682	674	656	720	842	1,074	1,323	1,378	1,391	1,540	1,732	1,832	1,938	2,054	2,206	2,340
Restricted	2,327	2,642	2,813	3,044	3,478	3,721	4,453	4,325	4,464	5,018	5,933	6,355	6,802	7,341	8,329	9,023
Student Aid																
Unrestricted	314	416	380	541	610	682	821	1,613	1,923	2,312	2,793	2,999	3,286	3,482	3,701	3,799
Restricted																
Undergraduate	86	2	407	452	575	743	862	823	728	751	728	791	878	905	931	963
Graduate	70	125	286	151	114	134	134	854	937	1,375	936	1,530	1,656	1,802	1,973	2,011
Current Expense																
Unrestricted	568	432	454	485	602	698	912	896	1,381	1,856	1,828	1,609	1,977	2,070	2,236	2,312
Restricted	806	825	761	833	1,011	1,135	1,563	1,692	2,788	1,221	3,174	2,541	2,718	2,935	3,222	3,469
Facilities & Equipment																
Unrestricted	33	49	72	148	267	278	299	168	75	117	163	91	99	108	118	128
Restricted	292	315	362	474	323	554	433	846	797	1,213	2,917	3,034	3,155	3,281	3,412	3,549
Expense Credit	−13	−155	−25	−12	−186	−62	−402	−596	−436	0	0	−50	−50	−50	−50	−50
Total Direct Expense	**7,065**	**7,281**	**8,286**	**9,284**	**10,289**	**11,963**	**13,786**	**16,092**	**18,558**	**20,340**	**25,163**	**26,587**	**28,636**	**30,475**	**33,193**	**35,099**
Indirect Expense																
Space	946	1,028	1,218	1,285	1,355	1,413	1,804	1,783	2,051	1,725	1,561	1,913	2,085	2,273	2,477	2,700
General Administration	274	323	335	348	377	424	507	579	686	824	934	956	994	1,034	1,075	1,118
General Expense	680	735	485	510	704	784	849	974	1,112	1,192	1,397	1,459	1,517	1,578	1,641	1,707
Total Indirect Expense	**1,900**	**2,086**	**2,038**	**2,143**	**2,436**	**2,621**	**3,160**	**3,336**	**3,849**	**3,741**	**3,892**	**4,328**	**4,597**	**4,885**	**5,194**	**5,526**
Total expense	**8,955**	**9,367**	**10,324**	**11,427**	**12,725**	**14,584**	**16,946**	**19,428**	**22,407**	**24,081**	**29,055**	**30,915**	**33,233**	**35,360**	**38,387**	**40,624**
SEAS Direct Performance	**−255**	**−55**	**0**	**149**	**233**	**271**	**923**	**532**	**785**	**840**	**179**	**467**	**580**	**708**	**850**	**1,008**
SEAS Overall Performance (within the University)	**−404**	**54**	**29**	**195**	**97**	**4**	**176**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

SEAS Capital Projects Summary: Facilities and Equipment Development, FY 1986-FY 1991

SEAS, Common Facilities	Project	Estimated Cost
Educational Resources Center (ERC)*	Renovation and equipment	$2,000,000
Laboratories		
VLSI Design Laboratory (UG/G) (CIS/EE)	Equipment	$350,000
Architecture and Systems Laboratory (UG/G) (CIS/EE)	Continued laboratory development	$500,000
Computer Structures and Microprocessor Laboratory (UG)	Continued laboratory development	$200,000
Electromechanics/Computerized Control Laboratory (UG/G) (EE/MEAM/SE)	Renovation and equipment	$200,000
Imaging Laboratory (Interdisciplinary)	New laboratory development	$1,000,000
SEAS Computing Facilities		
Graduate Educational Computing Laboratory	Renovation and equipment	$1,000,000
Computer Workstation Laboratories (6) (PC, Graphics, CAD)	Renovation and equipment	$1,500,000
Computer Network	Renovation and equipment	$1,000,000
Faculty/Graduate Student Offices	Renovation	$1,000,000
Moore/Towne Classrooms	Renovation	$300,000
Moore (6)		
Towne (4)		
Valley Forge Research Center	Renovation	$1,000,000
SEAS Staff Lounge	Renovation	$200,000
Moore School Computer Museum	Renovation; development of a "mini" museum	$200,000
SEAS Departments		
Bioengineering		
Hayden Hall	Interior Renovation	$1,500,000
Biomechanics Laboratory	Renovation and equipment	$1,000,000
Life Research (Animal) Laboratory	Equipment	$1,000,000
Undergraduate Instrumentation Laboratory	Renovation and equipment	$700,000
Biomaterials Laboratory	Renovation and equipment	$500,000
Cardiovascular/Biofluids Laboratory	Renovation and equipment	$500,000
Bioelectricity Laboratory	Renovation and equipment	$200,000*
Chemical Engineering		
Undergraduate Research and Teaching Laboratories	Renovation and equipment	$1,000,000
Graduate Research Laboratories	Renovation and equipment	$1,000,000
Civil Engineering		
Transportation Systems Laboratory	Equipment	$200,000
Computerized Structural Design Laboratory	Equipment	$200,000
Ecological/Resource Systems Laboratory	Equipment	$200,000
Computer and Information Science		
New Wing & Expansion of Present Wing	Building	$7,000,000
Computer Graphics Research Laboratory	New laboratory development	$600,000
Computer Robotics Laboratory	New laboratory development	$500,000
Computer & Cognitive Sciences Laboratory	New laboratory development	$500,000
Computer Vision Laboratory	New laboratory development	$500,000
Electrical Engineering		
Expanded Pender Building/Moore-Towne Interconnect	Building	$2,000,000
Undergraduate Research and Teaching Laboratories	Renovation and equipment	$1,000,000
Telecommunications/Signal Processing Laboratory	Renovation and equipment	$500,000
Microfabrication Laboratory	New laboratory development	$1,500,000
Integrated Optics Laboratory	Renovation and equipment	$300,000
Microwave/Millimeterwave Electronics Laboratory	Renovation and equipment	$300,000
Electronic and Optical Materials Laboratory •	Renovation and equipment	$200,000
Rotating Machinery Laboratory	Renovation	$50,000
Materials Science and Engineering		
Undergraduate Materials Laboratory	Renovation and equipment	$600,000
Graduate Materials Laboratory	Equipment	$400,000
Mechanical Engineering and Applied Mechanics		
Undergraduate Research and Teaching Laboratory	Renovation and equipment	$1,500,000
Mechanical Design/Robotics Laboratory	Renovation and equipment	$500,000
Thermal/Fluid Sciences Laboratory	Renovation and equipment	$250,000
Solar Simulator Laboratory	Renovation	$150,000
Wind Tunnel	Renovation and instrumentation	$500,000
Systems Engineering		
Manufacturing Systems Laboratory	New laboratory development	$500,000

* ERC part of Hayden Hall interior renovation