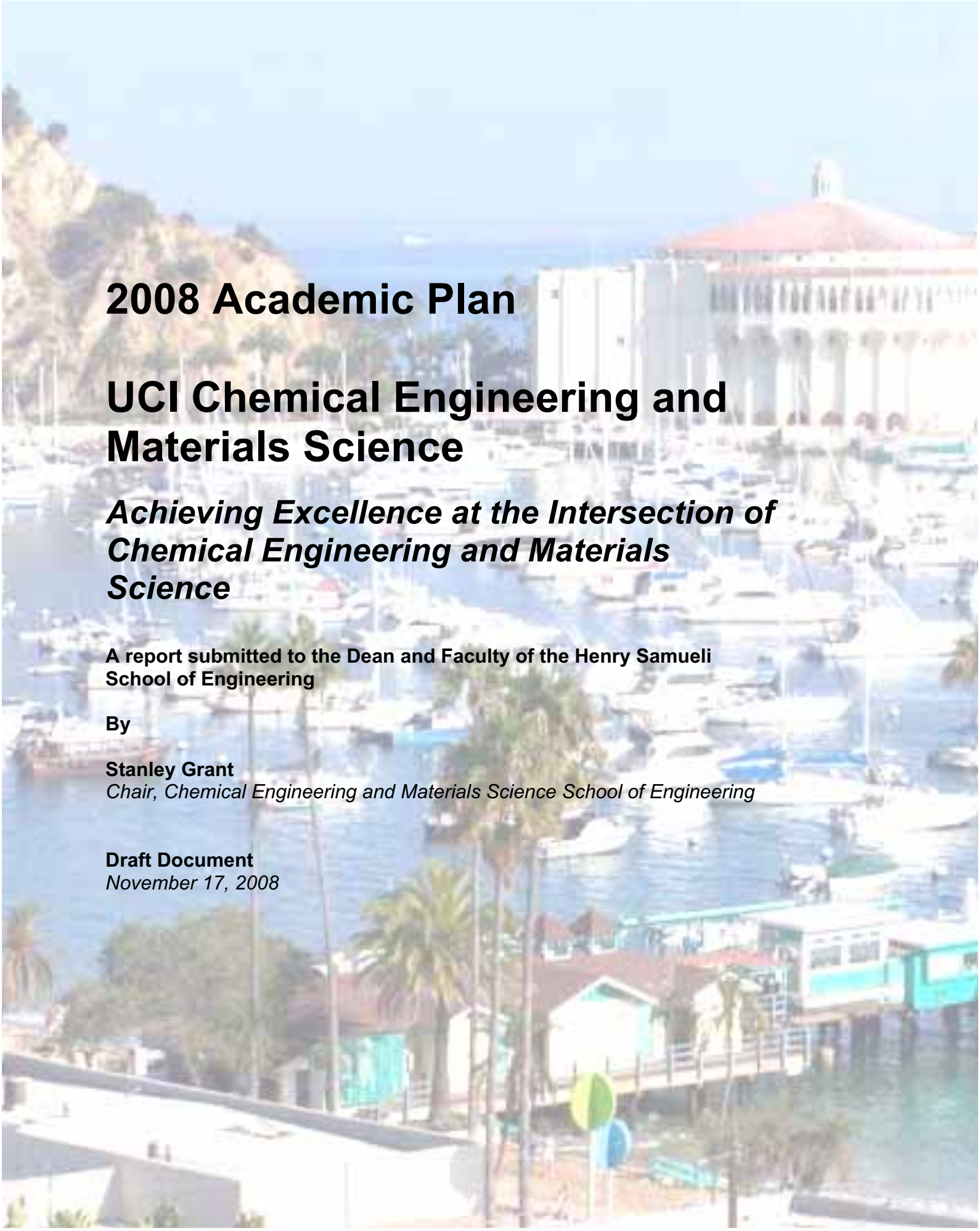

2008 Academic Plan

UCI Chemical Engineering and Materials Science

Achieving Excellence at the Intersection of Chemical Engineering and Materials Science

A report submitted to the Dean and Faculty of the Henry Samueli School of Engineering

By

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Chair, Chemical Engineering and Materials Science School of Engineering

Draft Document
November 17, 2008

ChEMS Academic Planning Document

Mission and Structure

The department's overarching mission is to create new knowledge in Chemical Engineering and Materials Science, and to prepare undergraduate and graduate students for successful careers in these respective fields. From its roots in separate programs, the department has moved toward a focus at the intersection of ChE and MSE. This new focus has paid dividends in a number of areas, including: (1) recruiting top junior and senior faculty; (2) improving number and quality of graduate students applying to the department; (3) increasing the pool of incoming graduate students interested in pursuing research in disciplines that bridge traditional ChE and MSE fields, such as biomaterials and alternative energy; (4) creating a new B.S. degree and a new minor in materials science engineering, both of which are becoming increasingly popular among UCI undergraduates; (5) maintaining gender and ethnic diversity of our faculty; and (6) increasing coordination of faculty recruitment and long-range departmental planning with other units on the UCI campus.

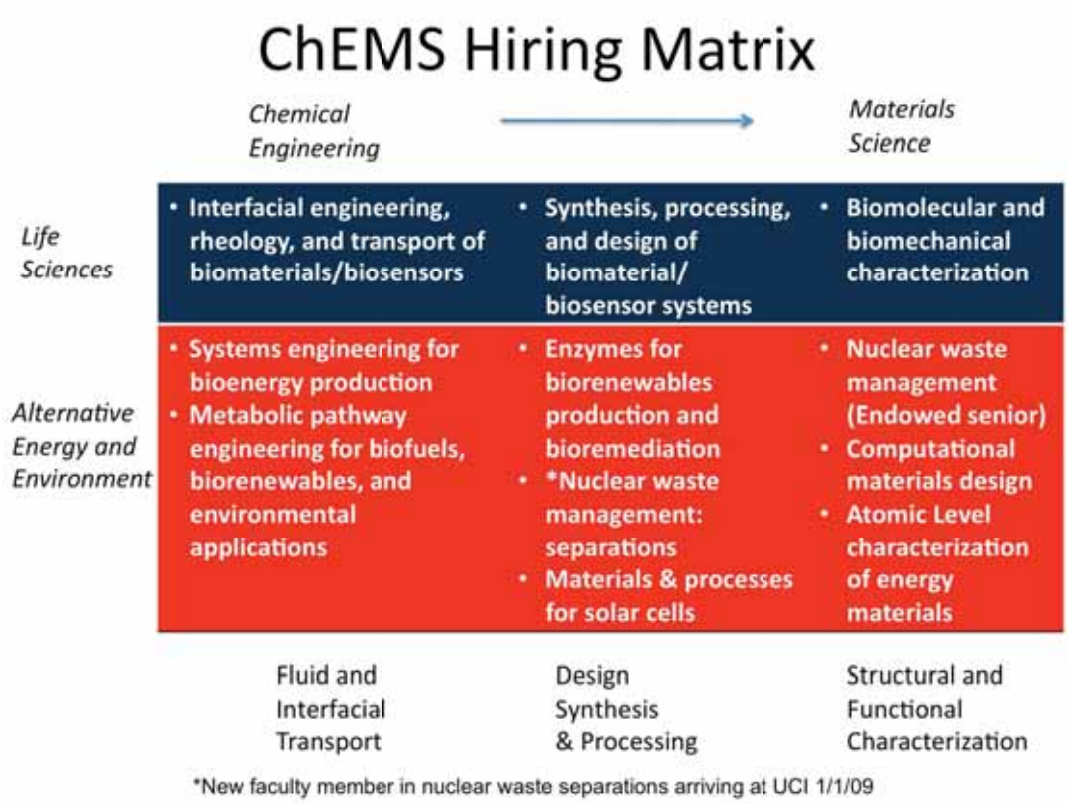

Figure 1. ChEMS' faculty hiring priorities over the next 7 years. Columns represent the proposed disciplinary focus of new faculty positions, on a spectrum from pure chemical engineering to pure materials science. Rows denote application domains in the life sciences or alternative energy and the environment.

Plans for Future Growth

In planning out to 2015, the department will continue to grow at the intersection of Chemical Engineering and Materials Science, with particular emphasis in two topical areas: (1) biomaterials, and (2) alternative energy and the environment (Figure 1). These two areas were identified as top priorities for faculty growth during a series of faculty retreats beginning Winter quarter, 2005, and have been refined during faculty discussions over the past several years. The retreats were attended by a full complement of ChEMS' faculty, and faculty representatives from the departments of Mechanical and Aerospace Engineering, Biomedical Engineering, Chemistry, Physics, and the Program in Pharmaceutical Sciences.

In its 2005 external review of ChEMS the Academic Senate's External Review Committee (ERC) concluded that "it would serve the Department well to continue to grow its strength in the areas of materials and biology, and this area would also lead to natural collaborations with the Department of Biomedical Engineering" (ERC Report, dated 3/28/05, pg. 29). The department's desire to grow alternative energy and biomaterials is consistent with the 2005 ERC recommendation.

The most recent US News and World Report ranked UCI's Chemical Engineering and Materials Science Engineering programs 53rd and 47th nationally (out of 123 and 88 universities, respectively, ranked in these fields). Over the next nine years, our goal is to improve ChEMS' rankings, ideally bringing it into the top 20 by 2015. To this end, it is useful to consider the advice offered ChEMS by the Academic Senate's ERC:

The ERC strongly recommends the recruitment of outstanding senior faculty members (primarily mid-career, full professors that have already made a mark); this should be a top priority for the Department, and should be pursued with the support of the SoE and the EVC. Other programs that have been successful recently in moving to the next level of recognition include UCSB and U. Texas. In both cases, the recruitment of senior faculty members that were successful in securing funding for national centers was a major factor in their ascendance in the rankings (ERC Report, dated 3/28/05, pgs. 29-30).

To sum up, there is strong support (among the faculty in ChEMS, among faculty in affiliated programs at UCI, and among faculty at other universities) that the department should (1) focus its future growth at the interface of biology, chemical engineering, and materials science, particularly in the areas of biomaterials and alternative energy, and (2) hire renown senior faculty who will improve the department's national and international visibility, and can help the department successfully compete for national research centers.

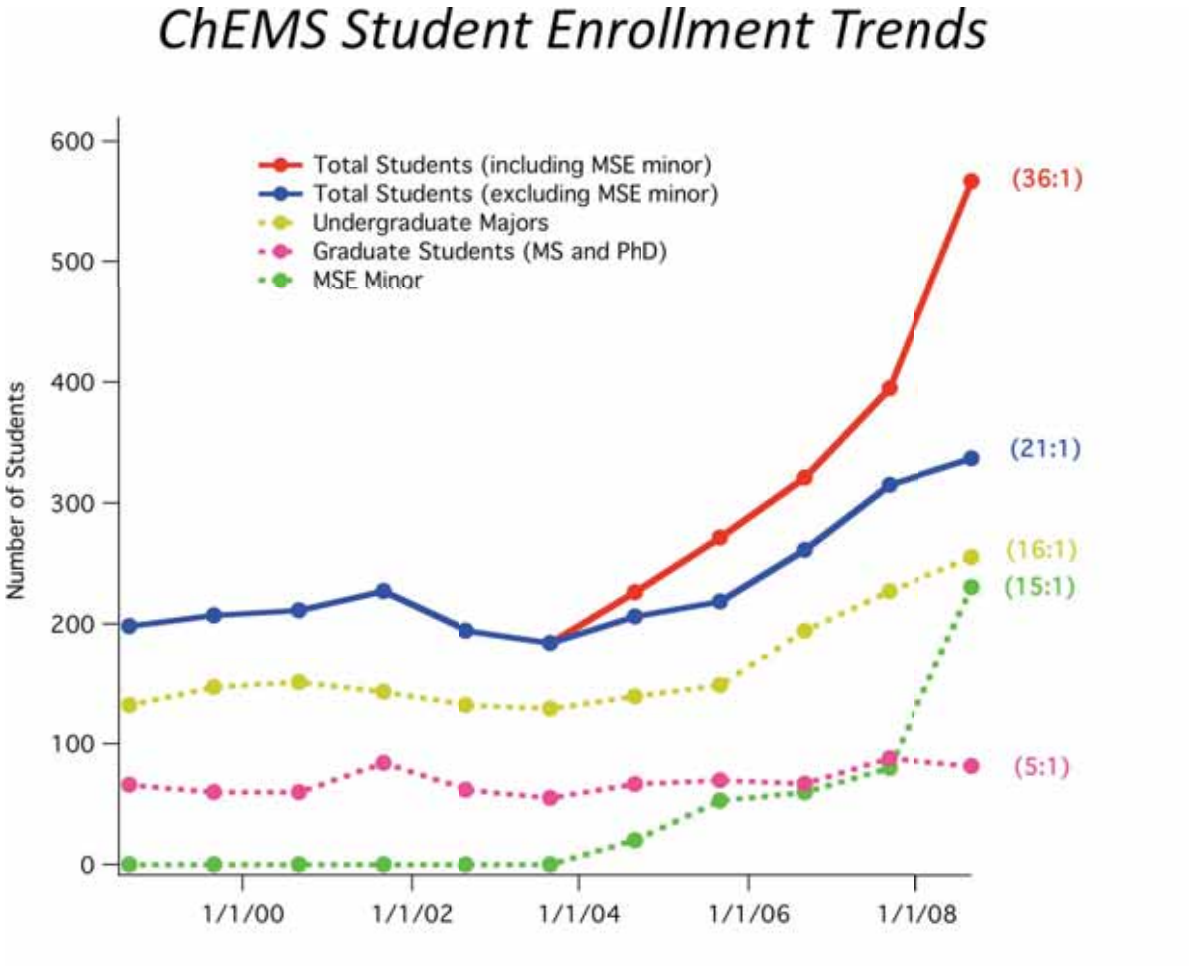

Figure 2. Student enrollment trends for undergraduate majors (students enrolled in the B.S. degrees in ChE and MSE), graduate students (M.S. and PhD in ChE and MSE), and students enrolled in the MSE minor. Total student enrollment is shown with and without including students enrolled in the MSE minor. Also shown are student-to-faculty ratios for each category, assuming 15.5 Faculty FTE.

Degree Programs and Student Enrollment

<u>*Overview*</u>. At the undergraduate level, the department offers ABET accredited Bachelors of Science degrees in ChE and MSE, and a popular campus-wide MSE minor. For graduate students, ChEMS offers M.S. and PhD degrees in ChE and MSE; our graduate students can also enroll in the graduate concentration in Materials Manufacturing Technology (formerly called the Interdisciplinary Concentration in Materials Science and Engineering) and the Interdisciplinary Concentration in Environmental Engineering.

Department student enrollment trends are plotted in Figure 2. Graduate student enrollment has remained relatively flat over the past 9 years, increasing modestly

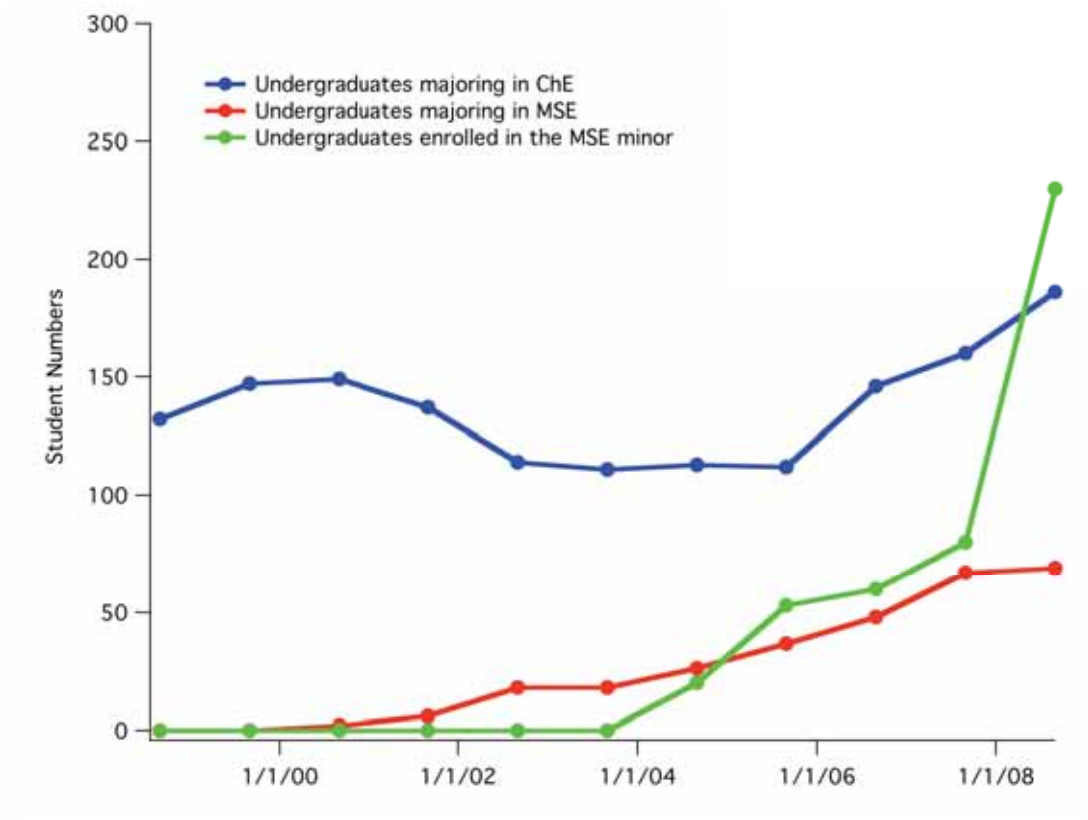

Figure 3. Student enrollment trends for the ChE and MSE majors, and the MSE minor.

from 66 students in 1999 to 82 students today. Undergraduate student enrollment, on the other hand, has surged over 70% in the last four years, from 149 students in 2005 to 255 students today. From its inception in 2003/04, the MSE minor has quickly become popular with undergraduates, with enrollments exceeding 200 students today. Student-to-Faculty ratios range from 5:1 for graduate students, to 15:1 for students enrolled in the B.S. ChE and MSE degrees. For all degree programs combined, the student/faculty ratios range from 21:1 (if students in the MSE minor are not included) to 36:1 (if students in the MSE minor are included).

Evaluation of Undergraduate Program Quality

In their review of the undergraduate program, the ERC was "generally pleased with the structure and enrollment in the chemical engineering program", although they noted that enrollment numbers in the MSE undergraduate degree were low. Since the ERC review, the department has made considerable progress toward increasing enrollments in the MSE undergraduate degree, from 18 students in 2004 (the year before the ERC visit) to over 60 students today (Figure 3). Many of these students are double majoring in MSE and either Mechanical and Aerospace Engineering (MAE) or ChE. Many students choose to major in MSE after they come to UCI, with the result that enrollments in the MSE undergraduate degree increase with class standing.

The ERC was concerned that, in a few instances, faculty teach classes that are required for both undergraduate and graduate students. The department no longer offers courses that fulfill both undergraduate and graduate degree requirements. A few *elective* classes are still offered to both undergraduate and graduate students, but only if that format makes sense pedagogically; e.g., Dr. Grant offers a course in which teams of undergraduate and graduate students design and carry out a field-based study of water pollution.

The ERC also noted that relatively little information was available on outcomes for graduates of the undergraduate and graduate programs in ChE and MSE. In general, ChE and MSE undergraduate students obtain jobs in their field of study, or go on to graduate school. Of the students who go to graduate school, many attend the best colleges in the US (e.g., Caltech, MIT, Stanford), and win prestigious graduate student fellowships, such as the National Science Foundation Graduate Fellowship. In addition to this anecdotal evidence, the department is putting more effort into contacting and surveying our ChE and MSE alumni, in an effort to continuously improve the undergraduate experience.

Faculty Make-up

The department has 15.5 faculty FTE; the 0.5 FTE is Professor Andrew Putnam's split position with Biomedical Engineering. Effective July 1st (2009) this number will drop to 15 when Professor Putnam leaves UCI for the University of Michigan. The department is recruiting two new faculty this year, including an Associate Professor in Chemical Engineering (to replace a recent retirement in the area of biochemical engineering) and an Endowed Senior Professor in the area of Nuclear Waste Management. Thus, by 2009/10 academic year, the department hopes to have 17 faculty FTE.

The 15.5 faculty FTE in the department break down by rank as follows: 6.5 Assistant Professors, 1 Associate Professor, and 8 Full Professors. ChEMS' faculty is the most gender diverse in the HSSoE, with four women at various ranks (Szu Wang, Nancy DaSilva, Regina Ragan, and Martha Mecartney). This fact was lauded by the Academic Senate ERC:

> *The Department is composed of 14 faculty, 5 of which are female[1], making it the most diverse Department within the College. It appears the two mid-career women, one in Chemical Engineering and one in Materials Science Engineering, who are actively pursue diversity, helped identify the four female assistant professors. The ERC recommends that other departments examine this example relative to their current faculty.*

[1] Note that since the 2005 ERC visit, one of our female faculty members, Professor Grace Lu, left UCI for a tenured faculty position at USC.

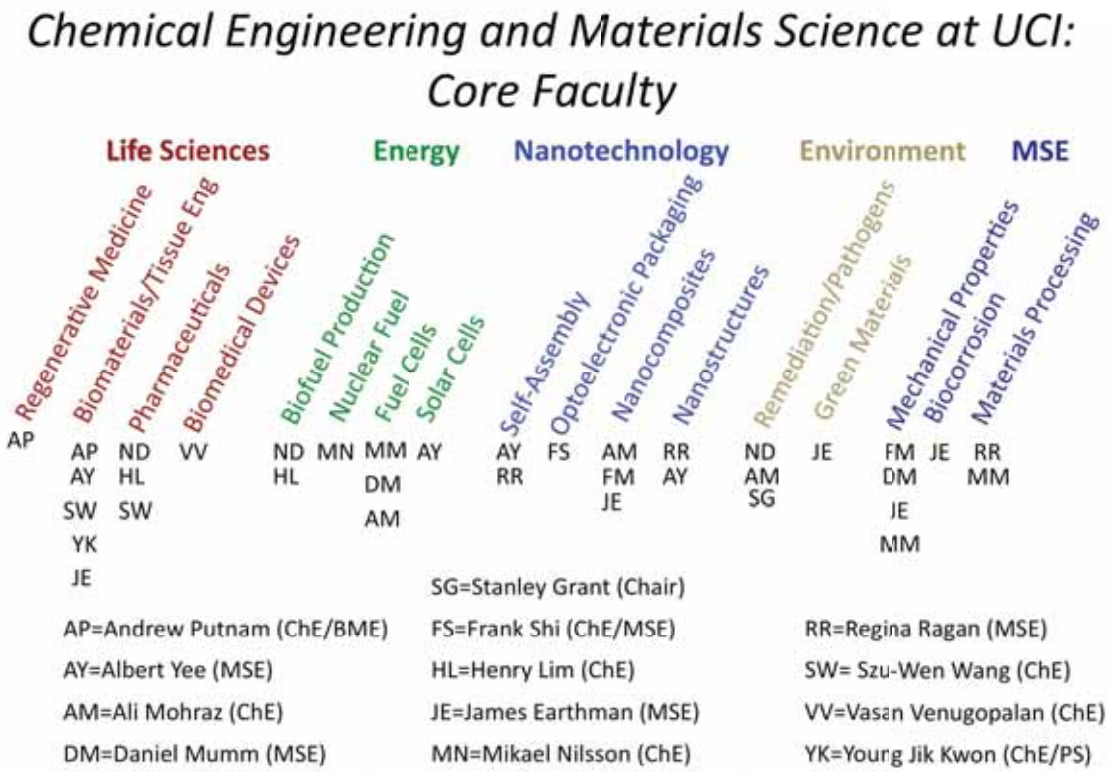

Figure 4. Research areas covered by faculty in ChEMS. Note the cluster of faculty conducting research in the areas of biomaterials, fuel cells, and mechanical properties.

The department is also ethnically diverse, composed of faculty with Asian (6 faculty), Caucasian (5 faculty), Hispanic (1 faculty), and Middle Eastern (2 faculty) heritage. It is important to note that gender and ethnic diversity is present at both senior and junior ranks, reflecting both past and present hiring practices.

Research Focus Areas

Research activities in ChEMS fall into four general areas: life sciences, energy, nanotechnology, environment, and materials characterization (Figure 4). The department has active, but relatively nascent, research programs in biomaterials and tissue engineering (Andy Putnam, Albert Yee, Szu Wang, Young-Jik Kwon, James Earthman), fuel cells (Martha Mecartney, Daniel Mumm, Ali Mohraz), nanotechnology (Albert Yee, Regina Ragan, Frank Shi, Ali Mohraz, Farghalli Mohamed), and structural/functional materials (Farghalli Mohamed, Daniel Mumm, James Earthman, Martha Mecartney, Regina Ragan and Ali Mohraz). Several faculty also conduct research in the areas of metabolic and biochemical engineering and biofuel production (Nancy Da Silva, Henry Lim) and nuclear fuel reprocessing (Mikael Nilsson).

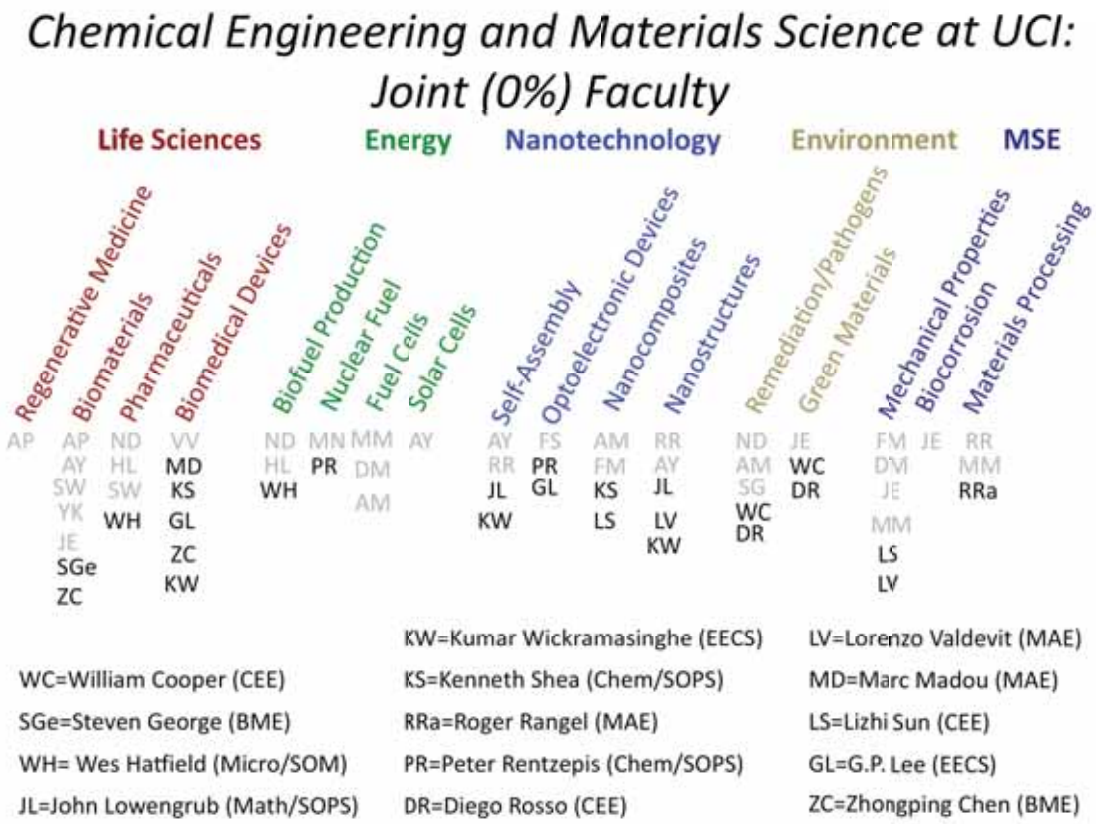

Figure 5. Research areas covered by faculty with a joint (0%) position in ChEMS. Note the relatively large number of joint faculty conducting research in medical devices.

Over the past several years, the department has approved the appointment of 14 joint (0%) faculty, many of whom supervise graduate students or cross-list courses. The research interests of joint faculty, relative to current departmental thrusts, are indicated in Figure 5. One of the joint appointees, Professor Young-Jik Kwon, is for all purposes a faculty member in the department, in that he teaches a capstone design class for the B.S. in Chemical Engineering, his laboratories are located in ChEMS space, and he actively participates in departmental service and planning. Professor Kwon was recently recruited as part of the new Pharmaceutical Sciences program at UCI, which currently does not have the infrastructure to support its faculty. Professor Kwon's final status *vis a vis* the department remains to be determined, although certainly one possibility is that he would have a split (i.e., non-zero) appointment in ChEMS, with the remainder of his appointment in the Department of Pharmaceutical Sciences.

Evaluation of Graduate Program Quality

To evaluate quality of the department's graduate programs, several metrics are considered below, including the department's annual research expenditures, Ph.D. graduation rates, recruitment yield, time-to-graduation for PhD students, and citation rates for the faculty. All of these metrics are evaluated in the context of feedback on the graduate program provided by the Academic Senate's 2005 ERC.

Table 1. Extramural funding expenditures for faculty in ChEMS

Academic Year	Department FTE by Rank				Expenditures (x$1,000,000)			Expenditures per FTE per year
	Assist.	Assoc.	Full	Total	Set-up	Extramural	Total	
2004/05	5	0	9	14	1.1	1.9	3.0	$210,000
2005/06	[a]3.5	[b]1.5	9	14	0.56	2.4	3.0	$210,000
2006/07	[a]4.5	1	9	14.5	0.64	1.7	2.4	$170,000
2007/08	[a]5.5	1	8	14.5	0.40	2.4	2.8	$190,000
2008/09	6	[a]1.5	8	15.5	N.A.	N.A.	N.A.	N.A.

[a] Professor Andrew Putnam has a 50% appointment in ChEMS (other 50% in BME)
[b] Professor Grace Lu had a 50% appointment in ChEMS (other 50% in EECS)

Research Expenditures. For the past five years, the department's total annual research expenditure has held steady at about $3 million per year (Table 1). When normalized by the number of faculty FTE in the department, the annual research expenditures range between $170,000 and $210,000 per faculty per year. By way of comparison, the HSSoE's average is approximately 400,000 per faculty per year. While the funding expenditure has remained relatively flat, and is perhaps behind where we would like to see it compared to other units in the School, shifting faculty demographics—both in terms of research focus and rank—are likely to increase this metric over time. This is evident in Table 2, where new research awards are shown by year and by faculty rank. In the last academic year for which data are available (2007/08) a record increase in new research awards, totaling $4.3M, were secured by Assistant Professors. Included among these new awards are three prestigious National Science Foundation Career Awards—a testament to the quality of the junior faculty.

PhD Graduation Rates and Time to Degree. Over the past four years, the department has graduated approximately 10 PhD students per year. When normalized by the number of faculty FTE in the department, this corresponds to a graduation rate of 0.7 PhD students per faculty per year, which is a reasonable graduation rate compared to other units in the School.

However, in their review of the department, the ERC raised concern about what appeared to be an increase in the time to completion of the PhD degree:

Table 2. New research contracts for faculty in ChEMS

Academic Year	New Research Funding by FTE Rank (x$1,000,000)				Number of conferred Ph.D's by FTE Rank				Graduate students per FTE
	Assist.	Assoc.	Full	Total	Assist.	Assoc.	Full	Total	
2004/05	.14	N/A	2.69	2.83		2	9	11	.79
2005/06	.11	.07	.28	.46			6	6	.43
2006/07	1.41	.10	.89	2.40	2	2	6	10	.69
2007/08	4.3	.45	1.97	6.72	2		8	10 ([c]11)	.69
2008/09									

[c]One student was supervised by Adjunct Prof. Nancy Allbritton, now at UNC.

The time to completion of the PhD degree appears to be increasing: the last 3 academic cycles showed a mean time to completion of 11, 15, and 16 quarters, respectively. The increasing trend is a concern for the ERC, and the Department is advised to address this increase.

To examine this issue, we compiled time-to-completion data (in quarters) for each PhD student enrolled in either the ChE and MSE graduate program. Over the past five academic years (from 2003/04 through 2007/08), the median (50th percentile) time to graduation for PhD students ranges between 15 and 17 quarters; i.e., approximately 5 years (Figure 6)[2]. Relative to the issue raised by the ERC above, it does not appear that the time-to-graduation for PhD students is increasing with time. Perhaps not surprisingly, within any particular academic year the time-to-degree varies dramatically, ranging from a low of 6 quarters (two years) to a high of 31 quarters (more than 10 years). A close examination of these data did not reveal specific problems that warrant corrective action; i.e., the very long times to graduation for a few students cannot be attributed to the supervision practices of specific faculty advisors. Instead, the few students with particularly long time-to-graduation times had unique situations beyond anyone's control, such as health problems, family constraints, and part-time work schedules.

<u>*Citation Rates*</u>. Two of the ChEMS faculty (Albert Yee and Farghalli Mohamed) are listed as "Highly Cited" by ISI Knowledge, which is an honor reserved for the top 0.5% of all authors worldwide. This distinction has been bestowed on relatively few faculty members at UCI, including only five in the HSSoE and 18 campus-wide. In addition to these highly cited researchers, a number of the mid-rank faculty in the department have relatively strong citation records (>100 citations per year). Overall, these results comport with the observations of the 2005 Academic Senate ERC:

[2] Note also that the ERC's use of mean time to completion is questionable, given the highly non-normal nature of the data; i.e., some students take a very long time to graduate, with the result that the distribution of times-to-graduation has a very long tail at the high end. Therefore, in the analysis presented here I used median and percentile values as non-parametric measures of central tendency and spread, see Figure 6.

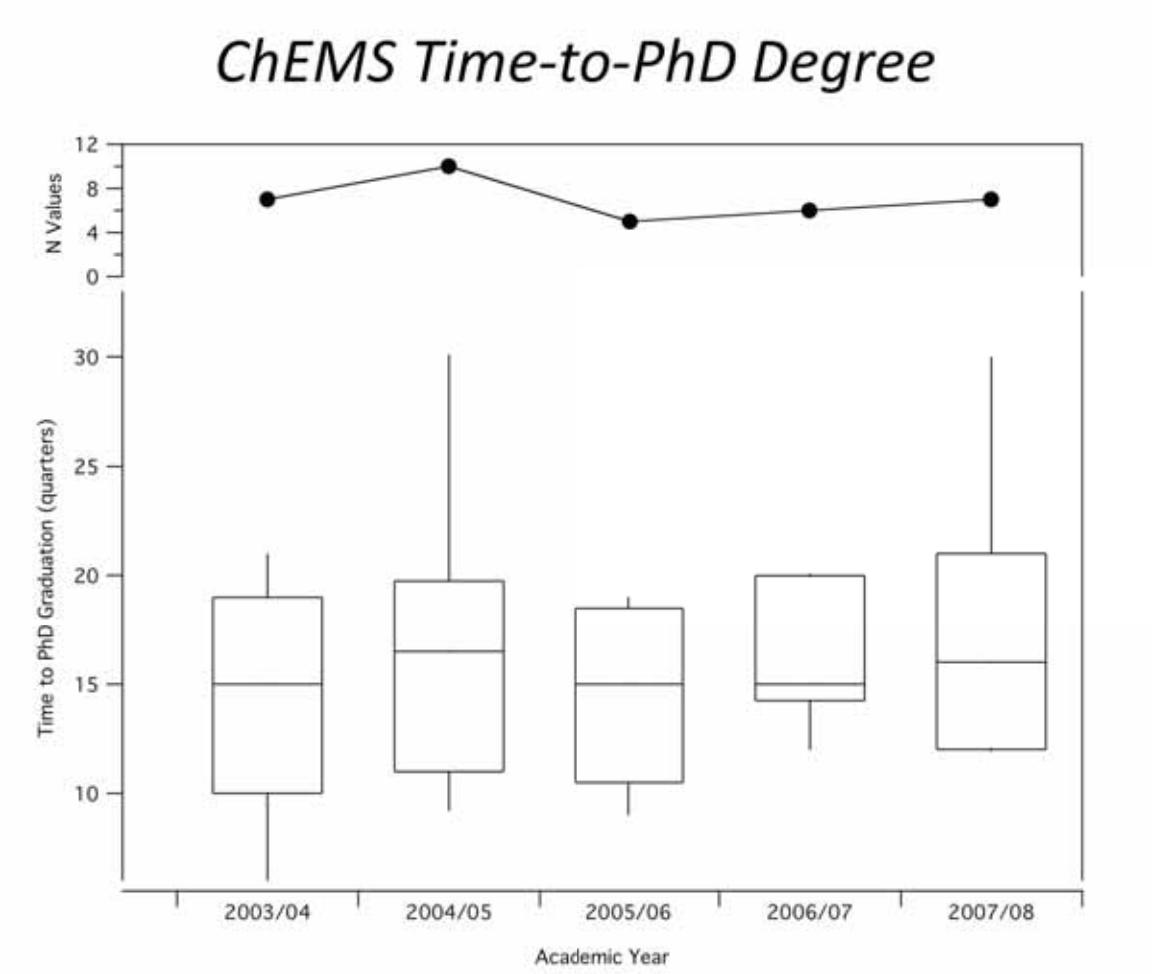

Figure 6. Box plots of the time to degree (in quarters, with three quarters per year) for PhD students graduating from the ChEMS ChE or MSE programs. The box plot format used here is a non-parametric approach for representing the central tendency and spread of data, based on percentiles. Percentile values are indicated by the top and bottom whiskers (90th and 10th percentiles), top and bottom of the boxes (75th and 25th percentiles) and horizontal line (50th percentile or median).

Although two senior faculty are well cited for their research contributions, and several mid-career faculty are becoming more recognized through citations, the Department as a whole has only a modest international reputation at present. The Department review lists all but one of their faculty distinctions in terms of teaching awards, not in awards for distinguished research. Aside from the most recent faculty hire (Director of the CalIT2), there have been no senior faculty hires since approximately 1987 when a senior professor joined the faculty to form the Department of Chemical Engineering. In order to leapfrog into the next tier of recognition, it is essential for the Department to conduct a concerted effort to recruit several senior faculty of international

repute. Such faculty would be expected to be more successful in leading grant applications for national and international centers.

Graduate Student Association. Another excellent development is the recent formation of a ChEMS' Graduate Student Association (GSA). The GSA, which was developed from the ground up by graduate students, fields two student representatives to attend faculty meetings, provides feedback on the department's annual teaching plan, helps organize the department's weekly seminar series, and will assist the department in its recruitment of undergraduate and graduate students to the program. The Department Chair holds weekly meetings with GSA officers to discuss (and hopefully resolve) issues of concern, with the goal of improving the overall quality of the graduate student experience. The GSA is also providing added value to the department, by providing a fresh perspective on a wide range of issues at departmental faculty meetings, and providing help and feedback on critical departmental efforts, such as the effort currently underway to redesign the department's website.

Overall Assessment. While there is some variability in the metrics used here to evaluate the department's graduate program, and there are clearly areas where the department could do better, overall the future looks very bright. The department has nurtured a gifted population of graduate students; after graduation these students go on to lead successful careers in industry and academia. Significant gains in both citation rates and annual research expenditures are expected in the near future as faculty demographics shift, and the research agenda becomes more focused on timely and exciting topics. As noted by the ERC, the hiring of renown senior faculty would dramatically improve the department's national and international reputation, and this strategy is being pursued with the recruitment this year of an Endowed Professor in the area of Nuclear Waste Management.

New Undergraduate and Graduate Degrees

ChEMS is considering the possibility of developing several new degrees over the next couple of years, consistent with the consensus opinion that the department should focus its future growth at the interface of chemical engineering, materials science, and biology. Discussions are ongoing regarding the development of a new undergraduate B.S. degree in Biomaterials, a new undergraduate B.S. degree in Chemical Engineering-Premed, and new graduate M.S. and PhD. Degrees in Biomaterials. Prior to moving forward on any of these initiatives, additional information will be acquired and analyzed relative to the potential impact these degrees might have on existing resources (e.g., instructional resources) and overall level of student interest and potential employability of graduates.

Summary

The information provided above paints a picture of a department in transition—away from separate programs in biochemical engineering and materials science engineering toward a focus at the interface of ChE and MSE, diversification of degree offerings for undergraduates and graduate students, and increasing extramural research funding to support faculty and students. This academic plan is endorsed by the department's faculty, leverages many resources on campus, and is consistent with the recommendations of experts hired by the Academic Senate to evaluate our graduate and undergraduate programs. Continued growth in faculty and students at the intersection of ChE and MSE should yield significant returns in the form of improved departmental and HSSoE rankings, and stronger research and educational ties between ChEMS, Biomedical Engineering, Pharmaceutical Sciences, Chemistry, and other departments in Physical Sciences and the College of Health Sciences.