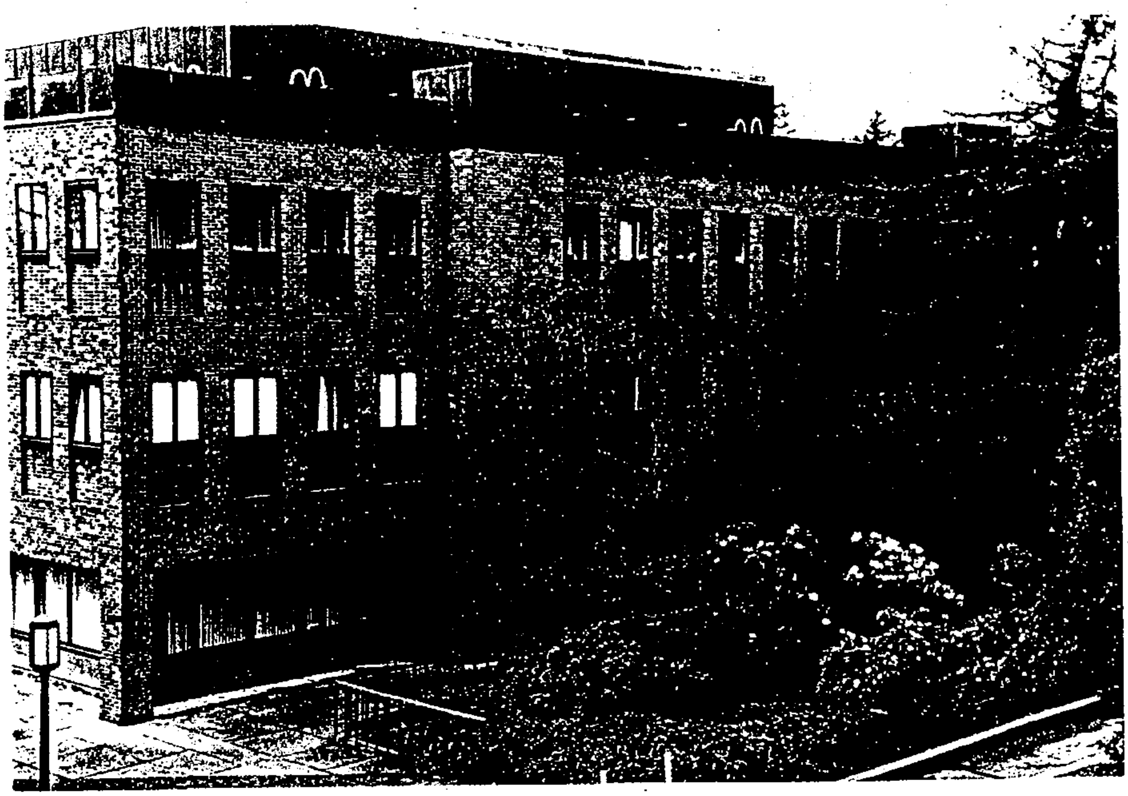
University of Washington

Department of Chemical Engineering

Ten Years in Review, 1986-87 to 1996-97

A Self-Study



March 1998

Self-Study Document
for the Ten-Year Review of the Department of Chemical Engineering
at the University of Washington

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CONTEXT

The Department of Chemical Engineering is one of nine departments within the College of Engineering at the University of Washington and offers the following degrees:

- Bachelor of Science in Chemical Engineering
- Master of Science in Chemical Engineering
- Master of Science in Engineering
- Doctor of Philosophy in Chemical Engineering

The Department of Chemical Engineering is a medium-sized department:

- 15 faculty
- 154 undergraduate students (in the junior and senior years) (32% women)
- 57 graduate students (mostly working towards a Ph.D.)
- 7 postdoctoral fellows (research associates)
- awarded 73 B.S. degrees in 1996-97 (43% to women)
- awarded 5 M.S. degrees in 1996-97
- awarded 9 Ph.D. degrees in 1996-97

Research expenditures (from grants, contracts, and gifts) were $2.5 million per year in 1996-97 and awards were $3.4 million in that year. In 1996-97 the faculty served on editorial boards of 36 technical publications, performed 1,136 hours of professional service for free, and engaged in 74 days of consulting activities with industry.

EXECUTIVE SUMMARY

The Department of Chemical Engineering has an excellent undergraduate program, which emphasizes independent learning, oral and written communication, design and teamwork, and project-based experiences in research and industrially-posed design problems. It is the second-largest undergraduate program on the West Coast, yet has only a moderately-sized faculty.

The Department has a solid Ph.D. production rate and is perceived as a department with a good balance of practical and theoretical training, and breadth in its research program. Among all chemical engineering departments in 12 western states, only Berkeley, CalTech and Stanford produce more Ph.D.s. The graduate program is highly interdisciplinary, having interactions with several other departments at the University of Washington as well as faculty worldwide.

During the next 10 years, the Department wants to maintain its experiential learning environment while increasing undergraduate enrollment to meet State demands (43% over 10 years). The Department cannot do this in existing space, since replacement faculty will need more space than is now occupied by faculty who will soon retire. Thus it is essential that loaned space be returned to the Department. The size of the graduate program will also increase as new research-active faculty are hired, as the new M.S.-T.A. program grows, and as research done by postdoctoral (research associates) increases.

The total expenditures in 1996-97 were $4.0 million, from the following sources:

- 39% state funded (including tuition)
- 31% federal research
- 19% industrial research
- 11% gifts and endowment

A total of $534,000 was given to the Department in 1996-97. The State budget is $1.56 million, but over $1.12 million is returned to the State in the form of overhead and tuition. In reality, State taxes pay only $440,000 or 11% of the Departmental budget.

The Department urges the University of Washington to empower the faculty to strive for excellence in the face of declining budgets and dictates from the Legislature. The Department welcomes enrollment growth that is accompanied by growth in budgets and incentives to departments that meet University-established goals.

THE BROADER VIEW

Synopsis of the Chemical Engineering Department

The Department began in 1904 as part of the Department of Chemistry. Professor Henry Benson became chair of Chemistry in 1919 and taught continuous processing to chemical engineers. In the 1930s and 1940s he initiated a research program focusing on the pollution from pulp and paper plants. In 1953, the Department of Chemical Engineering became a department on its own, in the College of Engineering, with R. Wells Moulton as the chair. Professor Moulton hired and encouraged Professor Les Babb to form the Department of Nuclear Engineering, and was instrumental in bringing Professors Babb and Scribner together to develop an artificial kidney machine. The machine they developed is the prototype for all home dialysis machines in use today. Chemical engineering embraced engineering science in the 1960s and so did the Department, with a gradual increase in the number of Ph.D.s awarded. Charles A. Sleicher became the third chair in 1977, and Bruce A. Finlayson became the fourth chair in the 94-year history in 1989. The history of the Department is in Appendix S.

Enrollment in chemical engineering nationwide has always fluctuated cyclically, but enrollment restrictions in the Department of Chemical Engineering have moderated the swings. Despite those controls, the enrollment of undergraduates has grown by 42% over the past eight years while grades of entering juniors have increased. From the 1960s on, though, the Ph.D. has played a more prominent rôle, with the number of degrees granted increasing from 5 per year in the 1960s to 10 per year in the 1990s. The numbers don't tell the whole story, however, since the fields of inquiry have broadened to include polymeric composites, electronic materials, and biomaterials in addition to the process-oriented fields of separations, process control, and modeling.

Chemical Engineering as a Field

Chemical engineers design, construct, manage, and operate equipment that reacts chemicals to make a more valuable chemical product and they develop processes that separates mixtures of chemicals into their component parts. The reactions are highly important in industries such as chemicals, petroleum, electronic materials, pharmaceuticals, polymers, and pulp and paper.

A big paradigm change occurred in 1960 with the publication of *Transport Phenomena*, by Bird, Stewart, and Lightfoot. This book brought about an increased emphasis on engineering science, which was fueled by the expansion of research on the national scale after Sputnik (in 1957). Then in 1973 the energy crisis began, and chemical engineers came into great prominence for their systems engineering skills. The increased employment partially hid the fact that many industries served by chemical engineering were becoming mature industries, with growth at lower rates than we had become accustomed to. In the 1980s the National Research Council conducted a study on the future directions of chemical engineering and reported that the discipline's core research areas (reaction engineering, separations, process design, and control) will appear in the many new technologies, such as electronic, photonic, and recording devices; microstructured materials; *in-situ* processing of energy and mineral resources; liquid fuels for the future, responsible management of hazardous substances, advanced computational methods and control, and surface and interface engineering. Thus, most departments have expanded in these areas. This presents a seeming dichotomy, in that the undergraduates are being trained for industries which have downgraded research, while the faculty is focusing on even more science-based investigations in a wider selection of industries. This dichotomy is illusory, however, because the undergraduate courses have changed their applications, even while the basic strengths of a systems outlook, mass and energy balances, separations and kinetics, process control, and design remain.

Now we have the global warming crisis – real or imagined. The reduction of carbon dioxide emissions sounds like a reduction in fossil fuels, and a corresponding reduction in the need for chemical engineers. However, it is chemical engineers that will make fuel cells a viable transportation motive source, and chemical engineers already know how to remove carbon dioxide from gas streams, and refineries do it daily. Most companies – and the chemical, petroleum, and electronic materials companies are no exception – market and manufacture and compete on the world stage. This has meant fewer new plants built in the United States and more design work done overseas. This international emphasis in turn demands that universities graduate people who can work with diverse people of all cultures.

Despite the many changes over the past century, chemical engineering has survived, and it shows all the signs of adapting to the world situation today. The Department of Chemical Engineering is eager to be a part of that progression.

Chemical Engineering Department within the University of Washington

In the 1996-97 academic year, the College of Engineering awarded 676 B.S. degrees, 303 M.S. degrees, and 84 Ph.D. degrees; there were 188 full-time equivalent faculty. The College is commonly rated about 25th in the nation. The Bioengineering and Computer Science and Engineering departments are the top-rated departments in the College. The recent NRC rankings, when converted to percentiles show that the following departments were in the top quarter of schools rated, based on 'Quality of Faculty': Computer Science (92nd), Bioengineering (90th), Civil Engineering (84th), Electrical Engineering (81st), and Chemical Engineering (78th). The percentiles based on 'Effectiveness of Graduate Program' are: Computer Science (94th), Civil Engineering (85th), Chemical Engineering (82nd), Bioengineering (81st), and Electrical Engineering (79th). Research awards for the College in 1996-97 were $41 million, to be combined with State support of $28 million. Statistics about the various departments in the College of Engineering are provided in Appendix K.

In addition to the roles of the Department serving chemical engineering students, the Department has many other constituencies. The Department provides undergraduate classes for approximately 15 juniors in the Paper Science and Engineering program. These students take four chemical engineering courses (of the total of 11 courses required for a chemical engineering degree), and two to three students from this program stay an extra year and get a B.S. degree in Chemical Engineering to go along with their Paper Science and Engineering degree. This teaching effort adds the equivalent of five chemical engineering students to the undergraduate enrollment.

The Department has six Joint Faculty members, three with Bioengineering, two with the Paper Science and Engineering program, and one with Microbiology. (Four of these participate actively in Departmental affairs.) In addition we have three Adjunct Professors in Chemical Engineering from the same departments, as well as one from Rehabilitative Medicine, and an Affiliate Professor from the Center for Process and Analytical Chemistry. Meanwhile, Chemical Engineering faculty hold Adjunct appointments in Materials Science and Engineering, Chemistry, Oceanography, and Bioengineering. The Department has one full-time member active in the University of Washington Engineered Materials (UWEB), and the director is a Joint Professor in the Department (25% Chem. E.). Three faculty are active in the Nanotechnology Center recently begun by the University.

The service activities of the Departmental faculty are mainly service to the profession and professional societies related to their research. The Department holds a yearly Refresher Course to help practicing engineers prepare for the Professional Engineers Exam. In the last three years, individual faculty members have held offices of member of Board of Directors, Chairman, Vice Chairman, Vice President, Co-chair, Program Chair, Secretary, Treasurer, Director, Trustee, Intern, and Fellow in various professional societies, and have performed over 1,136 hours per year of uncompensated service to their profession. Consultation opportunities are mainly individual, but these often lead to research projects. During the past year, the faculty spent a total of 74 days consulting.

UNDERGRADUATE EDUCATION

The undergraduate program is one of the top 10 programs in chemical engineering nationwide, based partly on its size, but mostly on its focus on oral and written communication, teamwork and project work, practical designs based on industrial problems, and undergraduate research opportunities. (These factors are now called experiential learning in current educational parlance.) A complete description of the objectives of the Department is given in Appendix H (Goal Statement).

Degrees Granted. The enrollment in chemical engineering (junior and senior years) is shown in Figure 1 and listed in Table I. The enrollment has grown 42% over the past eight years, for a growth rate of 4.5% per year. The number of B.S. degrees awarded in the past 10 years is listed in Table II.

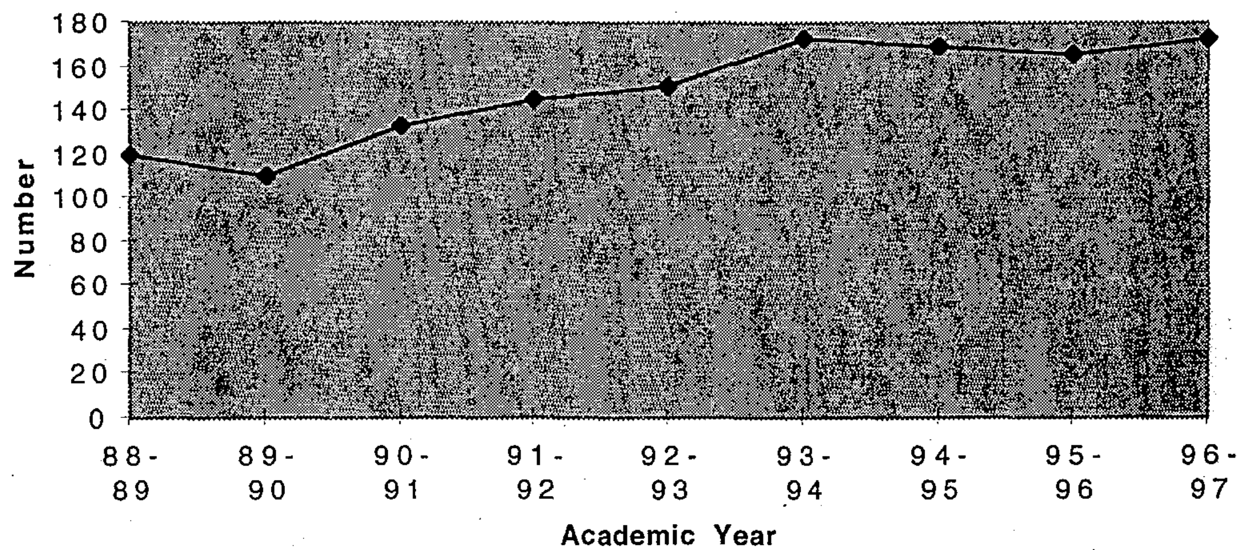

Figure 1. Undergraduate Enrollment in Chemical Engineering

Table I. Undergraduate Enrollment in Chemical Engineering (Source: Yearly Statistical Report)

Year	Total	Men	Women
88-89	119	163	37
89-90	110	81	29
90-91	133	106	27
91-92	145	106	39
92-93	151	106	45
93-94	173	111	62
94-95	169	105	64
95-96	166	101	65
96-97	173	113	60

Table II. B.S. Degrees in Chemical Engineering
(Source: UW Granted Degrees Reports each quarter)

86-87	87-88	88-89	89-90	90-91	91-92	92-93	93-94	94-95	95-96	96-97
65	67	41	50	52	52	52	65	54	66	70

The experiential learning environment is extensive (and time consuming): about 68% of graduating seniors have done undergraduate research in their stay in the Department (compared with 24% University-wide); about 40% of the undergraduates participate in industrially-created design projects, and 14% of the graduates have taken co-op positions. Team projects are given in many so-called lecture courses.

Undergraduate Research. We have had a strong emphasis on undergraduate research projects for many years, as indicated in the data below. The number of students enrolled in undergraduate research, and the size of the graduating class are indicated in the table below.

Table III. Undergraduate Research Students in Chemical Engineering

Year	UG Research	Grad. Seniors	%
1991-92	26	55	47
1992-93	24	53	45
1993-94	37	67	55
1994-95	25	57	44
1995-96	45	66	68
1996-97	50	73	68

(Some of the people taking UG research are juniors, and repeat in their senior year, so the fraction of graduating seniors who have taken UG research in their career is slightly less than the percentages shown.)

Industrial Design Problems. The Department also has recently emphasized industrial design problems, working with industry to define the problem and help the students develop a design. For example, a project was sponsored by Procter & Gamble's oleochemical group in Sacramento, where coconut oil is converted into alcohols, fatty esters and acids, and glycerin. It involved neutralization of an acidic wastewater stream prior to discharge to the municipal sewer treatment system. The student-generated solution is now being implemented by P&G.

Professor Jim Seferis used problems for the design course that were posed by companies making things with polymeric composites. Teams were formed involving these students, his graduate students, and company personnel, to work on the design problem. The companies involved were Sage Co., which makes premium fly fishing rods; Vaupell Industrial Plastics, which makes supports for the storage bins in Boeing 767 airplanes; and Heath Tecna, Hexcel, which makes the leading edge of the Boeing 757 wing out of composites. The course also included a four-hour lecture/discussion by Phil Condit, president and CEO of Boeing.

In addition, some of our students have been involved with a multidisciplinary design effort, the Fuel Cell Driven Locomotive. The project involves faculty from four other engineering departments and about 25 engineering seniors as they try to assemble a hydrogen fuel cell, motors, brakes, fuel tanks, rolling stock, and electronic controls. Chemical engineering seniors can work on this project in lieu of the regular design course, although they must participate their entire senior year.

Co-op Program. The teaching capacity of the Department expanded in the early 1990s when the Nuclear Engineering department was phased out and some of their faculty were added to Chemical Engineering, as well as when faculty retired and were hired back part-time to teach. The Department changed from teaching each required undergraduate course once per year to teaching it twice per year. (This is called the dual-track system, although there is so much exchange between the 'early' track and 'regular' track that the nomenclature is no longer appropriate.) There were two important results: we could accept more students and the students we did accept could engage in six-month internships. Internships were not possible previously because missing one course meant not having the prerequisites to continue until the next year. Consequently, the participation in the internship program has also grown as shown below. The following table shows statistics on undergraduate enrollment and enrollment in internships and co-ops.

Table IV. Chemical Engineering Undergraduate Enrollment and Enrollment in Internships and Co-ops

	Undergraduate Enrollment (Source: Registrar's 10-day lists) Yearly Average	Enrollment in Internships and Co-ops
1991-92	124	6
1992-93	128	7
1993-94	137	9
1994-95	144	23
1995-96	148	29
1996-97	156	31

Women in Chemical Engineering. The percentage of undergraduate students that are women is about 35%, although it varies from year to year.

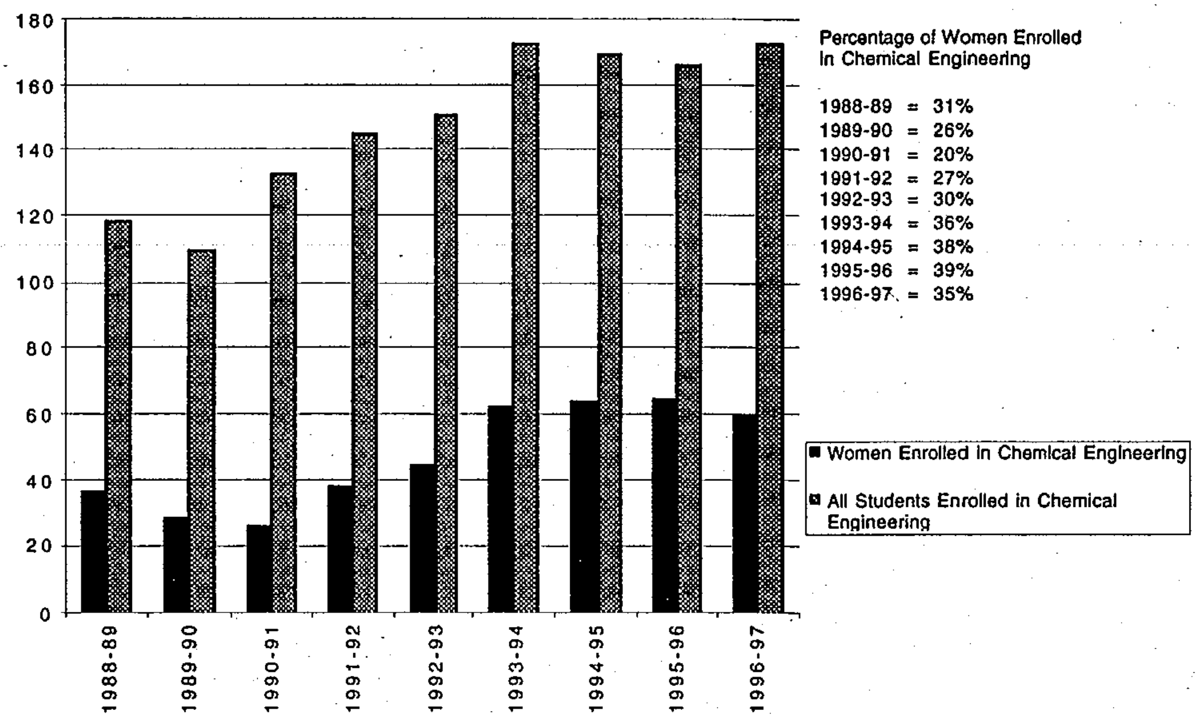

Figure 2. Women Enrolled in ChE

In the year 1996-97, 43% of the B.S. degrees went to women. This record is contrasted to that of the College, where the enrollment is only 20% women, and it is even lower for the College without Chemical Engineering.

Undergraduate Scholarship. Alumni gifts have endowed a number of undergraduate scholarships, which pay full in-state tuition. The number of scholarships (both Departmental and outside ones) is listed in Table III.

Table V. Undergraduate Scholarships for Chemical Engineering Students

	1990	1991	1992	1993	1994	1995	1996	1997
No. of Students:	20	26	23	31	39	25	33	34

Retention. The retention rate for students admitted to the Department is excellent. Of the 73 students admitted to the Junior Class in 1995, 63 of them graduated in June 1996, or shortly thereafter. Excluding those students that took one chemical engineering course and decided it wasn't the field for them, we had a graduation rate of 63 out of 67, or 94%. That high figure is a result of very good admissions decisions, hard work on the part of the students, and good teaching on the part of the faculty.

Time to Degree. In January 1994, we gathered statistics on everyone who took the capstone design course, Ch.E. 486. There were 64 students and their average time of residence in the Department was 6.8 quarters. It takes six quarters to take the courses in the 'regular' track and seven quarters in the 'early' track, so that this is an excellent record. If students pass the required courses, the succeeding courses are there for them when they need them.

Job Opportunities for B.S. Graduates. The following chart illustrates the kinds of jobs that the B.S. graduates have obtained upon graduation over the past five years. This picture is not the total story, however, because it reflects only jobs that students had on day of graduation. Statistics on day of graduation are summarized in Table VI. Some students do not have jobs on the day of graduation, and in fact some have never interviewed. Getting information after graduation is much more difficult and incomplete data are not provided.

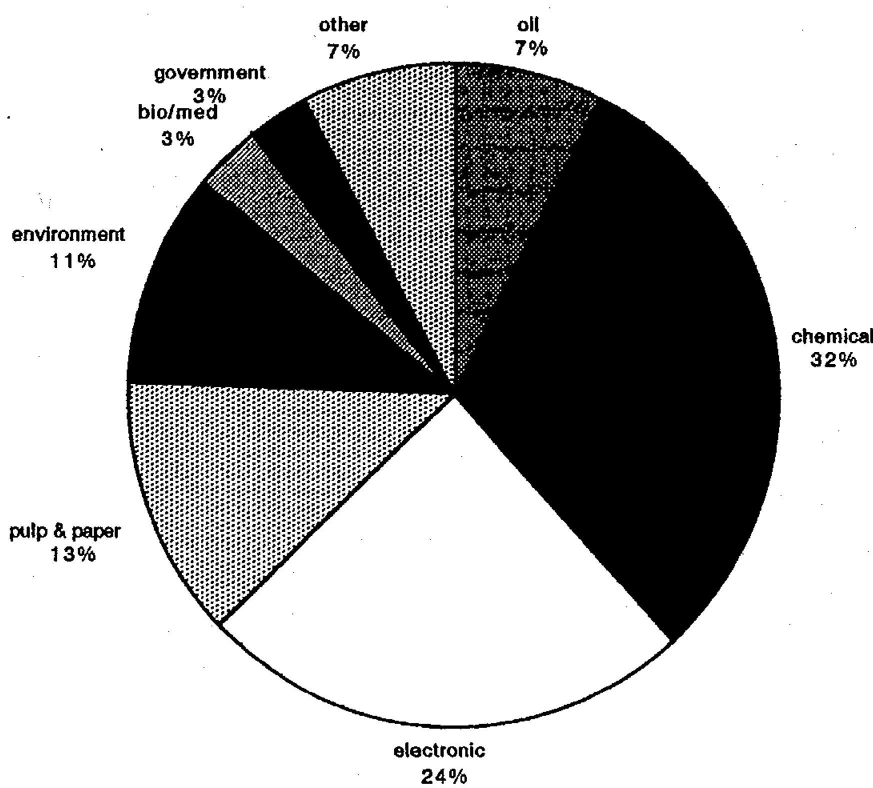

Figure 3. Employment of UW ChEs, 1993-97

Table VI. Job Opportunities

	1993	1994	1995	1996	1997
Accepted job	13	20	14	21	30
No Offer, June grad. (have not interviewed)	16	12	15	17(6)	19(8)
No Offer, Aug. Dec.	22	10	11	11	9
Grad School	12	7	10	7	9
Total responding	63	49	50	56	67
No response	1	5	5	7	1
Total	64	54	55	63	68
% of June grads w/jobs & grad school	61	69	62	62	67

B.S. Graduates Going to Graduate School. The B.S. graduates from this department are highly sought after, as evidenced by schools that make recruiting trips to the UW campus to recruit our students. About 8-10 students go to graduate school after their B.S. each year, and the schools they enter are diverse and distinguished. The schools our graduates have been admitted to for graduate school over the past five years are: Stanford; University of California at Berkeley, Los Angeles, Davis, Santa Barbara; the University of San Francisco; Washington State; University of Washington; Purdue; MIT; University of Virginia; Illinois; Texas; Johns Hopkins; Northeastern; Pennsylvania State; and Tulane; students have also gone on to law school, business school, and medical school.

International Students. There are usually 4-6 international students in the Department at any one time, and the Department has an exchange program with Chulalongkorn University in Thailand that brings two of their undergraduates here for the junior year, followed by an internship at Dow Chemical. Most chemical and oil companies are global in outlook, and these efforts need to be continued and expanded, provided the expense is minimized.

Assessment. The Department assesses its success in several ways. An important way is the interest shown in our graduates by industrial recruiters and graduate schools elsewhere. More formal mechanisms include the ABET accreditation, our peer review system, student evaluations of teaching, surveys of current students, surveys of alumni, and a roundtable discussion by all the faculty each year. The complete description is provided in Appendix I.

The last ABET accreditation visit was in 1995, with results announced in the summer of 1996. Our outcome was simple and direct:

"The program is especially strong in integrated design experiences, integrated computer experience, integrated oral and written communication experience, integrated safety and ethics, and applications of statistics throughout the curriculum. The introduction of process simulation in the first introductory course (and its later use throughout the curriculum) is especially noteworthy, as was the quality of capstone design reports in the curriculum exhibit examined."

The UW Office of Educational Assessment surveyed all University graduates in the years 1990, 1991, and 1993. The survey asked each person to rate their major department in 14 different categories. The Department of Chemical Engineering came out first in 3 of the 14 categories, competing against all departments in the University. The Department was first in:

- Learning Independently.
- Understanding and Applying Scientific Principles and Methods.
- Understanding and Applying Quantitative Principles and Methods.

The Department was second in:

- Defining and Solving Problems.

No other department at the University had this many first and second place results. Note also the confluence of this rating by students with the desire to instill the skills making possible lifelong learning. The complete survey is in Appendix I.

The University of Washington has standard surveys that faculty are asked to give to students in their classes, and the College of Engineering requires this be done in each class. Data from Winter Quarter 1994 through Winter Quarter 1997 shows that the faculty in 9 of 16 graduate courses achieved a rating of 4.0 or higher in the questions on instructor effectiveness (average of questions 3 and 4). Among senior courses, 18 of 47 were so rated, and among junior courses, 11 of 23 were rated 4.0 or higher. This is an extremely good record. The University of Washington concentrates on question 18, 'Amount learned in this course', and has a goal (not yet reached) of having 98% of the courses rated good or better in this category. For the 1996 and 1997 calendar years, the Department of Chemical Engineering was rated good or better in 97.2% of its classes. See Table VII, Ratings Summary.

Surveys of alumni are harder to perform, since we usually only get a 15% rate of return. However, the alumni consistently say that the most important aspect of their education was the camaraderie with their fellow students in the Department. They feel they got a good grounding in the fundamentals of science and engineering, but many complain that they did not get enough of the practical aspects of engineering. Since we survey students after two and five years, we have not yet surveyed students who have participated in the industrially-created design projects.

Following preparation of this document the Department will begin to address the assessment techniques that are necessitated by the ABET 2000 rules.

New Technology. The Department has embraced computer technology, and the tools used today are very different from those used 10 years ago. Currently the Department has a computer laboratory with 30 Macintosh computers (mostly Powermacs), and the process simulator ASPEN is introduced in the first course and used in successive courses, heavily in the capstone design course. Professor Holt developed a control experiment that has revolutionized the teaching of Process Control, and these experiments, tied to a computer, have drawn rave reviews from visitors interested in control. Professor Stuve has introduced a new experiment into the Unit Operations Laboratory to investigate the transport properties of gases under high vacuum. Additionally, many undergraduates engage in research projects in the graduate laboratories. Professor Finlayson routinely has students develop Web lessons in his courses, and creative lessons on fluidized beds, polyethylene, and membranes have been made by students.

TABLE VII.

Instructional Assessment System
Office of Educational Assessment
University of Washington

RATINGS SUMMARY
Chemical Engineering
Engineering
Engineering

Campus: University of Washington
Term: AU96, WI97, SP97, SU97
Printed: 10/9/97

The course as a whole

	No. of Classes	AVERAGE (0=very poor; 5=excellent) Dept	(Sub)College	Univ	DECILE FREQUENCIES 0	1	2	3	4	5	6	7	8	9
100-200	1	2.00	3.39	3.75	1	0	0	0	0	0	0	0	0	0
300-400	34	3.73	3.74	3.94	2	2	6	4	4	3	3	3	3	4
Grad	8	3.68	3.90	4.07	0	2	2	1	0	0	0	0	1	2
Total	43	3.68	3.67	3.89	3	4	8	5	4	3	3	3	4	6

The instructor's effectiveness in teaching the subject matter

	No. of Classes	AVERAGE (0=very poor; 5=excellent) Dept	(Sub)College	Univ	DECILE FREQUENCIES 0	1	2	3	4	5	6	7	8	9
100-200	1	2.00	3.47	3.88	1	0	0	0	0	0	0	0	0	0
300-400	34	3.83	3.76	4.01	1	3	1	4	3	8	5	3	5	1
Grad	8	3.58	3.93	4.08	1	0	3	1	0	0	0	1	0	2
Total	43	3.74	3.71	3.97	3	3	4	5	3	8	5	4	5	3

Expected grade compared to other courses

	No. of Classes	AVERAGE (1=much lower; 7=much higher) Dept	(Sub)College	Univ	DECILE FREQUENCIES 0	1	2	3	4	5	6	7	8	9
100-200	1	4.50	4.66	4.78	0	0	0	1	0	0	0	0	0	0
300-400	34	4.50	4.63	4.80	6	4	6	5	5	4	2	0	0	2
Grad	8	4.55	4.74	4.76	1	2	1	1	1	0	0	1	0	1
Total	43	4.51	4.66	4.78	7	6	7	7	6	4	2	1	0	3

Amount of effort to succeed relative to other courses

	No. of Classes	AVERAGE (1=much lower; 7=much higher) Dept	(Sub)College	Univ	DECILE FREQUENCIES 0	1	2	3	4	5	6	7	8	9
100-200	1	4.83	5.35	5.27	0	0	1	0	0	0	0	0	0	0
300-400	34	5.60	5.25	5.33	4	2	2	4	2	2	4	4	0	10
Grad	8	5.14	5.21	5.18	1	0	2	1	3	0	0	0	0	1
Total	43	5.49	5.27	5.27	5	2	5	5	5	2	4	4	0	11

Hours spent per week (including class sessions)

	No. of Classes	AVERAGE (hours) Dept	(Sub)College	Univ
100-200	1	9.50	9.81	8.74
300-400	34	12.49	10.01	8.92
Grad	8	11.68	9.98	8.64
Total	43	12.27	9.95	8.79

Grade expected in class

	No. of Classes	AVERAGE (GPA) Dept	(Sub)College	Univ
100-200	1	3.20	3.30	3.32
300-400	34	3.31	3.34	3.41
Grad	8	3.47	3.51	3.59
Total	43	3.33	3.37	3.41

In summary, the faculty are devoted to their teaching, are innovative in trying new techniques while keeping the successful old ones, and provide a first-class education to the B.S. graduates.

Leadership. The Department is providing leadership in the undergraduate education field, mainly through ASEE (American Society for Engineering Education). Finlayson served as director of the Summer School for Chemical Engineering Faculty, held in 1997. This school is held only every five years, and provides workshops and a means for exchanging teaching materials. As director, Finlayson organized the program and raised $120,000 to cover the on-site expenses of 180 participants from 99 schools. Several faculty have presented workshops at the last three conferences in 1997, 1992, and 1987. The faculty also present papers at the annual ASEE conference, giving eight papers in the five years through 1998. Finlayson has demonstrated his Chemical Reactor Design Tool at AIChE meetings (and installed it at 13 universities worldwide), and has also presented papers on project-based learning in a numerical analysis course, with Web lessons developed by the students. Holt developed a process control laboratory that has revolutionized the teaching of Process Control. The experiments, tied to a computer, have made the rather abstract mathematics principles of the topic very concrete. The University of Washington introduced process simulation early (in 1973 by Finlayson in Ch.E. 410), and later that course was disbanded since the use of process simulators was adopted for the design course. Now process simulators are used in the first course (Mass and Energy Balances) and the last course (Process Design II), and some courses in between, while the instruction booklet for ASPEN is distributed nationwide by CACHE (Computers and Chemical Engineering Education). Finlayson and three students prepared the MATLAB solutions to a set of 10 standard chemical engineering problems; this material is made available electronically nationwide and internationally.

In Appendix M are given several testimonials (unsolicited) from former students.

Plans for the Future. The teaching activities, particularly undergraduate research, industrial design projects, and multidisciplinary design efforts, require significant faculty investment of time. As enrollments creep up, it is getting harder and harder to provide that time. The enrollments at the University of Washington are expected to increase by 7,000 students over the next 10 years. A study done by Professor Finlayson, Appendix N, suggests that the growth in enrollment in the College of Engineering will be 43%, if the same proportion of students elect engineering as is done currently. Increases of such magnitude, especially when the Legislature wants to keep appropriations fixed, will be difficult to manage. The enrollment growth in the Department is shown in the table below:

Table VIII. Enrollment Growth

Autumn Quarter Statistical Report, University of Washington

	University of Washington		College of Engineering		Dept. Chemical Engineering	
	A89	A97	A89	A97	A89	A97
ug	24,442	25,740	1,505	1,530	104	148

Growth Rates Over Eight Years

	University of Washington	College of Engineering	Dept. Chemical Engineering
ug	5.3%	1.7%	42%

This enrollment growth was made possible by the confluence of two events: several faculty from the Department of Nuclear Engineering were folded into Chemical Engineering when the Nuclear Engineering department was disbanded, and several faculty retired, so that they were replaced but also taught part time as Emeritus Faculty. A discussion of the faculty retirements and future faculty hires is in the section on faculty. Suffice it to say here that another increase of 42% is not possible with level budgets.

GRADUATE EDUCATION

Graduate education involves both teaching graduate students how to conduct research and the research itself. Our goal is to educate our graduate students in sophisticated technical areas while maintaining the traditional engineering focus on improving processes (thus reducing operating costs), generating and understanding new materials with useful properties (thus creating new products), and developing problem-solving skills. The Department emphasizes the Ph.D. degree, and the research is highly interdisciplinary in nature. Most faculty have students or research projects involving faculty or students in other departments. The formal vision is described in Appendix H.

The research areas that chemical engineers work in have changed in the last decade, and these are documented in the Amundson Report of the National Research Council. The areas that were predicted in 1986 to be important, and which have in fact become important, are materials science, biochemical engineering, surfaces and colloids, and computer analysis. This has influenced the hiring in the Department. Of the last five hires, three of them do not have a chemical engineering degree: Bill Rogers (chemistry, surface science), Mary Lidstrom (microbiology), and Overney (physics, atomic force microscopy). The other two recent hires work in the newer areas as well: Schwartz (electrochemical engineering) and Baneyx (biochemical engineering). Thus the Department has positioned itself to be in the forefront of chemical engineering research as these people become better known. The Department has strong ties to the UWEB program, which uses molecular biology to design materials that are compatible in the body. Many of these newer research areas are taught as electives in the undergraduate program and influence the standard courses in chemical engineering are the same, but with different flavors depending on who is teaching the course. The Department is funded by both industry and the federal government, and some of the senior faculty enhance their programs with gift funds. The Department has a solid Ph.D. production rate and is perceived as a department with a good balance of practical and theoretical training, and breadth in its research program.

In terms of number of participants and funding levels, the materials and interfacial science effort in our chemical engineering department is world class. Efforts are currently being made by faculty involved in the materials and interface engineering area to create better synergy among the various laboratories. Two tangible results of these efforts include the development of an advanced laboratory course where a small group of graduate students get to acquire and analyze data from research equipment, and the development of LIME – the Laboratories for Interface and Materials Engineering. The Department excels in innovative teaching/curriculum development and in connecting these efforts with interdisciplinary involvement in research. An example is the availability of multiple courses in cutting-edge biology topics of interest to engineers. These courses provide engineers with access to information required to carry out top-level research at the interface between engineering and biology. As education and research become more tightly linked in the future, the Department will be in the forefront of this integrated approach.

Degrees granted. The degrees granted in the past five years are indicated in Table IX, which shows a steady production of 10 Ph.D. degrees and 6 M.S. degrees per year.

Table IX. Graduate Degrees Awarded by the Department of Chemical Engineering

Academic Year	Ph.D. Degrees	M.S. Degrees
1989-90	10	11
1990-91	14	6
1991-92	10	8
1992-93	10	2
1993-94	5	8
1994-95	12	8
1995-96	10	2
1996-97	9	5

Destination of graduates. The Ph.D.s that have graduated during the past five years have been employed in the fields shown in Figure 4.

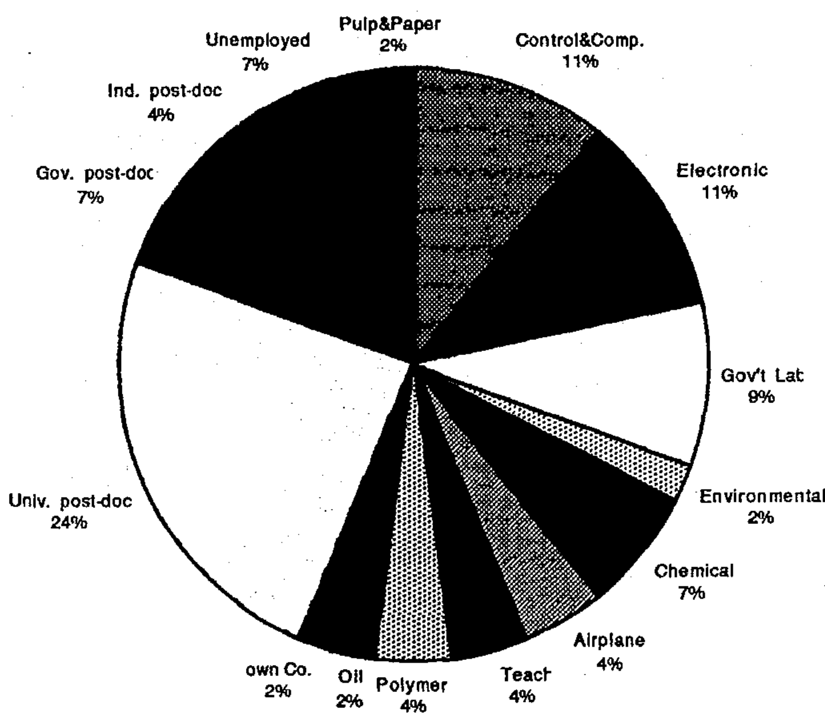

Figure 4. UW ChE Ph.D. Jobs Upon Graduation, 1993-97

Employment opportunities are diverse, and there is a growing trend to take postdoctoral positions, especially in the surface science and bioengineering fields. There is, however, ample opportunity for employment in the industrial sector. A few of the Ph.D.s take academic positions, as indicated in Table X.

Table X. Alumni of the Department of Chemical Engineering who are in Academia

Currently Teaching at Universities

Graduate	Degree Date	Advisor	University
	Ph.D. 63	WJH	Akron
	B.S. 76		Wyoming
	M.S. 77	BAF	Univ. Queensland, Australia
	Ph.D. 82	JCB	Idaho
	M.S. 62, Ph.D. 66	CAS	Arizona (ME)
	Ph.D. 81	CAS	UW
	Ph.D. 91	BDR	Duke (Bioengr.)
	Ph.D. 71	JCB	Inha Inst. Tech., Korea
	Ph.D. 61	MMD	UW
	B.S. 86		Florida
	B.S. 84		Arkansas
	Ph.D. 66	LNJ	UC Davis
	Ph.D. 95	ALB	UC Irvine
	Ph.D. 82	CAS	UW (Forestry)
	Ph.D. 78	ASH	Emory (Medicine)
	B.S. 86	BDR	UW (Dermatology)
	Ph.D. 68	CAS	Iowa State
	M.S. 56, Ph.D. 58	ALB	U Texas
	B.S. 63		Kean College of NJ (Mgt. Science)
	B.S. 78, Ph.D. 86	JCB	UW (Forestry)
	Ph.D. 77	RWM	Nat'l Taiwan U. of Sci. & Technol
	B.S. 77		Alabama
	B.S. 86		Purdue
	Ph.D. 86	BAF	Nat'l Taiwan Univ.
	Ph.D. 53	ALB	E. China Univ. of Sci. & Tech.
	Ph.D. 91	BDR	New Mexico
	M.S. 57	ALB	UW
	B.S. 58, M.S. 60	LNJ	Georgia Institute
	Ph.D. 68	JCB	UW (Forestry)
	Ph.D. 96	DTS	Guadalajara, Mexico
	Ph.D. 69	CAS	Rochester
	Ph.D. 71	JCB	Rochester
	Ph.D. 95	BDR	New Mexico
	B.S. 60, M.S. 63	WJH	UW (Civil Engineering)
	Ph.D. 62	MMD	Howard
	B.S. 52, Ph.D. 60	ALB	Arizona
	B.S. 79, M.S. 81	BDR	UC Davis (Pediatrics)
	Ph.D. 89	TAH	Memphis State (Biomedical Engr.)
	M.S. 58, Ph.D. 60	ALB	Brigham Young University
	Ph.D. 69	CAS	LSU
	Ph.D. 75	BAF	Nat'l Taiwan U. of Sci. & Technol.
	Ph.D. 92	BDR	Montana State
	Ph.D. 60	MMD	Mississippi State (Forest Prod. Eng.)
	Ph.D. 89	EJD	New Mexico

Have taught, not teaching currently

	M.S. 58, Ph.D. 60	ALB	Michigan State (Emeritus)
	B.S. 40, M.S. 42	RWM	Syracuse University (Emeritus)
	Ph.D. 64	ALB	UC Davis (Emeritus)
	Ph.D. 71	ALB	New South Wales
	Ph.D. 61	LNJ	Penn State (Emeritus
	Ph.D. 68	ALB/WJH	South Dakota School of Mines
	M.S. 68, Ph.D. 70	ALB	U Texas
	Ph.D. 83	JLM	Maine

A new course on "How to Teach Chemical Engineering" was instituted to encourage Ph.D. graduates to enter the teaching profession, but it has been singularly unsuccessful in doing so. The Department also has a TA training course that is given by CIDR, the Center for Instructional Development and Research (see Appendix Q).

Research funding has grown only modestly, but during this time 6 of 15 faculty were hired. Table XI provides the expenditures versus time.

Table XI. Research Expenditures in the Department of Chemical Engineering ($1,000)

	1/86-12/86	7/87-6/88	7/88-6/89	7/89-6/90	7/90-6/91	7/91-6/92	7/92-6/93	7/93-6/94	7/94-6/95	7/95-6/96	7/96-6/97
Federal	1,183	1,283	1,250	1,058	1,463	1,001	1,029	902	662	0	1,238
Industrial	1,018	985	1,050	1,114	1,032	1,158	1,195	894	875	0	762
Other	329	252	251	174	190	464	307	268	277	0	437
TOTAL	2,530	2,520	2,551	2,346	2,685	2,623	2,531	2,064	1,814	0	2,437

The Department has significant research expenditures being conducted using gifts, with no overhead, which must be taken into account when comparing with other institutions/departments which don't have the gifts. In addition, grants whose PI is a Joint Faculty member will sometimes be listed in the University's figures as Department of Chemical Engineering and sometimes as the other Department. Thus year-to-year figures are very difficult to interpret. Since all graduate students are supported, graduate degrees awarded is probably the best measure of the graduate education in the Department.

Productivity. Typical measures of productivity for graduate research are Ph.D.s granted per faculty, publications per faculty, and citations per faculty. Over the past decade, the faculty has averaged about 0.7 Ph.D./faculty each year, whereas the College average is about 0.3. The faculty published 154 papers from March 1995 to March 1997.

NRC rankings. All research-doctorate programs in chemical engineering were rated by the National Research Council in 1993. The results place the Department of Chemical Engineering at the University as 20th out of 93 schools rated for quality of faculty, and 17th out of 93 schools rated for effectiveness of the graduate program. Prior ratings of the Department are listed below.

Table XII. NRC Ratings

Year of rating	UW Ch.E.	in top %
1964	15 out of 56	27%
1969	16 our of 58	28%
1982	16 & 16 out of 79	20%
1993	20 & 17 out of 93	22/18%

Complete statistics for the 1993 survey are given in Appendix K. Considerable data is available in addition to the rating itself. If one concentrates on the schools in the top quartile, the Department is 14th in publications per faculty member, 15th in citations per faculty member, 8th highest in percentage female graduate students, 17th in Ph.D.s granted per faculty member, 5th in the percentage of Ph.D.s granted to women, 8th in the percentage of Ph.D.s granted to minorities, 4th highest in the percentage of U.S. citizens, and 17th in the mean years to degree. In every one of these statistics the Department is better than its overall rating of 17th - 20th, and in some of them it is much better. Clearly, the visibility of the Department needs improving.

Time to Ph.D. degree (from date entering the grad program to presentation of the thesis).

Table XIII. Time to Ph.D. Degree

Academic Year	Number	Years
1989-90	10	5.5
1990-91	14	4.9
1991-92	10	5.0
1992-93	10	4.8
1993-94	5	4.8
1994-95	12	4.6
1995-96	10	4.9
1996-97	9	4.9

Some faculty, particularly in the biological areas, argue for a longer time in graduate school, while others have their students graduate in exactly five years. Others have their students graduate between four and five years. In 1996 the Department agreed to review all graduate students' progress each January, in an effort to focus attention on problem students, and this has had a small impact.

Balance between Ph.D. and M.S. degrees. Within the graduate program, there is some concern that the Ph.D. degree is less important now, but others want to expand the number of graduate students. Some faculty are willing to have M.S. students who are supported the first year as Teaching Assistants, whereas others are not. The Department has not come to agreement on the preferred size of the M.S./Ph.D. program, although the last decision was to have three-fourths of the students working towards the Ph.D. degree and one-fourth working towards the M.S. degree. Dramatic changes in this measure will not be made because the faculty do not agree on the future importance of each degree.

Changes. The graduate program has continued to be focused on the Ph.D. degree, with an average of 6 Ph.D.s awarded per year in the 1980s and 10 Ph.D.s awarded per year in the 1990s. The graduate program is smaller than it was, with the major difference between now and 1989 due to a smaller number of chemical engineering students working for bioengineering professors. Recently the Department decided to offer an option to incoming students to be supported as a Teaching Assistant rather than a Research Assistant. There are many students who really want to come here but are denied admission because of the lack of support. The hope is that more of them can come. It also makes possible a larger M.S. program, since a research program won't have to support a student that takes classes half of their time in residence. Some, but not all, of the faculty are eager to use this program. The Chair believes that the Ph.D. degree is less desirable in today's market, since few Ph.D. graduates are working in research environments, and that the M.S. program should be expanded, but it is very difficult to run a first-class research program with M.S. students. The statement of the Department's goals says that the current population of graduate students should remain constant or expand by collaboration outside the discipline. In the fall of 1997, 14 graduate students were supported by external or Departmental fellowships and there were 9 TAs. Thus 40% (23/57) of the graduate students were supported by means other than a research grant. In 1990, the corresponding percentage would have been about 15%.

Curricular innovations. Seferis has developed a Team Certificate Program (see Appendix C). This program is designed for those who wish to develop or improve their existing team participation skills while working in a global business, education and research environment. The team consists of a group of about 10 members; some of them are graduate students, but most are from companies. The work proceeds through three stages, starting with project definition and team building, working at industrial sites on the project, and finally completing the personal and team objectives. The certificate is awarded by the University of Washington, and is signed by the president of the University as well as the presidents of the participating companies. The Team Certificate Program received an award from the American Society for Engineering Management as the 1995 Academic Innovation Award.

In October 1997, the faculty introduced a set of core courses for doctoral students in five categories: Math/Computer/Statistics, Thermodynamics, Transport Phenomena, Reaction Phenomena, and Materials and Biotech. In addition to the existing requirements by the Graduate School, doctoral students must complete five courses from at least four of these five categories and one Chem E course in a topic outside the student's main research area. See Appendix O.

The Department, in 1998, initiated a rotation class in which a few students will go from one laboratory to another (in successive weeks) and perform surface science, electrochemical, and polymer composite measurements in each laboratory as well as computational fluid mechanics. The goal is to make the students aware of the characterization techniques that exist in the building so that their outlook is broader than the single technique relevant to their thesis. Finlayson has offered a graduate numerical analysis course on the Televised Instruction in Engineering system as well as the National Technological University (NTU) twice and has had students from around the country take it on TV. Stuve is preparing a course on Fuel Cells, which will be given through the Televised Instruction in

Engineering program as well as possibly NTU. The funding mechanisms for NTU make it expensive for students at other universities to take the courses (they would be paying tuition twice), so that mechanism of delivery seems relegated to professionals working for companies. This makes it harder to develop a market for the courses, so that our efforts in this area have been limited. Finlayson also reports it is a lot of work to do a course on TV, compared with regular delivery.

Joint activity on campus. Naturally, a faculty with so many ties to other departments will have much joint activity. Projects that have occurred or are planned include ones with Olson in Genetics; Engel in Chemistry; Lory in Microbiology; Saxberg in Business (Creativity); Ferguson in Civil Engineering; Deming in Oceanography; Pearsall in Materials Science and Engineering; Chang in Rehabilitative Medicine; Bassingthwaighte in Bioengineering; Hlastala in Medicine, Physiology and Biophysics; Baker in Geophysics; as well as projects with the Center for Process and Analytical Chemistry, Restorative Dentistry, Pulmonary and Critical Care Medicine, the Nanotechnology Center, and the University of Washington Engineered Biomaterials program.

Joint activity with other institutions. The faculty have a broad collaboration with faculty at other institutions. A sample of the collaboration is given here. Professor Lidstrom collaborates with Professor Roelf Thauer, director, Max-Planck Institute for Terrestrial Microbiology, Marburg, Germany; Dr. Michelle Buchanan, director, Mass Spectrometry Laboratory, Oak Ridge National Labs, Oak Ridge, Tennessee; and Dr. Ron Oremland, USGS, Menlo Park, California. In all of these collaborations, each contributes key expertise and technology to projects that neither group could do alone, and shares personnel to maximize efforts. Professor Lidstrom also exchanges ideas on teaching molecular biology to engineers with colleagues in Environmental Engineering at Stanford and Biochemical Engineering at Iowa. Professor Schwartz has included Professor John Newman (UC Berkeley) and Professor Eliezer Gileadi (Tel Aviv University, Israel) as subcontractors on a recent DOE proposal, although only his portion was funded. Professor Allan collaborates with Western Michigan University, the University of Guadalajara (Mexico), and the University of Oviedo (Spain). Professor Ricker exchanges software, publications, and ideas via the Internet and regular attendance at professional meetings. For example, he published a series of papers with J. H. Lee at Purdue. He also collaborated with Professor M. Morari (then at CalTech, now at ETHS Zurich) on software tools for research and teaching. Professor Horbett wrote two reviews and co-edited two symposium books on proteins at interfaces with John Brash of McMaster University in Ontario, based on a large international symposia that they co-organized. He has also written research articles with I. Feuerstein of McMaster University and James Bryers, formerly at Montana State University. Professor Finlayson has co-published with Professor Hrymak at McMaster University as well as engineers at Lawrence Livermore Laboratory. Professor Overney has an active interdisciplinary project in the Material Research Science and Engineering Center (MRSEC) of "Engineered polymer surfaces" with the State University of New York, Stony Brook, New York. Professor Davis has a joint research program with Professor Gustav Schweiger of the Ruhr Universität in Bochum, Germany. The project involves a Research Associate, and exchanges students as well. Professor Berg has co-published with many people from around the world, and has sent six students to study in their laboratories:

- Professor Erwin Killmann, Technical University of Munich, Germany (2 publ.).

- Professor Heiko Cammenga, Technical University of Braunschweig, Germany.
- Professor Lars Ödberg, STFI and Royal Institute of Technology-Stockholm, Sweden (3 publ.).
- Dr. Bo Westerlind, SCA Teknik, Sundsvall, Sweden (1 publ.).
- Professor J. Lyklema, University of Wageningen, Netherlands.
- Professor Jacob Israelachvili, University of California, Santa Barbara, California.
- Professor Krzysztof Warmuzinski, Polish Academy of Sciences, Gliwice, Poland.
- Dr. Albert E. Seaver, 3M Company, St. Paul, Minnesota (1 publ.).
- Professor Richard O'Brien, University of Sydney, Australia (1 publ.).
- Professor Jan-Anders Mânson, École Polytechnique, Lausanne, Switzerland (2 publ.).

Other graduate students who have gone to other countries to perform part of their studies include:

- Stephen Porter who went to the University of Siena for six months to study polyurethane synthesis from a research group specializing in novel heparin-binding biomaterials.
- Gabe Lopez and Erika Johnston who both participated as speakers in international symposia and visited laboratories during their trips to Europe.

Research Associate Professor Dave Castner has co-published with many people in the United States and one abroad:

- Professor David Grainger, Colorado State University (11 refereed papers).
- Professor John Rabolt, University of Delaware, (3 refereed papers).
- Professor Ellen Fisher, Colorado State University, (2 refereed papers).
- Professor Kevin Healy, Northwestern University, (2 refereed papers);
- Dean Stuart Cooper, University of Delaware, (1 refereed paper).
- Professor Martin Schmal, University of Rio de Janeiro, (4 refereed papers).

Professor Seferis has collaborated with:

- Professor Jan-Anders Mânson, École Polytechnic, Lausanne, Switzerland.
- Professor Jae-Do Nam, Sung Kyun Kwan University, Korea.
- Professor G. Zachmann, University of Hamburg, Germany.
- Professor L. Nicolais, University of Naples, Italy.
- Professor I. Kimpara, University of Tokyo, Japan.
- Professor F. J. Balta-Calleja, Institute de Estructura de la Materia, Spain.
- Professor K. J. Lee, Seoul National University.
- Professor E. Woo, National Cheng Kung University, Taiwan.

Professor Seferis has approximately 22 publications in collaboration with foreign institutions. Some of his students have gone to other countries for part of their studies: Brian Coxon and Karl Nelson to University of Hamburg, Germany; and William Paplham to Instituto de Estructura de la Materia, Spain. Seferis's graduate student Wes Lawrence performed part of his studies at the University of Delaware.

Objectives and limitations. "Graduate education provided by conduct of experimental, computational, or theoretical projects is an essential part of a research university. It is through these projects that the Department pushes forward the frontiers of knowledge in specific fields. These efforts allow the Department to bring this new knowledge into the classroom and present students with the most up-to-date information related to their fields of study. Faculty need the ability to inspire critical evaluation skills and creativity in their graduate students. By publication and presentation the Department is able to attract the best students to attend graduate school and generate funds to support the graduate projects. The Department will maintain its outstanding research programs and facilities by providing space and other resources to successful programs and faculty. The Department will continue to support new faculty to help them become outstanding educators." (From the Department's Vision Statement, Appendix H.)

Several faculty commented in ways that emphasize different aspects of this vision.

- "Every effort I make to support the doctorate program has one singular objective: to develop students with the knowledge, learning tools, and communication skills needed to catapult them to success in whatever professional endeavors they choose. The more successful our students are – and the more they associate that success with lessons learned during their graduate experience – the more likely we as a department are to see programmatic success. The main impediment to helping catapult our students to professional heights is the size and intellectual drive of our graduate student body. One of the tremendous benefits of a large graduate program is the opportunity created by having successful alumni already placed at companies and universities across the country. A successful student begets more success for other students. Increasing the number of doctoral students in the program requires a sufficient resource base so there is a safety net in case we over-recruit. As it stands, we routinely under-recruit because there is no risk in under-recruiting (and we are a risk averse group). Boosting the intellectual drive of our students is more difficult. Traditional seminars can foster intellectual drive in some students, but I think the more personalized form of a broad-based Journal Club could elevate the expectations of more students; this requires serious participation by the faculty (something they've not been willing to do). Right now the sum of the parts does not add up to more than the parts individually. The Materials faculty have started in the right direction by offering a research methods class and by forming LIME (Laboratories for Interface and Materials Engineering)."
- "Objectives: develop persons with critical thinking skills, good communication skills, and accomplishment-based motivation who make significant contributions to chemical engineering practice and research in a variety of fields. Differences: Perhaps we focus a little more than others on our big clients, such as Boeing. Impediments: low acceptance rate of top-ranked graduate applicants; willingness of some students to accept low quality effort in others; lack of industrial experience in some students. Steps for improvement: increase national visibility, focus on graduate recruitment as a high priority, increase industrial participation in research activities."
- "Undergraduates are taught what is pretty well known and understood, and relatively little about how to discover new information. I think the main thing a Ph.D. program has to do is to teach people how to deal with the unknown and how to extract useful, correct information about it. Often, of course, this also means training in advanced measurement and analysis

techniques of various kinds, i.e., exposure to state of the art methodology and even further development of new methodology. In my field, all this boils down to becoming a first rate experimentalist, meaning the conception, design, performance, and analysis of experiments intended to test some relevant hypothesis. I often say that I know my students are ready to get out when they start recognizing what is wrong or right about a proposed or past experiment in greater detail and accuracy than I do, i.e., I can see them become absolute real experts in their experimental area. Impediments: In recent years, for me this has been the reluctance to take on new Ph.D. students much after the beginning of my grants. They run for three years, and taking a Ph.D. student on after year one in today's funding climate means he could be without funds for the majority of his career. I see no easy fix for this impediment! One way to improve our program would be to try to reduce the chances of wasting these resources on people who do not turn out well."

- "There should be an increase in graduate student numbers (at least to previous levels of approximately 75), and higher priority should be given to graduate student supervision and support in the Department."

FACULTY

Description of current situation. There are 15 faculty members in the Department of Chemical Engineering, 2 of them paid by Chairs funded by gift monies. Currently we can regard 12 as being full-time chemical engineering professors with teaching and research, 1 as teaching only (former administrator), 1 as a current administrator (Associate Dean), and 1 position is technically vacant, although the person is appealing a negative tenure decision. In the past eight years the Department has hired six faculty, in the following fields: biochemical engineering, surface science, microbiology, physics, electrochemical engineering, and polymer science. These are growth areas in chemical engineering, and we have been fortunate to be able to hire so many in the current growth areas. A group of faculty met in the summer of 1997 and suggested that the next hire be ". . . an outstanding chemical engineer that has research interests in developing innovative research programs in engineering materials and microstructures, biologically-based materials, and sensors development. The person should be able to interact with existing programs in these areas." but this has not been agreed to yet. The faculty member must be capable of teaching many of the core chemical engineering courses. During the past decade the Department has become more science based, and less engineering based, although its industrial support remains high. The complete history of faculty hirings and retirements/resignations is given in Table XIV.

The Chemical Engineering department has a long tradition which values excellence in teaching. This is evident in the outstanding undergraduate program, the devotion to the graduate program, and the multidisciplinary nature of that graduate education. Full-time professors are expected to engage in graduate research as well as undergraduate and graduate classroom teaching. Nearly all the professors have undergraduate research projects during the year. The research programs covered by the Department are: materials, colloid and surface chemistry, polymeric composites, biochemical engineering and bioengineering, environmental technology, computers and process control, transport phenomena, and physics.

In addition to the full-time faculty, the Department is fortunate to have several Joint Professors that contribute to the graduate program. First, Professor Mary Lidstrom is 100% Chemical Engineering and 0% Microbiology, and is funded by the Jungers Chair. Professor Buddy Ratner (25% Chemical Engineering, 75% Bioengineering) is director of the UWEB program for engineered biomaterials. Professor Tom Horbett (0% Chemical Engineering, 83% Bioengineering) has an active research program in blood compatibility with surfaces. Professor Graham Allan (0% Chemical Engineering, 100% Paper Science and Engineering) studies new fillers for paper that will reduce paper usage and require less energy for manufacturing. Research Associate Professor David Castner (75% Chemical Engineering, 25% Bioengineering) is the director of the NIH-funded NESAC/BIO Center for analysis of bio-related surfaces. Professor Babb, although Emeritus, has an active research program with Public Health related to mass transfer in the lung. Professors Allan and Babb also teach undergraduate courses, with Allan teaching Creativity and Babb teaching the beginning Mass and Energy Balance course.

Table XIV.

CHEMICAL ENGINEERING FACULTY

1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Berg	—	—	—	—	—	—	—	—	—	—	—
Davis	—	—	—	—	—	—	—	—	—	—	—
Finlayson	—	—	—	—	—	—	—	—	—	—	—
Holt	—	—	—	—	—	—	—	—	—	—	—
Krieger-Brockett	—	—	—	—	—	—	—	—	—	—	—
Ricker	—	—	—	—	—	—	—	—	—	—	—
Seferis	—	—	—	—	—	—	—	—	—	—	—
Stuve	—	—	—	—	—	—	—	—	—	—	—
Heideger	—	half time	—	—	—	—	retired				
Fisher	—	—	left								
Kaler	—	—	left								
Sleicher	—	—	retired								
				Rogers	—	—	—	—	—	—	—
				Wedgewood	—	—	—	—	—	—	—
					Schwartz	—	—	—	—	—	—
						Baneyx	—	—	—	—	—
						Woodruff	—	—	—	—	retired
									Lidstrom	—	—
										Bowen	—
										Overney	—
Research & Temp.											
Castner	—	—	—	—	—	—	—	—	—	—	—
										Chistoserdova	—
											Hayes (temp)
Joint Faculty											
Allan	—	—	—	—	—	—	—	—	—	—	—
Hoffman	—	—	—	—	—	—	—	—	—	—	—
Horbett	—	—	—	—	—	—	—	—	—	—	—
McKean	—	—	—	—	—	—	—	—	—	—	—
Ratner	—	—	—	—	—	—	—	—	—	—	—
Garlid	—	—	—	—	—	—	—	retired			
Babb	—	—	—	—	retired						
Sarkanen	—	—	—	—	deceased						

Leadership in the profession. National leadership of the Department is diverse, and the faculty participate actively in national organizations. Professor Berg chaired and brought to the UW campus the 1989 American Chemical Society Colloid and Surface Science Symposium with 550 attendees from all over the world. Finlayson has been a director of the AIChE and chairman of the Computers and Systems Division, Ratner has been the president of the Society for Biomaterials, Davis is currently president of the American Association for Aerosol Research. Finlayson has been asked to run for president of the American Institute of Chemical Engineers and has been a member of the Board on Chemical Science and Technology of the National Research Council. Rogers has been a member of the Board of Directors of the American Vacuum Society and is presently serving on the Executive Committee of the Applied Surface Science Division of AVS. He is on the Board of Governors of the American Institute of Physics as well. Stuve is a trustee of the American Vacuum Society and has served as director. Bowen has been president of the Board of Directors of ASEE and is the founding president of the Institute for Dynamics of Explosions and Reactive Systems. Faculty have served on 26 national panels during the past two years. Ratner is the director of the UWEB program. Ratner, Overney, Finlayson, and Stuve are highly cited in the national literature. Several faculty serve as associate editors of journals, as noted below.

Role in professional education. The Department yearly provides a Refresher Course for the Professional Engineers exam, thus providing professional education for practicing engineers in the local area. This is done despite the fact that no current full-time faculty members are registered professional engineers. Berg has a yearly Continuing Education industrial short course in Surface and Colloid Science. Seferis gives two Continuing Education courses each year, Thermal Analysis and "Prepreg" short courses, along with several workshops. During the last 10 years, he also has conducted short courses overseas in Asia and Europe. Finlayson has offered a graduate numerical analysis course on the National Technological University (NTU) and has had students from around the country take it on TV. Stuve is preparing a course on Fuel Cells, which will be given through the Televised Instruction in Engineering program as well as possibly NTU. On a regular basis NESAC/BIO sponsors workshops on "Surface Characterization of Biomaterials." For the last three years, a three-day workshop has been held on the UW campus under the Engineering Professional Programs with 1.6 Continuing Education Units offered for those that complete the workshop. Condensed versions of this workshop are given periodically at professional society meetings (e.g., Society for Biomaterials).

The courses we offer on the graduate level focus on the Ph.D. degree, and we have adjusted the course requirements recently (see Appendix O). Seferis has developed the AMMAP program to involve his students in teaming. Most of the graduate courses are not conducive to a Master's program, and, except for the AMMAP courses, are less suitable to someone in industry. There are only 500 members of the AIChE in western Washington, so that the demand for advanced degrees by local practicing engineers is weak.

Quality measures. The quality of the faculty is ultimately measured by the impact they have on their graduate students and society at large. This is very hard to measure, however. Criteria that are more easily measured include publications (which are peer reviewed for quality), research dollars (which are peer reviewed for quality and impact), citations to published work (that partially defines the impact in the work of others), awards (which are peer reviewed), books written, symposium led, and editorships (both awarded by reputation).

We look to schools such as Minnesota, Wisconsin, Berkeley, and Delaware for comparison. Since the University regards the following list of schools as our peers, the data will be compared (when possible) with the average from those schools. The peer list is Arizona, Berkeley, UCLA, Illinois, Iowa, Michigan, and Wisconsin.

The publication record of the faculty is described in Table XV.

Table XV. Publication Record (all kinds) of the Faculty
March 16, 1995 - March 15, 1997

Allan	16
Babb	6
Baneyx	14
Berg	21
Bowen	1
Castner	16
Chistoserdova	5
Davis	17
Finlayson	10
Holt	4
Horbett	12
Krieger-Brockett	6
Lidstrom	17
Overney	11
Ratner	51
Ricker	17
Rogers	8
Schwartz	14
Seferis	28
Stuve	10
Wedgewood	7
	291

The best source of data for the peer schools is the *ACS Directory of Graduate Research*. This book lists refereed papers of each faculty member published over a two-year period. The number of such papers is counted for two years, 1995-97, and the totals are given in Table XVI (excluding Emeritus faculty without publications).

Table XVI. Papers in ACS

School	1997 Volume	Pub./Fac.	Faculty in 1997
Arizona	97	6.1	16
Berkeley	222	13.1	17
UCLA	87	7.9	11
Illinois	92	6.6	14
Iowa	66	7.3	9
Michigan	168	8.0	21
Wisconsin	190	9.0	21
	922	8.5	109
divided by 7	131.7		15.6
Washington			
full time	119	7.4	16
+ Research & Joint			
& Emeritus	97	13.9	7
Total UW	216	9.4	23

The research dollars obtained by faculty in the Department in 1996-97 were $3.5 million. This amount does not put the Department in the top 25 schools of the country, as listed in Appendix L.4. for federal funding. Of course, some of the departments listed in that survey include Experiment Station revenue, which we do not have.

The total number of citations to faculty work over the past two years (1995 and 1996) are 917, or 61 per faculty member (excluding self citations). Three faculty members have over 170 in this two-year period, one has over 100, and several have about 50.

The faculty made 101 presentations during the last two-year period (March 1995 - March 1997), but only 18 of these were at AIChE or ACS meetings.

Awards. Two faculty members of the Department are in the National Academy of Engineering (Babb and Finlayson), one is in the Institute of Medicine (Babb), and 10 faculty members are Fellows of a professional society. In addition, faculty from the Department have received the following awards since 1986.

Table XVII. Faculty Awards Since 1986

G. Graham Allan

Burlington Northern Foundation, Faculty Achievement Award for Excellence in Teaching, 1986

A. Les Babb

Recipient of University of Washington College of Engineering Outstanding Teacher, 1987

Elected to Senior Membership in the Biomedical Engineering Society, 1988

Elected a Fellow of the American Nuclear Society, 1988

Recipient of NW Kidney Foundation Clyde Shields Distinguished Service Award, 1992

Received University of Illinois Alumni Association's Alumni Award at Commencement, 1993

Elected a Fellow of the American Institute of Medical and Biological Engineering, 1995

François Baneyx

Lavoisier Fellow, 1986-87

Career Award, National Science Foundation, 1995

John Berg

Invited Plenary Lecturer, Paper, Coating Chemical Symposium, Stockholm, Sweden, 1992

Visiting Professor at École Polytechnique Féderale Lausanne, Switzerland, 1995

Visiting Eminent Scholar: ERC for Particle Science and Technology, Univ. of Florida, 1997

J. Ray Bowen

Odegaard Award - UW Equal Opportunity Program, 1986

Rodney D. Chipp Memorial Award - Society of Women Engineers, 1995

Pioneer Award - UW Human Interface Technology Laboratory, 1996

E. James Davis

The Burlington Northern Award for Distinguished Research, 1988

National Academy of Sciences/Chinese Academy of Sciences, Visiting Scholar Award, 1989

The David Sinclair Award of the American Association for Aerosol Research, 1991

The Timothy J. O'Leary Distinguished Scientist Lecturer, Gonzaga University, 1992

Elected Fellow of the American Association for the Advancement of Science, 1997

Bruce A. Finlayson

Fellow, American Institute of Chemical Engineers, 1993

National Academy of Engineering, 1994

Martin Award for Best Chemical Engineering Paper, ASEE Conference, June 1994

Undergraduate Computational Engineering and Science Award, Department of Energy, 1996.

Phillips Lecture, Oklahoma State University, 1996

Thomas A. Horbett
Society for Biomaterials Clemson Award for Basic Research, 1989
Distinguished Lecturer In Controlled Drug-Delivery, College of Pharmacy, Rutgers University, 1989
Fellow, Society for Biomaterials, 1994
Fellow, American Institute of Medical & Biological Engineering, 1995

Mary E. Lidstrom
CalTech recipient, Woman at Work Award for Excellence, 1989
NSF Faculty Award for Women, 1991
Fellow of the American Academy of Microbiology, 1992
CalTech Associated Students Teaching Award, 1993
American Society for Microbiology Divisional Lecturer, 1994
American Academy of Microbiology Board of Governors, 1997

René M. Overney
Best-Paper-Award at the Exxon Chemical Company Long Range Research Meeting (CRC), 1995

Buddy D. Ratner
Clemson Award for Contributions to the Biomaterials Literature, 1989
Burlington Resources Foundation Faculty Achievement Award for Outstanding Research, 1990
Perkin-Elmer Physical Electronics Award for Excellence in Surface Science, 1991
Founding Fellow of the American Institute of Medical and Biological Engineering (AIMBE)
Fellow, American Vacuum Society, 1993
Fellow, Society for Biomaterials, 1993
Van Nes Lecturer, Rensselaer Polytechnic Institute, 1996

J. William Rogers, Jr.
Exceptional Contribution Award for "Applications to Military Programs," Sandia National Labs, 1988
Battelle PNL Professorship, 1991-1994
NORCUS-DOE Faculty Fellowship, 1992-1994

Daniel T. Schwartz
Junior Faculty Award in Environmental Restoration, Department of Energy, 1993
NSF Young Investigator Award, National Science Foundation, 1994
Award for Outstanding Faculty Achievement in Engineering, UW, 1995

James C. Seferis
Fellow of the Alexander von Humbolt Foundation of Germany, 1987-88
Academician of the National Academy of Athens, Greece, 1989

Mettler Award, North American Thermal Analysis Society, 1995
Fellow of the Society for the Advancement of Material and Process Engineering, 1996

Eric M. Stuve
NSF, Presidential Young Investigator Award, 1986

Gene L. Woodruff
Arthur Holly Compton Award, American Nuclear Society, 1986

Books have been written in the last decade by Baneyx (*Introduction to Molecular Cloning Techniques*), and Finlayson (*Numerical Methods for Problems with Moving Fronts*). Davis and Berg have notes that can be developed into books. In addition the faculty has edited seven books since 1986.

Faculty size. Data from across the country was analyzed to estimate the proper faculty size. The numbers came from the AIChE phone book, which lists degrees granted and faculty. Data was used for 75 Ph.D. granting departments and correlated with five-year graduation statistics. A multivariate regression provides the following result ($r^2 = 0.51$).

$$\text{No. of Faculty} = 9.26 + 0.105 * \underset{\text{over 5 years}}{\text{No. Ph.D.s Awarded}} + 0.0101 * \underset{\text{over 5 years}}{\text{No. B.S.s Awarded}}$$

From this formula the Department should have 17.4 full-time faculty. It currently has 15, counting 1 Associate Dean, 1 empty position that has not been allowed to be filled, and 1 faculty position that will disappear when the faculty member retires. Thus we have 13 faculty that are involved with the undergraduate program, and 13 that are involved with the graduate program. Two of these positions are funded by gifts from Chairs, so that the State is only supplying 11 positions. Thus we are short-staffed now, and will likely be more short-staffed in the future.

The Department has a problem. About 31% of the teaching of required courses is being done by Emeritus Faculty, or faculty about to retire. Some of those positions are temporary and will be permanently lost, since they are positions of former administrators whose position reverts to the Provost when they retire. Thus the teaching capacity of the Department could be crippled in short order, by events over which the Department has little control. One way to look at the next 10 years is to look at the faculty age distribution now, in 5 years, and in 10 years. The assumption is made that every faculty member retires when they are 65, they teach two years as Emeritus (the University average), and are replaced by an Assistant Professor the year after they retire (i.e., there is one year in between for the recruiting). The age distribution of the faculty under this scenario is shown in Table XVIII. This table shows a reasonable age distribution in the next 10 years provided faculty replacements occur.

Table XVIII. Projected Age Distribution of Faculty in the Department

Age	1997	2002	2007
31-35	1	1	2
36-40	2	1	1
41-45	2	2	1
46-50	4	2	2
51-55	1	4	2
56-60	2	1	4
61-65	2	2	1
66-67	4	0	0

(Hire new faculty in 2001, 2004, 2005.)

When a new faculty member arrives, they are assigned two faculty mentors to whom they can go for advice. In addition, they meet with the Department Chair once per year for a formal meeting with a letter summary. At the end of two years they are evaluated again by the faculty for a second three-year appointment. In their fifth or sixth year here they are evaluated for tenure and promotion to Associate Professor. The Promotion and Tenure Standards are in Appendix J.

Another problem the Department faces is salary. Careful statistics of the Department's peer schools (established by the University of Washington) shows that the salary lag three years ago was 6.2%, two years ago 9%, and one year ago 13%. There were no salary raises for a period of two years. In July 1997, a 4% raise was obtained, so that the salary lag would have been decreased if the other universities had no pay raises. New data will be available in April 1998, but it is clear that the pay scale for Chemical Engineering is behind its peers, and it is staying behind. The average NRC rating of the peer schools is the same as that of the Department of Chemical Engineering at the University of Washington, so the salary at those institutions is a valid comparison. The Department has been successful in hiring its top candidate in all faculty searches that have taken place during the past decade, primarily by hiring at market rates and offering attractive start-up packages. This leads to salary compression, and in some cases salary inversion. Unfortunately for the Department, chemical engineers are highly paid, here and elsewhere, and other departments in the University have an even worse problem. Thus it will be difficult to address the problem. The average salary raises in the College of Engineering are shown in Table XIX, which amounts to a 34% increase over nine years, or 3.3% per year.

Table XIX. Average Salary Raises in the College of Engineering

Year	Percent Raise
1/1/89	---
1/1/90	1.3
1/1/91	5.6
1/1/92	2.9
1/1/93	2.9
7/1/95	4.0
7/1/97	3.5

Cumulative 34%, or 3.3%/year.

DEPARTMENTAL CONSIDERATIONS

This section of the report gives data on State support, research support, funds raised from alumni, the endowment of the Department, space, and accountability measures.

Appendices A and B give information collected by the Graduate School about the Department. The first table gives long-term trends of graduate student numbers as well as lists some quality measures. The next table identifies resources and shows how they were used.

The State appropriations for the Department are shown in Table XX. The total of faculty salaries has increased, partially due to pay raises but mostly due to additional faculty when two faculty from Nuclear Engineering joined the Department of Chemical Engineering.

Table XX. State Budget 1989-99

	1989-91	1991-93	1993-95	1995-97	1997-99
Faculty Salaries	$1,262,618	$1,239,452	$1,667,802	$1,837,002	$1,940,175
Staff Salaries	$484,752	$495,744	$581,400	$552,480	$631,128
TA Salaries	$181,332	$181,332	$171,306	$178,128	$185,292
Hourly Salaries	$9,896	$9,896	$9,896	$13,896	$6,000
Total Salaries	*$1,938,598*	*$1,926,424*	*$2,430,404*	*$2,581,506*	*$2,762,595*
Other	$82,577	$82,577	$88,847	$77,644	$81,942
Total	$2,021,175	$2,009,001	$2,519,251	$2,659,150	$2,844,537
State Funded Faculty	9.50	11	12.50	13	13
			Nuclear Engr. faculty added		

The research done in the Department is harder to characterize because a significant fraction of it is done in other departments, on budgets housed in other departments. The data of research expenditures in the Department of Chemical Engineering is given in Table XI (page 19). The future looks brighter since over $3.35 million in awards was made last year.

The Department keeps in contact with its alumni, who are very supportive of the Department. The Department publishes a newsletter/magazine once per year (see Appendix R), and held All-Classes Reunions in 1989 and 1997. Year by year, about 16% of addressable alumni give money. In fact, 42% of all alumni who ever graduated from the Department since 1904 have given money back to the University. The amount of money raised by gifts from alumni and their company matching programs is given in Table XXI.

Table XXI. Development Fund Receipts in Chemical Engineering ($1,000)

1993	1994	1995	1996	1997	5-year total	5-year average
335	209	291	212	277	1,324	265

About 80% of this money goes into endowed funds, a portion of whose earnings can be spent each year, mostly for undergraduate scholarships and graduate fellowships. The funds represent $18,000 per faculty member per year.

The Department is blessed to have significant endowment, which has been provided by alumni. The largest fund is the Rehnberg Chair, which pays for roughly half of the salary of Professor Berg and Professor Finlayson. Professor Lidstrom is paid by the Jungers Chair, which is maintained in the Dean's office and need not be a chemical engineer. The growth of the endowment, due to investment return and new contributions, is shown in Table XXII.

Table XXII. Endowment of the Chemical Engineering Department (end of year, $million)

1989	1990	1991	1992	1993	1994	1995	1996	
2.44	2.30	?	3.23	3.58	3.43	4.31	4.87	
							+1.50	Jungers Chair
							6.37	

The University policy is to return to the departments 5% of the value of the fund, based on a three-year rolling average. Since the University averages about 13% rate of return per year over 10 years (above 25% in recent years), the principal keeps growing.

Equipment. The faculty of the Department have over the years created and bought extensive research equipment. Listed here is equipment with a purchased price of $10,000 or more. Equipment for biologically-related faculty (Baneyx, Lidstrom, Horbett, Ratner) includes: autoclaves (2), scintillation counter, centrifuge, fermentors, preparative electrofocussing unit, fluorescence spectrophotometer, HPLC, coulter counter, culture chambers (2), and a microimaging and image analysis system.

Surface science equipment includes 14 high-vacuum chambers. Castner's equipment includes: Surface Science Instruments SSX-100 ESCA system, a Surface Science Instruments S-Probe ESCA system, and a Physical Electronics 7200 ToF SIMS system in the Surface Analysis Recharge Center (SARC). There is a Physical Electronics 3600 Quad SIMS system, a HP 5950A ESCA system, and a UHV catalyst treatment system (attached to HP ESCA system). Both SSI ESCA systems are cyro-pumped UHV instruments with variable spot size, monochromatized Al Ka X-ray sources, variable acceptance angle analyzer lens, multichannel detectors, variable temperature sample stages, and sample preparation chambers. The ToF SIMS instrument has a Cs+ ion source, reflectron mass analyzer, multichannel detector, and sample introduction chamber. The quad system has an Xe+ ion source, 90 degree energy filter, quadrupole mass analyzer, variable temperature sample stages and a sample preparation chamber. The HP ESCA system has a monochromatized Al Ka X-ray source and multichannel detector. Professor Stuve has three major experimental systems: (1) ultrahigh vacuum surface analysis chambers with a quadrupole mass spectrometer, low energy electron diffraction (LEED), electron stimulated desorption ion angular distribution (ESDIAD), and kelvin probe for work experiments; (2) *ex-situ* ultrahigh vacuum/electrochemical system with a quadrupole mass spectrometer, low energy electron diffraction, Auger electron spectroscopy, high purity electrochemical cell, triple source electron beam deposition system; the system can hook up to the SSX-100 ESCA system for high energy resolution x-ray photoelectron spectroscopy and secondary ion mass spectrometry; and (3) field ionization mass spectrometer with a quadrupole mass spectrometer, reflectron time-of-flight mass spectrometer, and field ionization microscope. In addition, Stuve has a dual electrochemical cell system with a potentiostat/galvanostat and ultrahigh purity liquid handling system. Professor Schwartz has a F/4 Imaging Spectrograph, a Cryogenic CCD Array Detector, a 5-watt Argon Ion Laser System, a 2-watt Krypton Ion Laser System, a 500-MW Tuneable Diode Laser System, two Potentiostats PAR 273's, one Potentiostat PAR 173, and an Impedance Analysis System. Professor Rogers has (1) an UHV/high-pressure MOCVD coupled reactor containing the following diagnostics: UTI-100C Quadrupole Mass Spectrometers, Mattson Model 5000 Fourier Transform Infrared Spectrometer, VSW 150 mm Hemispherical Sector Electron Energy Analyzer, Varian 3 keV LEED-Auger System, Leybold-Heraeus Dual X-ray Anode, a gas dosing system capable of handling a variety of Group III metal organic and Group V vapor sources; (2) a UHV/high-pressure MOCVD coupled reactor containing the following diagnostics: UTI-100C Quadrupole Mass Spectrometers, Bomem Fourier Transform Infrared Spectrometer, PHI Single-Pass Cylindrical Mirror Electron Energy Analyzer with coaxial Electron Gun, and a gas dosing system capable of handling a variety of Group III metal organic and Group V vapor sources; (3) an UHV/high-pressure MOCVD coupled reactor containing the following diagnostics: Extrel Quadrupole Mass Spectrometer/ SIMS unit, PHI Double-Pass Cylindrical Mirror Electron Energy Analyzer with coaxial Electron Gun, and a gas dosing system capable of handling a variety of Group III metal organic and Group V vapor sources; (4) a Crystal Specialties Model 425 MOCVD Reactor with the following capabilities: 2" and 3" substrates, diagnostics for temperature and gas flow (jointly operated: Rogers, Pearsall, Ohuchi); and (5) a Fisons VG Model V-80H Chemical Beam Epitaxy Reactor capable of handling 2" or 3" substrates, metal organics, arsine, and ammonia as well as other dopants. The instrument has analytical capabilities for (i) temperature measurement and control, (ii) residual gas analysis, and (iii) microprocessor control of growth, (iv) RHEED, and (v) an ECR-nitrogen source (jointly operated: Pearsall, Rogers).

The Center for Surfaces, Polymers, and Colloids laboratories of Professor Berg comprise six laboratory rooms with a total of approximately 2,500 square feet of space. The equipment available permits a wide range of characterization of the surface and colloidal properties of materials. Surface/interfacial tension measurement: Drop weight system for surface tension measurement with Mettler balance; Maximum bubble pressure system (SensaDyne) for dynamic surface tension measurement (computer automated); Wilhelmy system (with Cahn electrobalance) for surface/interfacial tension measurement; Langmuir-Wilhelmy trough (Joyce-Loebl) for monolayers and Langmuir-Blodgett films (computer automated). Wetting/contact angle measurement: Goniometer (Ramé-Hart system), with environmental chamber; Dynamic wetting systems (2) with Cahn electrobalance, Burleigh Inchworm translator, (computer automated).

Surface area measurement: BET system (Micromeritics FlowSorb). Liquid density measurement: Microdensitometer (Paar-Mettler). Titration facilities: Potentiometric/conductometric autotitration (Radiometer); Potentiometric/conductometric/electro-acoustic autotitraton (Matec). Scanning Probe Microscopy: STM, AFM facility (Park Sci. Inst.). Optical Microscopy: Backfield and darkfield microscopes (2 Wild macroscopes; 1 Nikkon; 1 Leitz), video and conventional cameras. Chromatography: Gas Chromatographs (1 Varian, 1 Hewlett-Packard); High performance liquid chromatograph (HPLC) (Varian). Particle size characterization: Dynamic (PCS) and classical light scattering (Brookfield, with Malvern goniometer) (computer automated); SediGraph (Micromeritics); Centrifugal particle size analyzer (Horiba); Electrophoretic light scattering (Malven Zetasizer) (computer automated); Differential refractometer (Wood). Electrokinetic properties of colloids: Particle electrophoresis system (Rank Brothers Mark II); Particle electrophoresis system (PenKem Lazer Zee); Electrokinetic analyzer (PenKem). Rheological properties of colloids: Couette, cone-and-plate viscometer (Bohlin VOR) (Computer automated).

The Department has three scanning probe microscopes (two for Overney), as well as countless lasers. Professor Davis has a 5w Spectra Physics argon-ion laser, a 5w coherent argon-ion laser, a Spectra Physics nd:yag pulsed laser, a SPEX 0.8 m double monochromator, a 600 channel Princeton Instruments optical multichannel analyzer, an Acton 0.5 m triple grating monochromator, a 25w carbon dioxide laser, two specially built electrodynamic balances with optics and electronics, and optical and electronic instrumentation. Professor Krieger-Brockett has a High Performance Liquid Chromatograph (HPLC) with photo-diode array UV detection and fluorescence detection, quantachrome surface area/porosity analyzer, process gas chromatograph with automated sampling, FID and TC Detectors, UV-VIS photon counting spectrophotometer.

The Polymeric Composites Laboratory of Professor Seferis contains an autoclave, FTIR microscope and TGA interface, a Battenfeld Injection Molding Machine, a hydraulic Instron testing machine, a screw Instron testing machine, an optical microscope, an acoustic microscope, a custom-made Prepregger I, a California Graphite Prepregger II, a Tetrahedron press, and the following thermal analysis equipment: 2 DMAs (Dynamic Mechanical Analyzers), 2 DSCS (Differential Scanning Calorimeters), a TGA 950 (Thermal Gravimetric Analyzer), a TGA 2950 (Hi-Resolution Thermal Gravimetric analyzer), a TMA (Thermal Mechanical Analyzer), a DEA (Dielectric analyzer), a MDSC (Modulated Differential Scanning Calorimeter), and an SDT 2960 (Simultaneous Differential Techniques, combining DTA & TGA).

The Department has a complete machine shop (with one Engineering Technician), an electronic shop (with one Research Engineer), a central computer control center (with one Computer Specialist), a darkroom, cold storage room, and flammables storage room, a conference room, two student lounges, a computer lab, three storage rooms, seven administrative offices, 11 student offices, 21 faculty offices, and 48 research labs.

UO Lab. The Unit Operations (UOPS) Laboratories provide Chemical Engineering undergraduates opportunities to synthesize and use classroom theory on real-world engineering equipment and problems. In addition, the laboratories deepen the student's understanding of chemical engineering principles. The objectives are:

- To develop the student's ability to formulate a laboratory study from a brief request made by a hypothetical engineering manager.
- To perform the appropriate engineering measurements with minimum uncertainty and error.
- To analyze and clearly present the data and its uncertainty.
- To succinctly report and interpret the results in a form that is responsive to the request from an engineering supervisor.

These experiences are combined with learning to work in a two- or three-person team, presenting short oral reports alone and as a team, writing and revising engineering reports, and critical evaluation of their fellow students. The chemical engineering operations that are illustrated include fluid flow, heat transfer, separation processes, and reactor behavior, covering the core subjects within our discipline.

Two courses, CHEM E 436 and 437, required of all students, utilize the UOPS Laboratory. Experimental devices available to CHEM E 436 students include:

1. student-built and student-tested devices to measure mass diffusivity, viscosity, and thermal conductivity;
2. heated rods to observe fin temperature profiles under heat conduction and convection;
3. tanks and pumps to assess common fluid transfer operations;
4. fluid flow loops to assess measurement of flow rates and fluid velocity profiles; and
5. fluid flow loops to assess friction and drag on piping systems and submerged objects.

Available devices to CHEM E 437 students are:

1. packed towers to measure flow characteristics, separation efficiency, and humidification;
2. heat transfer loops to measure heat duties, overall heat transfer coefficients, and fouling;
3. distillation unit to measure separations under batch conditions;
4. continuous distillation unit with four types of contacting methods (trays) to illustrate staged operations;
5. liquid-liquid extraction unit with reciprocating plates to illustrate liquid separations; and
6. catalytic reactor to illustrate rapid, continuous reactions typical of automotive exhaust emission control (based on GM automotive catalyst).

CHEM E 461. The Electrochemical Engineering Laboratory (CHEM E 461, 3 credits, Winter Quarter, 16 students maximum) is a topical course aimed at giving students from varied backgrounds a foundation in electrochemical science and engineering. Lectures (1.5 hours/week) are used to complement state of the art laboratory experiments (3 hours/233k). During the first four weeks of laboratory, students perform a series of basic electrochemistry experiments that probe the fundamental aspects of electrochemical equilibrium, electrode kinetics, and mass transfer phenomena. Two additional experiments (two weeks each), allow the students to study a variety of electrochemical technologies, including electrochromic materials, rechargeable battery technology, alloy electrodeposition, and environmentally benign cation separations.

CHEM E 455. (Surface and Colloid Science Laboratory, 3 credits for full course or 1 credit for lectures only, Spring Quarter; 20 students maximum for laboratory.) The course introduces the student to the fundamentals of surface and colloid science as well as to a variety of up-to-date experimental techniques used by both research scientists in this area and in industrial laboratories for quality control, pollution monitoring, etc. For the students, the course consists of two hours of lecture and one four-hour laboratory session per week. The lecture coverage includes the basics of capillarity, capillary hydrostatics and methods for measuring boundary tension, wetting, spreading, transport of liquids in porous media, adhesion, the thermodynamics of interfacial systems, adsorption, the kinetic behavior of fine dispersions (diffusion, sedimentation, phoretic processes), the stability of colloids to aggregation, electrical double layer properties and phenomena and interfacial hydrodynamics. The laboratory experiments (20 in all) are divided into four categories: (1) measurement of surface/interfacial tension; (2) adsorption, wetting, spreading and wicking; (3) properties of colloids and dispersions; and (4) interfacial hydrodynamics. Students, working in two-person teams, perform one experiment from each group, with each experiment requiring two four-hour laboratory sessions. It is of interest that this course has filled to capacity every time since it was first offered in 1981.

CHEM E 480. (Process Dynamics and Control Laboratory, 4 credits, Autumn and Winter quarters.) This senior course in chemical engineering is designed to give the student the ability to design modern control systems for chemical processes. Students attend a weekly three-hour laboratory in which they: (1) take data and identify dynamic models for systems; (2) design feedback controllers for real processes; (3) take frequency data and make Bode plots; (4) integrate feedforward controllers with feedback schemes; (5) implement cascade control schemes; and (6) apply decoupling to a multivariate process. MatLab and Simulink run on Mac II and Power Mac computers are used throughout the quarter on homework assignments. Students use Workbench to measure process dynamics of a real process and to design and implement controllers for those systems.

The total assignable square feet in Benson Hall is 41,026 (See Table XXIII). Of that, 15% is used for undergraduate classrooms and laboratories; 50% is research space assigned to faculty; 15% is for shops, storage, and common spaces; 9% is for faculty offices; 6% is assigned to faculty in Bioengineering not involved with Chemical Engineering; 3% is for staff offices; and 2% is for lounges.

The Department has a severe space problem. Currently, we cannot hire a new faculty member because we have no space for an experimental program. Considerable space is allocated to Bioengineering professors, and we try to utilize space in other departments as well. For example, our professors have collaborations in Oceanography and Materials Science, and this helps relieve the pressure in Benson. It is most important that a Bioengineering building be built so that the chemical engineering space now used by bioengineering programs can be utilized by chemical engineering. We can't expand the number of undergraduates involved in research very much due to the limits on space.

Table XXIII. Space in Benson Hall

Research Space			
	Full-time Ch.E. Faculty		15,914
	Joint Faculty		4,560
	Allan	235	
	Ratner	3,048	
	Horbett	1,277	
Bioengineering			2,506
	Lybrand	1,618	
	SAC	888	
Faculty Offices			3,576
Teaching Labs			4,301
Classrooms			1,826
Lounges			874
Shops			2,988
Staff Offices			1,387
Storage			1,823
Common Space (conf. room, cold storage, photo, etc.)			1,271
			41,026

Accountability. The State Legislature wants the faculty to be accountable, and has set targets for the University of Washington. The first criteria they set is a graduate efficiency index. This index is the percentage of classes that a student takes that apply towards the degree requirements. The goal is 95% for students entering as freshmen, and 90% for transfer students. This measure is difficult to assess within the Department, since students enter the Department sometimes with extensive course records, only some of which applies to their Chemical Engineering degree. The faculty hope that the State Legislature doesn't want us not to admit them because they have changed their mind on careers before they enter the Department. The role the Department can play is to be sure that the courses needed for the degree that are taught in the Department are there, and they are, 100%.

The second criteria set by the Legislature is the retention rate. As noted above in one study within the Department, of the entering Junior Class of 73 students, only 10 left the Department, for a retention rate of 86%. However, six of those students dropped out after the very first course, and the retention rate of those entering the second course in the curriculum was 94% (63/67). The University is currently at 86.7% and the goal is 95%. We have not done a study to find whether the students that left the Department eventually graduated from the University. Their University record was acceptable even though their Departmental record may not have been, so that the 86% Departmental figure would lead to a much higher figure for the University as a whole.

The third criteria set by the Legislature is a five-year graduation rate of 65%. The University is currently at 61.7%. As noted above, the graduation rate for the Department of Chemical Engineering is 86% based on students in the first course, and 94% based on students in the second course in the curriculum. Thus the Department has clearly met this criteria.

In addition to measures established by the Legislature, the University of Washington has established other productivity measures. One goal is to have 80% of the spaces in all classes used. In the Department's case, such a measure would be absurd, because the classroom space is not assigned based on the number of students, but on some other random basis (it appears to the faculty). Since we can't get a classroom of the correct size, the Department can't do anything about this measure. Frequently, however, the classrooms are filled to capacity and sometimes over capacity. (There have been cases of people sitting on the floor, so that the Department might claim a greater than 100% utilization of space!)

The second measure established by the University of Washington is the quality of instruction, defined as the percentage of faculty scoring 3.0 (good) or better on question 18 of the student ratings. The University is at 94.5% and has a goal of 98%. The Departmental record on this question in the 1997 calendar year is 97.3%.

The third measure is the research dollars raised per faculty member. Since the Department raises gifts that are used for research, the number is reported based on research expenditures per year per faculty member (including overhead when that is charged). The Department is at \$170,000 in 1996-97 and awards that year were \$226,000. The University is now at \$197,948 and the goal is \$203,946.

The fourth measure is the student credit hours per faculty member. The Department has 5,786 SCH in 1996-97, with a FTE faculty count of 17.50, including graduate teaching assistants, for a ratio of 331 SCH/faculty. The University average is now 202, and the goal is 212.6, so the Department is way ahead of the goal.

The fifth measure is undergrads-intensive research. Currently the University involves 300 students in intensive research (defined as 10+ hours/week working with a professor), and the goal is to increase this to 600 students. The Department had 30 students doing so in Winter 1998.

The sixth measure is the individual instruction as a percent of credits. Currently 3.8% of the University credits are individual instruction, and the goal is 5%. For the Department, 3.7% of the undergraduate credits are individual instruction.

The seventh measure is the number of students in public service internships. The University currently has 500 students in internships during the year, and the goal is 2000. This number is out of an undergraduate student population of about 25,000. Thus the goal is 8%. As noted above, 14% of the chemical engineering students engage in government and industrial internships, so that the Department has met this goal.

The eighth measure is student research experience. The University goal is that 25% of the undergraduates have this experience (now 20.7% do). In the Department of Chemical Engineering the number is 68%.

In summary, based on these criteria set by the State Legislature and the University of Washington, the faculty of the Department of Chemical Engineering are doing a great job!

Additional data on other departments is given in Appendix K. Shown there are the NRC rankings of chemical engineering departments across the country, a Council on Chemical Research survey of Departments, as well as data on graduation rates, research expenditures, and space.

Staff. The Department has an administrator, fiscal specialist, five office staff (assistant to the chairman, academic counselor, secretary supervisor, secretary senior (3/4 time), and secretary), an Engineering Tech III in the machine shop, a research engineer in the electrical shop, and a computer specialist (see Appendix P). During the time since the last review, one machinist position was lost due to budget cuts and lack of work, and 1.75 office staff were added from Nuclear Engineering. Staff salaries have increased 30% from the 1989-91 biennium to the 1997-99 biennium.

Staff productivity. Chemical Engineering has 10 state-funded staff (technical, administrative, and clerical), and 6 research-funded staff. Productivity is encouraged through clear and complete job descriptions with specific and detailed performance criteria for each position. Yearly performance evaluations are conducted as well as regular job description revisions or position reclassifications in response to changing responsibilities. Staff meet monthly for the opportunity to share information and provide input about Departmental issues.

Staff are recognized for good performance in a variety of ways. Personal letters of commendation, department-wide e-mails noting a particular accomplishment, and acknowledgment in the yearly departmental publication, *Reflux*, occur regularly. Individual staff are acknowledged at the monthly staff meeting for their achievements, and are nominated for outstanding performance awards at both the College and the University level annually. Staff are also recognized for length of service through the University's service award program.

Release time and class fees for on-campus and off-campus training are provided for all staff to foster opportunities for professional growth and development. Participation on College and University committees is also encouraged to allow staff to receive exposure to a wider variety of experiences.

The Chair has designated one secretary to be responsible for preparing 'boiler plate' material for grant proposals, and the administrator reviews budgets before the proposal leaves the Department. Sometimes the administrator prepares the budget as well. The Chair gives first priority to signing proposals once they have been checked by the administrator. One person is designated to walk the proposal through the various steps to minimize delays. While there are still problems that arise from time to time, the process works reasonably smoothly. One faculty member would like more help ordering materials, but the existing state-funded personnel do not have time to do that. The Department has a machine shop and electrical shop, and those resources need to be maintained in the building if we are to insure efficient work on the part of the faculty. The biggest impediments to faculty productivity are: there is too much to do, there is not enough space, and the quality and amount of computer support is restrictive.

Advising. Advising is done by faculty and the departmental advisor. Before a student enters the Department they usually meet with the departmental advisor, and the departmental advisor also arranges the applications for admission to be judged by the Admissions Committee. Once a student is in the Department, they have a faculty advisor, who at least signs the student's program once per quarter. The departmental advisor manages the entry codes to chemical engineering classes (which are restricted mostly to Ch.E. majors in good standing). As the graduation date approaches, the faculty advisor signs the application for a degree, the departmental advisor checks it, and the Chair signs it.

Committees. The Department has several committees, some more time-consuming than others, and a complete list is given in Table XXIV.

Table XXIV. Committee Assignments, 1997-98

Committees	Member(s), (Chairs in bold)
AIChE Chapter	**Baneyx**
Computers	**Holt**, Ricker, Rogers, Ramsey
Graduate Program Advisor	**Stuve**, Schwartz, Ricker
Peer Review Committee	**Holt**, Lidstrom, Baneyx
Safety	**Horbett**, Davis
Scholarship	**Berg**
Seminars	**Overney**
Undergraduate Admissions	**Krieger-Brockett**, Holt, Schwartz, Madrano
Future Committee	**Finlayson**, Baneyx, Lidstrom, Overney, Ricker, Rogers, Schwartz, Seferis, Stuve
10-Year Review	**Finlayson**, Krieger-Brockett, Bowen, Ratner
Criteria 2000 (ABET)	**Finlayson**, Ricker, Stuve, Bowen, Holt
COE Committees	
Educational Policy	Ricker
Faculty Affairs	Krieger-Brockett
Faculty Senate	Holt
P&T (Promotion & Tenure)	Rogers
P&T Alternate	Ricker
Research Policy	Davis
Student Affairs	Allan
AD Search	Schwartz
ENGR	Stuve, Rogers
Entrepreneurship & Innovation	Allan
Restructuring	Rogers

Goal setting. The Department sets its goals by discussion and consensus and this will continue. Sometimes a committee works to establish a draft document, which is revised and adopted by the faculty as a whole, although sometimes the goals are set in a committee of the whole. Small changes in goals are made routinely in the biweekly faculty meetings, but large changes in the goals are made at infrequent intervals. The mission and goals of the Department were adopted in October 1993 (see Appendix H) and have not been modified since then.

GOALS

- To expand opportunities for research, design, and internship experience for undergraduate chemical engineering majors.

  Faculty of the Department have worked diligently to provide an experiential learning environment for chemical engineering majors. Currently 68% of the undergraduates are involved in research projects; 40% in industrial design problems and 14% in industrial internships. Impending faculty retirements jeopardize the ability of the Department to increase, or even maintain, this level of activity, but it remains a very high priority, and the Department is committed to additional expansion of such opportunities.

- To increase undergraduate enrollment and bachelors degree production by more than 40% over the next 10 years.

  This increase in enrollment is a consequence of the projected emphasis on access to higher education throughout the state. Because chemical engineering is offered only at UW and WSU, and the University of Washington's program is by far the more visible and attractive, a 40% increase over 10 years may be understated.

- To increase the number of faculty to 17 full-time members.

  Given the level of teaching and research activity in the Department it is significantly understaffed. Data for chemical engineering departments across the country were analyzed using a multivariate regression analysis to determine the correlation of faculty size with the number of Ph.D. and B.Ch.E. degrees awarded annually. The result was ($r^2 = 0.50$):

  Number of Faculty = 9.26 + .525 · (Ph.D.s Awarded) + .0505 · (B.Ch.E.s Awarded).

  If the correlation were applied to this department, there would be 17.4 full-time faculty. Currently there are only 15, including 1 member who serves as Associate Dean of the College, 1 empty position that has not been allowed to be filled, and 1 position that will revert to the Provost when the faculty member retires. Thus, if nothing is done, the Department, already short-staffed, will be even farther below an acceptable staffing level. Furthermore, two of the positions are funded by an endowed chair.

- To develop interdisciplinary research and teaching, particularly in the areas of materials processing and bioengineering.

These areas have been emphasized in recent faculty hires, but need tangible support to develop and thrive. Interdisciplinary efforts are time-consuming and involve the development of pioneering courses and research programs. They also require a critical mass of faculty. These efforts and the commitments needed for their success must be recognized, rewarded, and supported. The Department will serve both as advocate and supporter of the programs.

- To recapture research space that has been temporarily loaned to other programs so that existing and new faculty members, research associates, and graduate students will have adequate space in which to conduct their research.

  A significant fraction of the laboratory and office space in Benson Hall has been loaned to programs other than chemical engineering. Recapturing this space is necessary to attract new faculty with active research programs and to support growing research and interdisciplinary programs of existing faculty members.

- To convince administrators and State officials that positive incentives to departments that meet University-established goals and high standards of excellence are important.

  Declining budgets, across-the-board budget cuts, and increased emphasis on external audits can be demoralizing, especially in departments that have achieved high standards of excellence and take pride in their programs. The Department will work to help central University and College administrators reject policies that discourage rather than empower the faculty in their efforts to reach higher levels of excellence.