PROPOSAL FOR A DEPARTMENT OF BIOENGINEERING AND A MASTER OF SCIENCE DEGREE PROGRAM IN BIOENGINEERING

A proposal from the School of Engineering

January 3, 2012

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EXECUTIVE SUMMARY

Since the creation of a BS Bioengineering degree program in 2009, the School of Engineering has seen consistently increasing enrollment in this degree program as well as interest in an MS Bioengineering degree program. Though a number of full-time faculty and staff currently support the BS Bioengineering degree, the creation of a Department of Bioengineering will facilitate both continued excellence in the BS degree program as well as creation and expansion of the MS degree program. Thus, we propose the following changes to the bioengineering program and curriculum:

- Establish a Department of Bioengineering
- Create an MS Bioengineering degree program

The proposed changes will strengthen the quality of education offered to bioengineering students at SCU and enhance the reputation of SCU as a whole.

PURPOSE AND CENTRALITY

> *Discuss the primary goals of the proposed program and the rationale for instituting this program at Santa Clara University. Specifically, describe the ways in which it advances the mission and goals of the University and the relevant college or school. For example, a proposal might describe how the program contributes to a learning environment that promotes ethics or fosters the University's commitment to a more humane and just world.*

In recent years, the field of bioengineering and biomedical science has advanced many technologies with the potential to radically change the world of healthcare as well as society's perspectives on life in general. Stem cells, genetic sequencing, and electronic medical records have all been in both national and scientific news, discussed as both positive and in some cases very negative new technologies. As with any powerful technology, these advances have the potential to negatively impact the

lives of human beings the world over if they are not advanced in ethically and socially responsible ways. As a Jesuit Institution, SCU is bound to participate in this field as a voice promoting the high ethical standards and social responsibility that have always been landmarks of our university. In order to effectively participate in these fields, we must house faculty members of the highest quality and attract high achieving students. We must then train these students effectively and completely, ensuring that they will be highly successful, influential ambassadors of SCU in the bioengineering world.

As the field of bioengineering grows, so too must our influence in this field. It is our responsibility as a Jesuit institution to ensure that the field of bioengineering and biomedical science is populated with people who value both scholarship and service to the underprivileged and impoverished. The influence of bioengineering and biomedical science on society at large will only increase with time, giving SoE a unique opportunity to further its goal of "Engineering with a Mission" by actively participating in bioengineering and the biomedical sciences. SCU can encourage students within both its undergraduate and proposed graduate programs to use their knowledge and expertise to help society at large as well as the 4 billion impoverished and underprivileged people of the world. A bioengineering lab at Rice University recently developed a portable, low cost fluorescent microscope for the express purpose of making this type of technology available to the many clinicians and doctors with few financial resources in geographically isolated settings[1]. This is the type of high quality, socially responsible, service-minded research that SCU will be better equipped to facilitate upon creation of a formal Bioengineering Department and a Master's Degree Program in Bioengineering. With the devoted resources of a department and the enhanced academic environment created by the addition of a pool of graduate students, SCU will be able to more effectively impress upon our students the value of this service-oriented mindset. SCU can forge a new type of bioengineer whose work is constantly guided by the knowledge that a significant

[1] http://arstechnica.com/science/news/2010/08/cheap-300-fluorescent-microscopes-for-developing-world.ars accessed 11-15-2011

[2] http://www.mddionline.com/article/manufacturing-new-registration-fees-help-clarify-industry-

portion of the world lives in constant poverty, and bioengineering can and should be used to serve them.

Though SCU is advantageously located in the heart of Silicon Valley and already offers a BS Bioengineering degree, it is imperative that we formally declare support of Bioengineering by creating a Department of Bioengineering. Furthermore, in order to solidify our presence in the field of bioengineering, it will be extremely advantageous to offer an MS Bioengineering degree program in addition to our current BS program. As explained below, both of these changes are necessary and highly beneficial to SCU as whole. The University will be able to attract superior students and faculty, to offer more advantages in terms of internships and jobs, and to reinforce our reputation as an educational institution committed to playing an active role in today's most relevant fields.

Rationale for A Department of Bioengineering

In late 2009, a proposal for the creation of a Bioengineering BS degree was approved and implemented within the School of Engineering. Since that time, enrollment in the BS Bioengineering major has grown steadily, surpassing our highest expectations. Currently the BS Bioengineering degree program is supported by four full-time bioengineering faculty, twelve affiliated faculty and advisors, multiple adjunct faculty members, one full-time administrative assistant (shared with the Department of Electrical Engineering), and an advisory board of six external members. While the BS Bioengineering degree program has successfully expanded its course offerings and secured funding for several state-of-the-art undergraduate teaching labs in the absence of a departmental structure, the creation of a Department of Bioengineering would facilitate further growth and educational enrichment of this burgeoning program.

With the full-time faculty, adjunct faculty, lecturers, and administrative assistant, the support staff for the BS Bioengineering degree already perform many of the functions of a department without the support structure and advantages that a department could provide. With the

creation of a Department of Bioengineering, the faculty and staff would have more freedom to focus on quality and depth of instruction than in the present arrangement. Furthermore, a Department of Bioengineering will ease the task of recruiting and retaining faculty to the bioengineering program, as the University's commitment to excellence in Bioengineering education will be clear. Creation of a Department of Bioengineering would also assuage fears of potential faculty about the uncertainty of obtaining a tenure-track position within a discipline rather than a formal department. This change would draw the interest of higher caliber potential faculty members with more cutting edge research portfolios to SCU, expanding and enhancing our community of scholars. A formal department would also help in attracting external research funding. A departmental Chair could more directly support grant applications, for example by providing assurances of space, positions, percent effort, cost-sharing, and so on. More importantly, the creation of a Department of Bioengineering will be a strong statement of support for biomedical research and excellence, which will enhance the reputation and stature of SCU as a whole.

Bioengineering students will benefit in a number of ways from the creation of a Department of Bioengineering. As previously mentioned, the departmental structure will allow current Bioengineering faculty to put more focus on rigorous curriculum and effective teaching methods. This will directly lead to a superior student experience both during their undergraduate studies and beyond. Students will be more comprehensively educated on bioengineering topics, which will prepare them fully for successful careers in biomedical sciences and engineering, eventually leading to a higher profile reputation for SCU within the world of biomedical sciences and bioengineering. Eventually, this will improve both internship and job prospects for all bioengineering students, as SCU will have a more well-known reputation for excellence in molding successful bioengineers, and a formal department can more effectively build long-term relationships with local companies, who are potential employers.

Additionally, the creation of a Department of Bioengineering will increase prospective student confidence in the Bioengineering BS degree at SCU. This may cause some students to matriculate at SCU who might otherwise have chosen to attend an undergraduate institution with a bioengineering department versus one with just a Bioengineering Program within the Department of Electrical Engineering. The creation of a Department of Bioengineering will demonstrate that the University is steadfastly committed to the continued and expanded presence of bioengineering at SCU. Current students will also benefit from the creation of the Department of Bioengineering at SCU, as it will provide them a home-base with departmental resources and additional ways to make the most of their BS Bioengineering degree programs.

The creation of a Department of Bioengineering at SCU is the logical next step in expanding the presence of SCU in the increasingly popular and bustling field of bioengineering. Our location in the heart of Silicon Valley, surrounded by countless medical device and pharmaceutical companies as well as eminent academic institutions, puts us in a unique position to do just that. The presence of a Bioengineering Department at SCU would indicate to the academic community at large that SCU is committed to applying its rigorous academic expectations, high ethical standards and philosophies of social responsibility to the broad field of biomedical science and engineering. This will ease the task of attracting financial support, high caliber students and faculty, and internship and job opportunities to SCU.

Rationale for an MS Degree in Bioengineering

Being advantageously located in the heart of Silicon Valley, SCU draws many students who are interested in biomedical technology, biotechnology, and applied biochemistry. These students typically go directly into industrial positions, enter advanced programs in the health professions or pursue graduate degrees in bioengineering. In addition to the opportunities SCU provides in the way of undergraduate degrees in the biosciences and bioengineering, it is essential that we begin offering advanced degrees in these fields. Students graduating with BS degrees from SCU and other universities often have the desire to

increase their specialization before entering the workforce. Likewise, many industry professionals desire to supplement their current education with deeper, more specialized knowledge in the field of biomedical science and bioengineering. SCU is poised to provide that for both classes of prospective graduate students.

The current Bioengineering BS degree program focuses on the broad application of engineering principles to biomedical science. Though the Bioengineering BS degree program does educate students in the development and implementation of specific technologies and devices in biochemistry and biotechnology, a graduate level degree would complement the existing undergraduate major by providing students with the opportunity to specialize in a specific area and expand their knowledge beyond the undergraduate level. It would also further establish SCU as a premier institution devoted to high quality education in the emerging field of bioengineering.

Both current and prospective students will be attracted by the highly interdisciplinary nature of the Bioengineering MS degree program, which focuses their interest in applying their knowledge of physical and engineering sciences to answer questions related to diseases and improving health. More importantly, students who complete graduate studies in Bioengineering at SCU will be exposed to the high ethical standards and commitment to social justice that are the hallmarks of Santa Clara education, and represent an essential component of education in the 21st century. This will allow SCU to more effectively impact the nature of ethics and awareness of the social impact of biomedical advancement.

The School of Engineering has an excellent record of preparing its graduates for successful careers. We routinely place students in top-tier graduate programs, and many of our students work in the Bay Area technology and medical device sector. Companies who have hired SCU engineering graduates contact us regularly in their search for new hires. We are noted not only for a rigorous curriculum but also for engaging students in independent research with our faculty. A graduate program

in Bioengineering will also complement current faculty research efforts, as students can contribute to and expand the breadth of externally funded research. Along the same line, the department may have a better chance to win funding for training grants once it houses a graduate program.

Engineering faculty members have also developed programs to teach ethics and to engage under-represented students in Engineering. Students interested in bioengineering will benefit greatly from having a 5-year BS/MS degree program as well as a stand-alone MS degree program offered by a full Bioengineering Department committed to maintaining and improving upon the already outstanding learning environment provided by the School of Engineering. With our existing coursework, core and adjunct bioengineering faculty, we can create a high-quality, rigorous MS Bioengineering degree program with minimal new resources. Currently we have four full-time bioengineering core faculty members and five adjunct faculty members from local medical device and biotech industries. The Bioengineering graduate degree program also dovetails with our recent curricular restructuring, reflecting an emphasis on emerging bioengineering research areas, which include Biomaterials, Implantable Devices, Tissue Engineering, and Protein Engineering.

SCU is ideally suited to establish a center of excellence in graduate teaching and research in Bioengineering and Biotechnology, a task which will be facilitated by the creation of a Department of Bioengineering. Tremendous career opportunities in the biomedical technology and biotechnology industries exist throughout the Bay Area. According to the December 2008 issue of Medical Device and Diagnostic Industry (MDDI) Magazine, California has, by far, the most publicly traded medical device companies with 81, and Massachusetts ranks a distant second with 40[2]. More recent information from the November 2010 issue of MDDI indicates that California is the leading state in terms

[2] http://www.mddionline.com/article/manufacturing-new-registration-fees-help-clarify-industry-demographics accessed 11-1-2011

of FDA registered medical device establishments with 4521[3]. This places California several fold ahead of other states like Florida (1774), New York (1708), Texas (1178), and New Jersey (1055). Additionally, in comparing the information from the 2010 issue of MDDI to that of the 2008 issue, the number of FDA registered medical device establishments has more than tripled in the course of three years. This further underscores the increasing demand for biomedical scientists and engineers as well as the uniquely opportune position in which SCU finds itself, being located in a hub of biomedical businesses.

In addition to sectors of extreme interest in the medical device industry including cardiovascular stents, interventional devices, cardiac rhythm management and congestive heart failure devices, reconstructive devices, and surgical and drug delivery devices, new areas of bioengineering are emerging through the fusion of information technology, biotechnology, and nanotechnology. The emerging areas of bioengineering including biosensors, biochips, genomics, proteomics, bioinformatics and bio-nanotechnology, are projected to have a market potential of more than $1 trillion over the next 10 years[4]. Local companies leading this revolutionary convergence include Affymetrix, a leader in biochips; Applied Biosystems (now a subsidiary of Life Technologies), a leader in DNA/RNA/protein chips, DNA sequencers and analysis; Applied Materials, a leader in semiconductor chips and nano-manufacturing; Genencor, a leader in protein engineering and eco-friendly biodefense, bioproducts and biofuels; and many others.

It is likely that the future of Silicon Valley will feature a significant component in bioengineering, perhaps on a scale to rival semiconductors and software. There are already hundreds of biotechnology firms in the Bay Area, ranging from giants like Boston Scientific and Genentech, to small startups. As one measure of this activity, Price Waterhouse Coopers reported $552 million in venture capital investments in San Francisco Bay area biotech companies for the

[3] http://www.mddionline.com/article/medtech-snapshot-manufacturing accessed 11-1-2011
[4] Collaborative Economics, Inc

second quarter of 2011[5]. This was the largest segment of VC funding for the quarter, exceeding that invested in all other regions of the US. The Bay Area has long been a center for biotechnology companies, and their presence has been ever increasing in recent years. Currently there are 800 such companies employing over 85,000 employees[6]; 31 academic research institutions are also involved in biotechnology and bioengineering, with some 250 new companies having spun off from area universities. With this level of interest in biomedical science and engineering in the local area, we anticipate that a new Department of Bioengineering combined with a Bioengineering MS degree program will encourage the development of collaborations between SCU and industry professionals, improving immediate internship and job prospects for SCU graduates as well as increasing enrollment in the graduate degree program from industry professionals.

According to official records from the Registrar's office, the Bioengineering program at SCU currently has 118 declared majors. Of these, 53 (45%) are females, a percentage that is extremely high for any engineering department at SCU[7]. The undergraduate major degree program has hired several full-time bioengineering faculty members in the last few years to solidify it as a premier bioengineering department. Dr. Yuling Yan was first hired for the express purpose of facilitating creation of the undergraduate degree program in bioengineering. Dr. Unyoung Kim, Dr. Prashanth Asuri, and Dr. Zhiwen Zhang were hired to meet the challenge of teaching and advising current and future bioengineering major students along with Dr. Yan. Alongside the affiliated faculty members and term-lecturers, this team has successfully fostered the development and growth of the bioengineering major at SCU.

With the growth of the bioengineering major, students and local industry professionals have expressed interest and demand for an MS

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[5] http://www.pwc.com/us/en/press-releases/2011/11q2-life-sciences-moneytree-release-high-dollar-deals.jhtml accessed 11/1/2011

[6] http://www.sfvirtualshop.com/biotech.htm accessed 11/1/2011

[7] Overall, engineering currently has about 25% women students, with individual majors ranging from 10-30%

degree program in bioengineering. Therefore the creation of a Department of Bioengineering and a bioengineering graduate degree is extremely timely and will address this new demand. The courses necessary for the graduate degree program in bioengineering are already in planning and several of them have been enacted as of the 2011-2012 academic year.

Program Goals

The proposed MS degree in Bioengineering at SCU will better serve our students and the community. To accomplish this important mission, we have formulated the following program goals:

1. To train and educate a new generation of graduate students by improving the quality and scope of interdisciplinary education through basic and applied research and teaching at the interface of engineering, the life sciences, and the health professions;
2. To prepare SCU graduate students for careers in the biomedical and biotechnology industries or entry into advanced health professions;
3. To produce graduates who understand how bioengineering enables innovation in technology that helps advance human health and promote environmental sustainability, thereby meeting two of the greatest challenges of modern times;
4. To produce graduates whose work will be guided by an understanding of and sensitivity to, the social, political, ethical, and legal relationships between their work and those that it affects;
5. To promote and foster teaching and research collaborations between Engineering and Life Sciences faculty at SCU;
6. To produce graduates with comprehensive understanding of bioengineering topics as well as highly specialized knowledge and skill sets in their chosen areas, thereby establishing SCU as a source of superior biomedical industry job candidates.
7. To foster interfacial research collaborations with local companies that could generate new intellectual property (IP), and to facilitate translation of that new IP to the biotechnology/biomedical

technology industry in the Bay Area for the benefit of students, SCU and the Silicon Valley community.

PROGRAM REQUIREMENTS

Identify the curricular and other requirements students will be expected to meet. What is the rationale for these requirements?

The central course sequence for the proposed Bioengineering MS degree consists of the following courses: BIOE 270 + BIOE 270 L (Molecular and Cellular Bioengineering + Lab), BIOE 272 (Fundamentals in Tissue Engineering), and BIOE 275 (Physiology and Disease Biology). These courses are designed to hone students' understanding of engineering principles and practices, educate them on the intricacies of the biological systems with which all biomedical technologies must interface, and deepen their understanding of interdisciplinary knowledge over multiple scales of biological organization, ranging from molecules to organs.

Many of the courses required for the proposed MS Bioengineering degree program were already in existence in a less rigorous format within the BS Bioengineering or MS General Engineering curricula. Recent curricular restructuring and expansion has been accomplished by the bioengineering faculty, resulting in the creation of all the courses necessary for the proposed MS Bioengineering degree program. All of the courses have been developed or are in development, but some have not yet been taught.

One of the research-oriented additions we propose is the continuation of the supervised independent research course (BIOE 199) and the senior design series (BIOE 194, 195 and 196) by creating "Master's thesis research" or "Directed Research" units to allow students to more actively participate in research projects.

Students pursuing a 5-year combined BS/MS degree may take the 5th

year to work on their research/design projects. This will encourage industry involvement in the design and execution of these projects. Industry professionals will have the luxury of presenting students with more complicated and challenging bioengineering problems knowing that students will have a full two years to create real, viable solutions to those problems. This same process will be further facilitated by the creation of a formal Department of Bioengineering.

The core courses of the Bioengineering graduate program require that students also take foundational classes in Advanced Mathematics, and Cellular & Molecular Biology. Undergraduate students who opt into the 5-year combined BS/MS degree program will be able to satisfy certain graduate requirements with upper-division bioengineering technical elective courses (a maximum of 9 units), allowing them to take additional advanced courses in their senior year and obtain a higher level of specialization in their graduate degree. A proposed curriculum for the 2-year MS degree in Bioengineering is outlined in Table 1 and accounts for a total of 45 course units. This course load is consistent with the requirements for other graduate level engineering majors within the School of Engineering at SCU, as well as the bioengineering graduate programs offered by other institutions including UC systems and Stanford University. Proposed curricula for the 5-year BS/MS program with the med-device and biomolecular/pre-med tracks are shown in Table 2, 3 and 4 respectively. An example of the 2-year course plan for the MS Degree is shown in Table 5.

SCU Core Requirements

The proposed program incorporates the School of Engineering version of the University Graduate Core that took effect in the fall of 2009. The Graduate Core requires engineering graduates to take courses in each of three areas: Emerging Topics in Engineering, Engineering and Business Entrepreneurship, and Engineering and Society. Since all of these topics are covered in some way in the bioengineering curriculum already in place, there is a natural link between the Graduate Core and the proposed Bioengineering graduate degree. This provides easy

integration of the major and mission of Santa Clara University into the graduate degree in bioengineering.

Table 1: Proposed MS Bioengineering Curriculum

	Course	Topic	Units
Major Requirements	AMTH 200 & 201, (*equivalent to AMTH 202*) or AMTH 210 & 211 (*equivalent to AMTH 212*)	Probability, Numerical Methods	4
	AMTH 220, 230, or 235	Advanced Engineering Mathematics	2
	BIOE 270 + BIOE 270L	Molecular and Cellular Bioengineering + Lab	5
	BIOE 272	Fundamentals in Tissue Engineering	2
	BIOE 275	Physiology and Disease Biology	2
Technical electives	Three to seven electives from graduate level courses in research, protein and tissue engineering, device invention, imaging, microfluidics, or synthetic biology		24
SCU Graduate core	Three courses from Emerging Topics in Engineering, Engineering and Business/Entrepreneurship, and Engineering and Society		6

Total: 45 Units

Table 2: Sample Five Year Plan

5-year Bachelor of Science/Master of Science in Bioengineering (Device Track)

Freshman

Fall	Winter	Spring
Calculus I (MATH 11)	Calculus II (MATH 12)	Calculus III (MATH 13)
Intro. Engineering (ENGR 1)	Phys I (PHYS 31)	Phys II L/L (PHYS 32)
Chem L/L (CHEM 11)	CTW 2	Intro Bioengineering (BIOE 10)
CTW 1	C & I 1	C & I 2
CORE (Rel. 1)		

Sophomore

Fall	Winter	Spring
Phys 33 (PHYS 33)	Cell & Mol Bioeng (BIOE 22)	Logic Design (ELEN 21)
Calculus IV (MATH 14)	Chemistry II L/L (CHEM 12)	Chem III L/L (CHEM 13)
Intro Physiology (BIOE 21)	Differential Equations (AMTH 106)	Graphic Design (MECH 10)
CORE (Soc. Sci.)	CORE (Ethics)	CORE (Diversity)

Junior

Fall	Winter	Spring
Organic Chemistry I (CHEM 31)	Bio. Transport (BIOE 155)	BioInstrumentation (BIOE 161)
Electric. Circuits I (ELEN 50)	Intro Programming (COEN 44 or 45)	Prob. & Stats. (AMTH 108)
Biomaterials (BIOE 153)	Bio Signals (BIOE 162)	Biomechanics (BIOE 154)
CORE (Rel. 2)	Tissue Engineering (BIOE 172)	Physiol. & Anat. (BIOE 171)

Senior

Fall	Winter	Spring
TE1* (BIOE 107)	Senior Design (BIOE 195)	Senior Design (BIOE 196)
Senior Design (BIOE 194)	TE3*: Biomed Instrument/Device (BIOE 163)	TE4*: Microfluidics (BIOE 274)
TE2*: Intro Biofuels Eng. (BIOE 157)	CORE (Rel. 3)	TE5*: Device Invention (BIOE 207)
ENGL181	CORE (C & I 3)	ENGL 182

MS

Fall	Winter	Spring
AMTH 201		
TE6*: Medical Imaging (BIOE 642)	AMTH 202	AMTH 220
TE7*: Biophot. & Bioimag. (BIOE 268)	Master's Thesis Research (BIOE 295)	Physiol. & Disease Biology (BIOE 275) Fund. Tissue Eng (BIOE 272)
Master's Thesis Research (BIOE 295) GRAD CORE	Graduate Research Seminar (BIOE 200) GRAD CORE	Master's Thesis Research (BIOE 295) GRAD CORE

* Technical elective satisfies BS and MS TE requirements.

CORE: University undergraduate core courses; GRAD CORE: University graduate core courses

Table 3: Sample Five Year Plan

5-year Bachelor of Science/Master of Science in Bioengineering (Biomolecular Track)

Freshman

Fall	Winter	Spring
Calculus I (MATH 11)	Calculus II (MATH 12)	Calculus III (MATH 13)
Chemistry I L/L (CHEM 11)	Chemistry II L/L (CHEM 12)	Chemistry III (CHEM 13)
Intro. Engineering (ENGR 1)	CTW 2	Intro Bioengineering (BIOE 10)
Intro Physiology (BIOL 21)	CORE (C & I 1)	CORE (C & I 2)
CTW 1		

Sophomore

Fall	Winter	Spring
Calculus IV (MATH 14)	Physics for Engineers (PHYS 31)	Physics for Eng. II L/L (PHYS 32)
Organic Chemistry I (CHEM 31)	Organic Chemistry II (CHEM 32)	Differential Equations (AMTH 106)
Cellular/Molecular Biology (BIOL 24)	Cellular Biology Lab (Biol 25)	Logic Design (ELEN 21)
CORE (Rel. 1)	CORE (Rel. 2)	CORE (Ethics)

Junior

Fall	Winter	Spring
Physics for Engineers III L/L (PHYS 33)	Programming (COEN 45)	Bio-device Eng. (BIOE 163)
Biomolecular Engineering I (BIOE 175)	Electronic Circuits I (ELEN 50)	Prob. & Stats. (AMTH 108)
Biomaterial Science (BIOE 153)	Biomolecular Eng. II (BIOE 176)	TE1* Tissue Engineering (BIOE 173)
CORE (Rel. 3) (BIOL 171)	CORE (Soc. Sci.)	CORE (Diversity)

Senior

Fall	Winter	Spring
TE2*	Biosignals (BIOE 162)	TE5*: Topics in Bioeng. (BIOE 249)
ENGL 181	Senior Design (BIOE 195)	ENGL 182
Senior Design (BIOE 194)	TE3*	Senior Design (BIOE 196)
CORE (C & I 3)	TE4*: Intro Biofuels Eng (BIOE 157)	Biol. Transport (BIOE 155)

MS

Fall	Winter	Spring
AMTH 210		
TE6*: Graduate Research Sem. (BIOE 200)	AMTH 211	Physiol. & Disease Biology (BIOE 275)
Master's Thesis Research (BIOE 295)	Master's Thesis Research (BIOE 295)	Fund. in Tissue Eng (BIOE 272) AMTH 220
TE7*: Stem Cell Bioeng. (BIOE 269)	Grad. Research Seminar (BIOE 200)	TE8*: Biother. Eng (BIOE 280)
GRAD CORE	GRAD CORE	GRAD CORE

* Technical elective satisfies BS and MS TE requirements.
CORE: University undergraduate core courses;
GRAD CORE: University graduate core courses

Table 4: Sample Five Year Plan

5-year Bachelor of Science/Master of Science in Bioengineering (Pre-med Track)

Freshman

Fall	Winter	Spring
Calculus I (MATH 11)	Calculus II (MATH 12)	Calculus III (MATH 13)
Chemistry I L/L (CHEM 11)	Chemistry II L/L (CHEM 12)	Chemistry III (CHEM 13)
Intro. Engineering (ENGR 1)	CTW 2	Intro Bioengineering (BIOE 10)
Intro Physiology (BIOL 21)	CORE (C & I 1)	CORE (C & I 2)
CTW 1		

Sophomore

Fall	Winter	Spring
Calculus IV (MATH 14)	Physics for Engineers (PHYS 31)	Physics for Eng. II L/L (PHYS 32)
Organic Chemistry I (CHEM 31)	Organic Chemistry II (CHEM 32)	Organic Chem III (CHEM 33)
Cellular/Molecular Biology (BIOL 24)	Cellular Biology Lab (Biol 25)	Logic Design (ELEN 21)
CORE (Rel. 1)	CORE (Rel. 2)	CORE (Ethics)

Junior

Fall	Winter	Spring
Physics for Engineers III L/L (PHYS 33)	Programming (COEN 45)	Bio-device Eng. (BIOE 163)
Differential Equations (AMTH 106)	Electronic Circuits I (ELEN 50)	Prob. & Stats. (AMTH 108)
Tissue Eng. I (BIOE 172)	Biomaterials Science (BIOE 153)	Physiol. & Anat. (BIOE 171)
CORE (Rel. 3) (BIOL 171)	CORE (Soc. Sci.)	CORE (Diversity)

Senior

Fall	Winter	Spring
Biol. Transport (BIOE 155)	Biosignals (BIOE 162)	TE3: Tissue Eng. II (BIOE 173)
ENGL 181	Senior Design (BIOE 195)	ENGL 182
Senior Design (BIOE 194)	TE1* Tissue Engineering (BIOE 173)	Senior Design (BIOE 196)
CORE (C & I 3)	TE2*: Intro Biofuels Eng (BIOE 157)	

MS

Fall	Winter	Spring
AMTH 210 TE4: Biomolecular Eng. (BIOE 175)	AMTH 211 TE7: Stem Cell Bioeng. (BIOE 269)	AMTH 220 TE9: Biophotonics (BIOE 268)
TE5: Microfluidics (BIOE 274)	TE8: Directed Research (BIOE 297)	TE9: Directed Research (BIOE 297)
TE6: Directed Research (BIOE 297)	Physiol. & Disease Biology (BIOE 275)	TE10: Biother. Eng (BIOE 280)
GRAD CORE	Grad. Research Seminar (BIOE 200) GRAD CORE	GRAD CORE

Table 5: Sample Two Year Plan

2-Year Master of Science in Bioengineering

First Year

Fall	Winter	Spring
AMTH 200 Molecular and Cellular Bioengineering + Lab (BIOE 270 + BIOE 270 L) GRAD CORE	AMTH 201 Graduate Research Seminar (BIOE 200) TE1* GRAD CORE	AMTH 220 Fundamentals in Tissue Eng. (BIOE 272) TE2* GRAD CORE

Second Year

Fall	Winter	Spring
Physiology & Disease Biology (BIOE 275) TE3*: MS Thesis Research (BIOE 397) TE4*	TE5*: MS Thesis Research (BIOE 397) TE6*: Grad. Research Sem. (BIOE 200)	TE7*: MS Thesis Research (BIOE 397) TE8* TE9*

GRAD CORE: University graduate core courses

***See Table 6 for a selected list of Technical Electives**

Table 6: Bioengineering Technical Electives

Examples of Technical Electives for the MS degree

ǂBIOE 200 (1)	Graduate Research Seminar	ǂBIOE 269 (2)	Stem Cell Bioengineering
ǂBIOE 207 (2)	Medical Device Invention	BIOE 274 (4)	Microfluidics for Biomedical Applications
BIOE 249 (2)	Topics in Bioengineering	ǂBIOE 280 (2)	Special Topics in Bio-therapeutic Engineering
BIOE 250 (2)	Introduction to Bioinformatics and Sequence Analysis	ǂBIOE 282 (2)	Bioprocess Engineering
BIOE 254 (4)	Introduction to Biomechanics	ǂBIOE 297 (1~6)	Directed Research
BIOE 256 (2)	Introduction to Nano-Bioengineering	ǂBIOE 397 (9)	Master's Thesis Research
BIOE 257 (2)	Introduction to Biofuels		
ǂBIOE 258(2)	Synthetic Biology & Metabolic Engineering		
ǂBIOE 266 (2)	Advanced Nano-Bioengineering		
ǂBIOE 268 (2)	Biophotonics and Bioimaging		

ǂCourse already in course catalog but has not yet been taught

INTEGRATING ETHICAL ISSUES IN BIOENGINEERING CURRICULUM

In support of the spirit and the letter of the educational mission of SCU, we have already integrated discussions of ethical issues relevant to the study of bioengineering into the curriculum for the undergraduate Bioengineering major, meaning that they are already in place within the curriculum for the proposed graduate Bioengineering major. We have included controversial issues such as human and animal experimentation, the practice and applications of stem cell research as well as cloning and genetic engineering. Other general issues on ethics such as conflicts of interest, confidentiality and privacy and plagiarism are also discussed. For example, we ask questions on the roles and responsibilities of research entities who determine or analyze DNA sequences of patients and whether they should make this information available to the Government or to a healthcare provider, and, if so, under what circumstances; if not, what should be done to protect the individual's rights and privacy? Since we now live in a time when stem cell research and its potential application for the treatment of human disease is seen in a positive light, we ask students to thoughtfully consider how to deal with conflicts in society such as a person's, or religious organization's negative stance on the use of stem cells?

Most of the ethical issues that need to be discussed in the bioengineering graduate curriculum such as those mentioned above are already covered within existing course offerings. As part of the Graduate Core, students often take ENGR 310, Engineering Ethics, which covers a number of ethical issues pertinent to all engineering careers. A bioethics course is currently under development within the bioengineering faculty; this course will also be cross-listed within the Graduate Core under the Engineering and Society heading.

Since the field of bioengineering is very new, with several major Universities only having formed a department within the past few years, one might anticipate that new ethical issues will arise in parallel with new discoveries in the field. This will necessitate frequent updates and maintenance of these topics within existing ethics and bioengineering

courses. This has been proven by a recent study that shows that adult cells can be re-programmed to form pluripotent stem cells without the need for harvesting embryonic stem cells or through genetic manipulation of cells. This new discovery has created enormous excitement within the field. In principle, stem cells can now be made from an individual's own adult cells, making the "harvesting" of stem cells in this manner very similar to the practice of storing one's own blood for a later transfusion. New breakthroughs such as this might reduce ethical concerns on how stem cells are generated but they do not necessarily alleviate concerns about the actual use of stem cells, regardless of how they are produced. We will consult with our colleagues at SCU and beyond for specific advice on how these issues should be presented and discussed in our curriculum.

COMPARISONS WITH OTHER PROGRAMS

A review of bioengineering programs at other institutions in the US reveals that many programs have specific focus areas in Bioengineering that reflect faculty expertise or institutional priorities. For example, programs associated with a medical school offer specialization tracks in Biomedical Imaging whereas programs within other universities may build their Bioengineering programs around an expertise in bio-nanotechnology or biomaterials.

Considering the expertise of the faculty at SCU and the interest among our students who are coming from both engineering and the life sciences, we offer two specialization tracks, namely, Bioinstrumentation /Medical Device track, and Biomolecular/Pre-med track. We will also offer early morning, evening, and weekend classes for the MS Bioengineering curriculum. This will allow working professionals to keep their full-time jobs while still pursuing a graduate degree. This course scheduling choice is unique to SCU among many other graduate programs in Engineering and stands in contrast to other programs like the accelerated MS BME degree programs at USC and UC Berkeley which require one full-year of full-time study to complete, thus precluding the option of maintaining a full-time job while pursuing the MS degree. This

stark contrast between the proposed MS degree program at SCU and others in the local area will make SCU a superior and more amenable choice to many working professionals due to not only the simplicity of scheduling, but also to the convenient location in Silicon Valley.

EVIDENCE OF INTEREST

Document the level of interest in the program on the part of faculty, current and potential students, and other stakeholders. Are tenured and tenure¬track faculty sufficiently interested in the program to contribute their energy and offer its curriculum on a sustained and regular basis? Are current and potential students sufficiently interested in the program to maintain adequate enrollment in its classes? How have these levels of interest been ascertained?

Background

The School of Engineering strongly supports the creation of the bioengineering graduate degree. Since June 2009, the year that the Bioengineering undergraduate major was officially approved, we have witnessed rapid and unrelenting growth in undergraduate enrollment. Our undergraduate population has quadrupled from 34 in the 2008-2009 academic year to an estimated 136 at present. This extraordinary growth has brought enrollment numbers in the bioengineering undergraduate major to the same level seen in two other engineering majors (MECH and COEN) having their own departments that existed for many decades. The creation of a bioengineering graduate major is a timely move that will allow the department to meet an increasing and documented demand for both the undergraduate degree as well as the graduate degree.

The proposed Bioengineering graduate degree program is supported by the Faculty of Engineering and the Faculty of Arts and Sciences who had previously approved the undergraduate degree major in Bioengineering. The committee that proposed and approved the existing program was composed of five tenured faculty members -three department Chairs (Electrical Engineering, Mechanical Engineering and Biology), the Associate Dean for Undergraduate Engineering (Ruth

Davis), and the senior Associate Dean of the College of Arts and Sciences (Amy Shachter).

Support for the bioengineering graduate program was also provided by industry leaders and educational professionals (Carl Simpson, Paul Davison, Ron Schilling, Mike Helms, James Spudich and Thane Kreiner). In particular, Dr. Thane Kreiner, Executive Director and Howard and Alida Charney University Professor of Science and Technology for Social Benefit, Mr. Carl Simpson, the Director of Coronis Ventures, Dr. Mike Helms, the Director of Strategic Development at Stanford University School of Medicine, have reviewed this proposal and provided valuable suggestions.

Student Survey

To measure the level of interest in the proposed 5 year BS/MS program and predict future enrollment, we surveyed two groups of SCU students; this study included 24 freshmen/sophomores already enrolled in the undergraduate bioengineering degree program and 24 seniors/juniors on the cusp of graduating with a BS BIOE degree. The students were given a description of the course requirements for the proposed bioengineering graduate major and asked to rate their personal interest in the graduate major as Definitely Interested, Somewhat Interested, Maybe Interested, or Not Interested.

***Survey Question**: "The Bioengineering Program at SCU is planning for a five-year BS/MS degree program in bioengineering. How would you express your interest in such a program?"*

As expected, there was significant interest among both Freshmen /Sophomores and Seniors/Juniors surveyed, as indicated in Figure 1. In total, 44/66 students surveyed were interested in the BS/MS BIOE option, with interest expressed by junior and senior students falling short of that expressed by lower classmen and BMES club members. This result is easily understood in light of many of the Seniors' written comments, indicating that they are uninterested because it is simply too

late for them to take part in this program. Furthermore, 92% (22/24) of this year's freshman/sophomore group classified themselves as definitely or maybe interested in the program. A more telling view of this interest is revealed in the written comments of the students, included in Appendix C of this proposal.

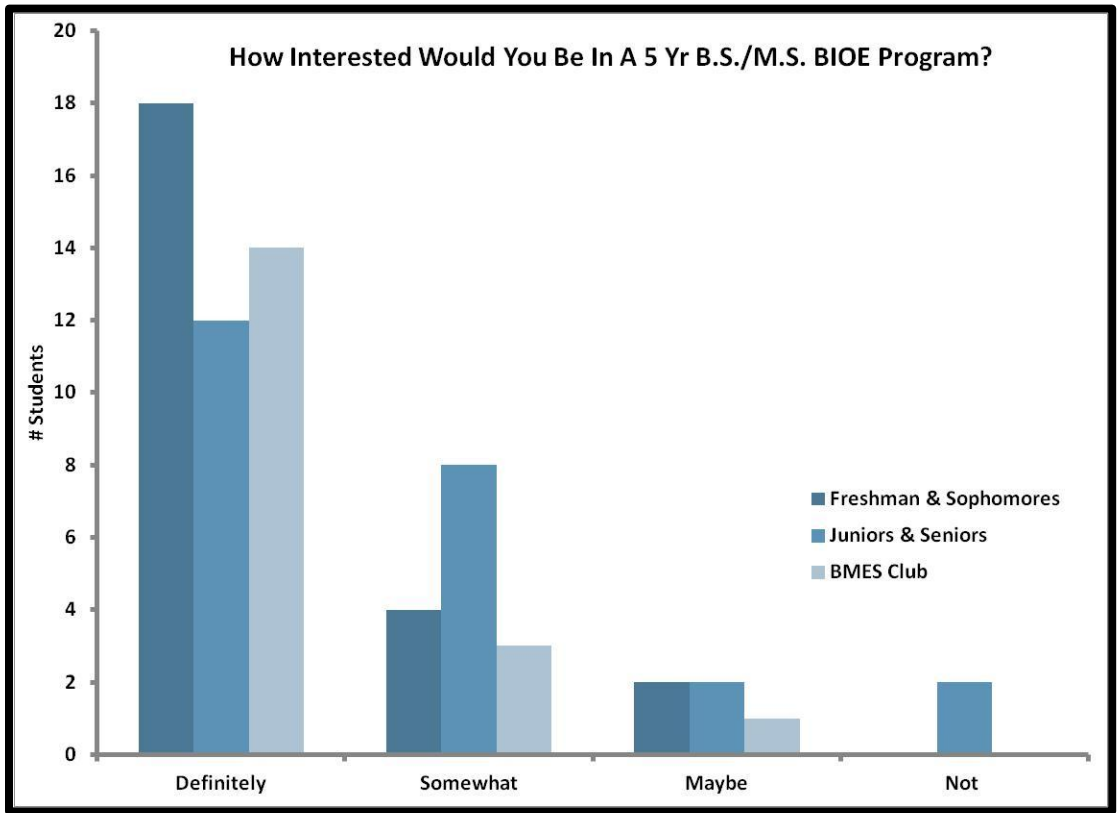

Figure 1: Undergraduate interest in MS Bioengineering degree program

Similar and Related Domestic Programs

Since the first bioengineering program was established at Duke University in 1967, many other programs have been established. According to the Whitaker Foundation[8], there are 118 bioengineering/biomedical engineering programs in the US. These programs are not typically derived from within science departments, but rather they grow out of shared research interests among

[8] Whitaker Foundation, www.whitaker.org.

engineering faculty, and most often involve strong faculty involvement from a medical school. Most frequently these programs are offered at the graduate level. Currently, ABET lists 73 accredited undergraduate programs in the US, and only 2 accredited graduate programs in bioengineering, neither of which are housed in universities known for influence in biomedical science[9]. US News and World Report ranks the top ten best graduate schools for bioengineering, one of which still does not offer a stand-alone undergraduate degree in bioengineering, and over half began as stand-alone graduate degree programs in bioengineering[10]. US News and World Report also lists the top ranking undergraduate degree programs in bioengineering; 9 of the top 10 schools on the undergraduate ranking are in the top ten on the graduate ranking[11]. This indicates the mutual benefit provided to each other by a graduate and undergraduate program in bioengineering.

UC system institutions including Berkeley, San Francisco, San Diego, and Davis offer Bioengineering, Biomedical Engineering or Biomolecular Engineering graduate programs with widely different areas of emphasis in specializations that reflect the expertise of their faculty and the availability of resources. Recently Cal-Poly has begun offering a hybrid BS/MS program in bioengineering. This development is noteworthy in light of Cal-Poly's reputation for being an undergraduate oriented institution, much like SCU. Their offering of a BS/MS program suggests the importance of this option to a quality undergraduate education.

For the present proposal it is also relevant that we compare the SCU bioengineering program with similar programs at Jesuit Universities. There are eight Jesuit Universities in the US that have an engineering school, two of which offer a bioengineering undergraduate degree program. Of the two (Georgetown and Marquette), Marquette offers a graduate degree in bioengineering; they also offer a hybrid BS/MS program like the one proposed in this document. Georgetown does not

[9] http://main.abet.org/aps/AccreditedProgramSearch.aspx/AccreditationSearch.aspx accessed 11-1-2011

[10] http://grad-schools.usnews.rankingsandreviews.com/best-graduate-schools/top-engineering-schools/biomedical-rankings accessed 11-1-2011

[11] http://colleges.usnews.rankingsandreviews.com/best-colleges/rankings/engineering-doctorate-biological-biomedical accessed 11-1-2011

offer a graduate degree in Bioengineering although they do offer a Biotechnology MS degree.

ENROLLMENT PROJECTION

Data from the Registrar's office show that the number of students following the Bioengineering bachelor's degree program from 2008 to present has increased from 27 to 118 (as of November 22, 2011. We note that the final number is actually higher as many freshmen and sophomores have not yet declared a major. An estimated enrollment based on ENGR 1 indicated an increase from 34 to 136). The Enrollment has been broken down into class status, as shown in Figure 2.

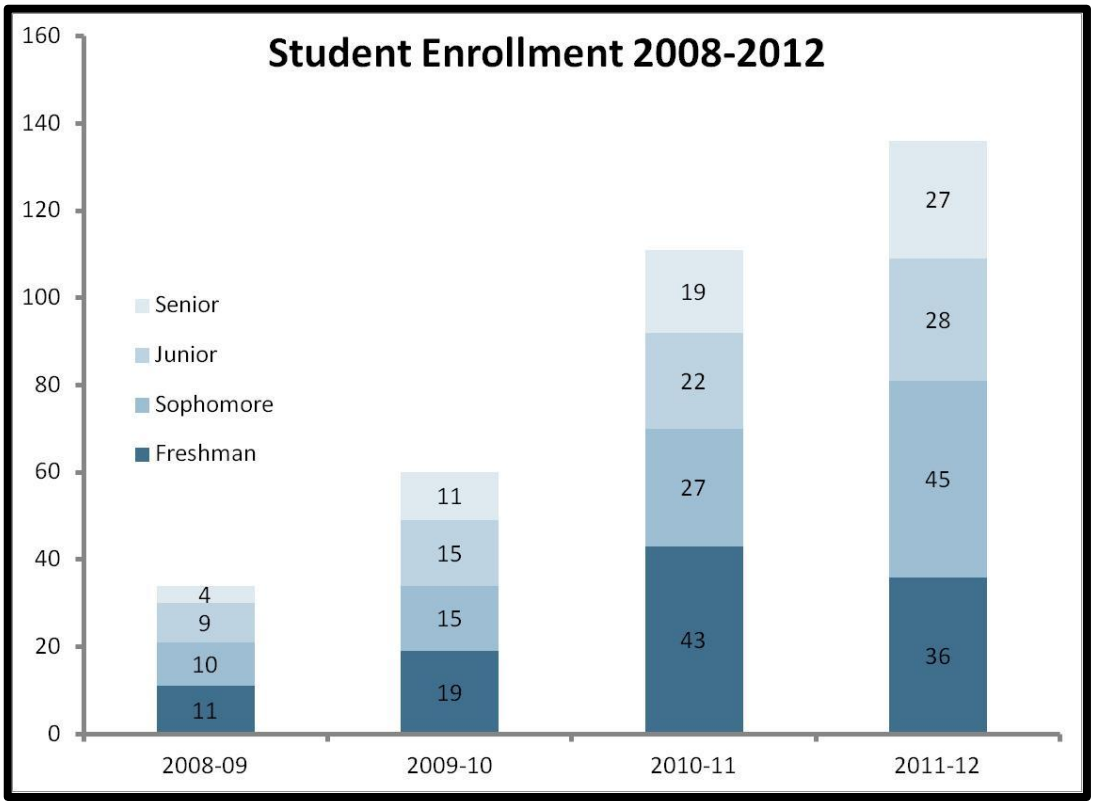

Figure 2: Student enrollment in the BS BIOE undergraduate program

Assuming that the M.S. in Bioengineering is approved by the Board of Trustees for implementation in the fall of 2012, we expect that a significant number of freshmen, sophomores, and juniors currently enrolled in the B.S. BIOE program will choose to enroll in the BS/MS

hybrid degree program. Based on an anticipated enrollment of 30 students (10 industry professionals, 5 international students, and 15 graduating seniors from SCU and other domestic universities) for the 2012-2013 academic year and assuming a modest annual increase in subsequent years, we arrived at the projection for student enrollment in the Bioengineering graduate program shown in Figure 3.

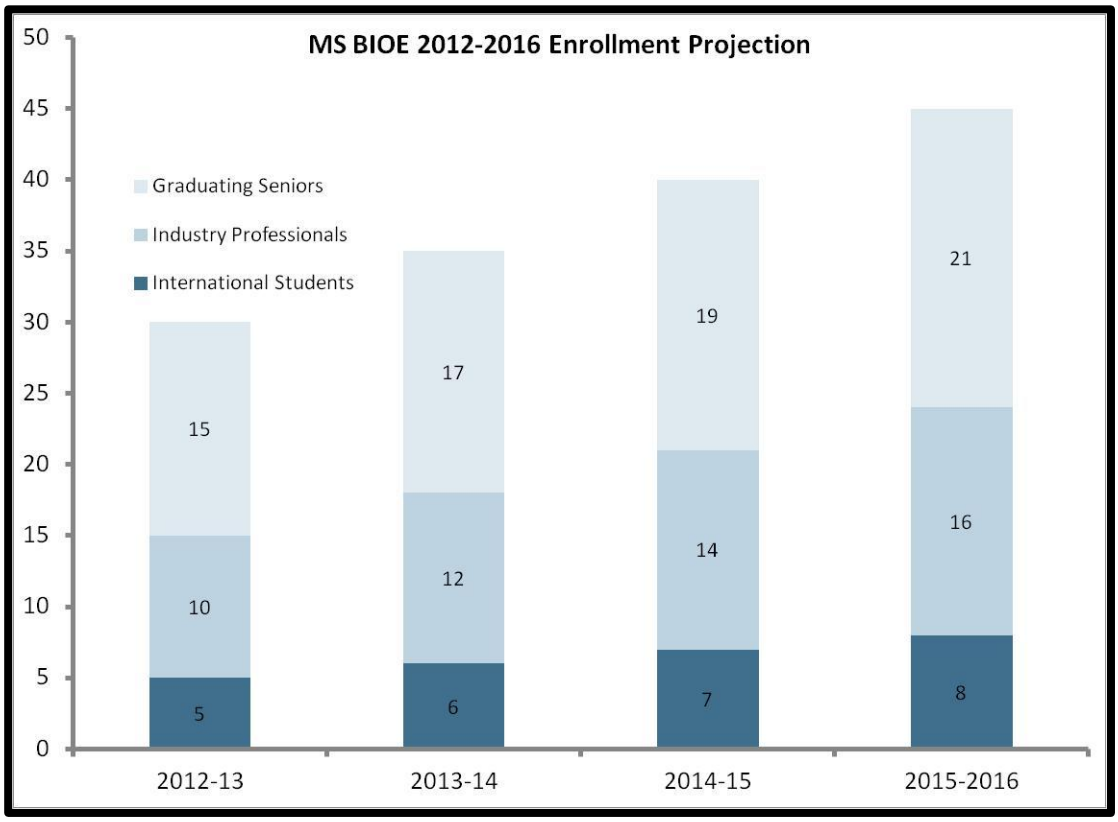

Figure 3: MS BIOE 2012-2016 Enrollment Projection

IMPACT ON OTHER PROGRAMS

Describe the anticipated impact of the proposed program on other academic programs and priorities. Will it require reassignment of current faculty or funds?

Do faculty involved already teach the classes on a regular basis? If not, do the chairs of the departments involved agree to reassign faculty members from other duties in order to participate? Are other programs likely to suffer systematic enrollment losses? Will other programs or services have to be discontinued to establish this program?

We expect that the number of students enrolled in the new graduate program will gradually increase over the first couple of years. This new option is not expected to significantly redistribute students within the School of Engineering, but we do expect that it will attract students who may not otherwise have chosen to matriculate at SCU, both from private industry as well as graduating high school seniors interested in the BS/MS option. The proposed Bioengineering major will help to stabilize overall enrollment in the School of Engineering, and in the long run should not have any adverse impact on other programs.

The new graduate bioengineering major is expected to enrich the course offerings available both to graduate and undergraduate students at SCU. With the creation of a graduate program and enrollment of graduate students within that program, it will be possible to offer a wider variety of courses which do not necessarily require current tenure-track faculty members to teach them. Instead, adjunct faculty members with exceptional expertise in their areas of specialty can teach these upper level courses. In fact, adjunct faculty members have already been identified, and some are already providing these course offerings to students enrolled in the undergraduate bioengineering degree program as well as students from Electrical Engineering, Engineering Management, and Mechanical Engineering. Some students in biology, mechanical engineering, or electrical engineering undergraduate programs may also choose to stay at SCU to pursue an advanced MS in Bioengineering.

Undergraduate students choosing to participate in the BS/MS program will have the option of continuing their undergraduate research participation for an additional year in the form of “Directed Research”, which may in fact cause some students to choose SCU over other universities without a 5-year BS/MS program. This option will also

make industry collaborations on these research projects more attractive to industry professionals as well as more productive, fostering increased strategic connections between SCU and the local biomedical industry. As those connections are multiplied and strengthened, the task of bringing industry on campus for career fairs will become easier. This will provide additional internship and job opportunities to bioengineering students as well as general engineering and bioscience students, raising SCU's reputation as a whole and further establishing SCU as a provider of an exceptionally high quality education.

The probability that the Bioengineering graduate major will draw large numbers of students from other programs, such as Mechanical Engineering and Electrical Engineering or Applied Mathematics is small. We fully expect that the five year BS/MS program in Bioengineering attract even more exceptional math- and science- minded high-school students to SCU. We spoke with some students and parents who attended the past SCU Open House events and indicated that they were concerned that the university did not have a formal program/department of Bioengineering, and some of them also inquired about a 5-year BS/MS option. The creation of a department of Bioengineering and the addition of a five year BS/MS degree program in bioengineering will further assuage concerns of similar minded prospective students and their parents. The effective marketing of biomedical technologies and biotechnology to the community, through a program like the Bioengineering MS degree, will improve the reputation of SCU in the community and that could reflect favorably on other programs at SCU. Students attracted to SCU because of the five year BS/MS Bioengineering major may subsequently switch their majors to or double major in Biochemistry, Biology, Biotechnology, Mechanical, or Electrical Engineering, or even to Business.

A Bioengineering graduate major is expected to positively impact undergraduate and graduate research programs at SCU. Students attracted to SCU by the Bioengineering undergraduate or/and graduate degree are likely a priori to be interested in bioengineering research. Because engaging students in research is a central tenet of the Engineering faculty, we are certain that these students will not only join

laboratories in Bioengineering, Electrical, and Mechanical Engineering, but their interest and experience will also alert them to research opportunities in biochemistry, biology and physics. The opportunities for these kinds of collaborations will further increase upon including a graduate degree program within the bioengineering major. Industry professionals who choose to pursue an MS degree at SCU will be able to serve as research mentors and colleagues to undergraduates. This will improve the depth, quality, and quantity of undergraduate research and research as a whole at SCU. Having more talented students interested in undergraduate and graduate research provides greater support for faculty scholarship and reinforces the research culture that is the foundation of our "Teacher scholar model". Many faculty members in Mechanical, Electrical, and Computer Engineering as well as those in Biology, Chemistry, and Physics conduct interdisciplinary research at the interface of Engineering, Physics, the Life Sciences and Medicine. Most of these research activities will also be of interest to Bioengineering graduate and undergraduate students, who will be able to make substantive contributions to the advancement of the field.

In turn, offering a graduate degree in Bioengineering will produce many more SCU graduates aspiring to pursue careers in industry and advanced research. As these students enter professional schools and industry, they become ambassadors advocating the high-quality SCU interdisciplinary education at the interface of Engineering and Bio-sciences. We have already seen how programs and employers try to recruit our engineering graduates. Having new majors graduating with a graduate degree in Bioengineering translates into having more ambassadors in a field new to SCU, improving the University's reputation.

RESOURCE REQUIREMENTS AND IMPLICATIONS

Include the checklist in Attachment B with the proposal and describe all relevant resource requirements and implications in the text. Based on these requirements,

as well as anticipated sources of revenue, present a five-year budget projection that accounts for both one-time and continuing expenses. Once the program is established, can it be adequately funded and supported with current resources or will additional increases in budgets be needed? This section should be developed in consultation with the University Finance Office, Facilities Planning and Projects (Facilities), Information Services (including Orradre Library, Media Services, and Information Technology), and any other relevant offices. Identify the people and offices consulted in formulating and verifying resource projections.

The current resource requirements for the proposed bioengineering graduate major are: one annual year (AY) lecturer, five term lecturers, and one part-time administrative assistant. Qualified lecturers for the proposed MS degree electives have already been identified.

Budget requested for the Bioengineering MS Degree Program:

Five term lecturers (each teaches 3 course units on average):
$1460 x 15 = **$21,900**
50% administrative assistant: $40,179/2+35% benefit = **$27,120**
One laboratory manager: $52,783 + 35% benefits = **$71,257**

Total: **$120,277**

While at the moment, we do not have urgent need for additional laboratory space as we have recently received funding (from Fletcher Jones Foundation and the School of Engineering) and established a Tissue Engineering Laboratory, a Molecular Bioengineering Laboratory, and a Bio-signals Laboratory. These labs are being used for several upper-division BIOE lab courses including BIOE 162-Biosignals, BIOE 171 Physiology & Anatomy for Engineers, BIOE 172-Tissue Engineering, BIOE 175 - Biomolecular Engineering, and BIOE 163- Biodevice Engineering.

A description of the five-year persistent programmatic needs for the new department of bioengineering and a MS degree program is included in Appendix D.

PROMISE OF QUALITY

Discuss the level of quality that can realistically be achieved with the resources available. Will the program enhance the academic stature of the college or school and the University? What indicators of program quality should we expect of the program within five years?

All required engineering courses enjoy continuous assessment, evaluation, and improvement as part of the WASC and ABET professional accreditation process. The quality of the overall curriculum is high because the selection of topics was influenced by respected Bioengineering programs at UC Berkeley, Stanford University, Duke University and other schools, yet reflects SCU's unique perspective on applying interdisciplinary knowledge to the benefit of humanity and within the greater social context.

The curriculum for the proposed Bioengineering graduate degree program consists of courses that are either already offered or planned to be offered in the 2012-2013 academic year.

ASSESSMENT PLAN

All students within the MS Bioengineering degree program will fulfill the expectations of the learning outcomes below. These will be assessed within each course offered in the curriculum.

Expected Learning Outcomes

Basic Knowledge:

1. In-depth knowledge of engineering principles, mathematics and computational methods;
2. In-depth, comprehensive knowledge of the human anatomy and physiology, hierarchy and organization of biological systems from molecules, cells, tissues to organs, and structure, function and regulation of genes and proteins;

3. Working knowledge of and extensive hands-on experience with bioengineering laboratory practices.

Inquiry/Problem Solving/Professional Development:

1. Ability to apply advanced mathematics, cutting edge computational techniques, science, and engineering to formulate and solve problems at the interface of engineering and biology;
2. Ability to make measurements on and interpret data from living systems, addressing the problems associated with the interaction between living and non-living materials and systems;
3. Understanding and profound awareness of professional and ethical responsibility, and contemporary issues as they apply to bioengineering;
4. In-depth understanding of the impact of bioengineering solutions in a global and social context;

TIMETABLE

Present a timetable for initiation and development of the program.

Introduction of Approved New Courses

Undergraduate Curriculum:

All of the upper-division bioengineering courses listed either as requirements or as electives in the undergraduate curriculum already exist in the catalog, although BIOE 163 (Bio-device Engineering), BIOE 172 &173 (Tissue Engineering I & II), and BIOE 175 &176 (Biomolecular Engineering I and II) are the most recent additions to the course catalog and are being offered in the Fall and Winter of 2011 or Spring of 2012.

Proposed Master's Degree Curriculum:

Some of the courses listed either as requirements or as electives in the proposed MS program curriculum already exist in the catalog under ENGR, MECH, or/and BIOE headings (ENGR 249, ENGR 250, MECH 254, ENGR 307/BIOE 107, ENGR 257/BIOE 157, ENGR 257/BIOE 174, BIOE 256, ELEN 642/BIOE 289), other new course additions are noted in the course listing on page 36.

Faculty Staffing

We are requesting approval of the proposed MS degree for the 2012-2013 academic year for the following reasons:

1. The Bioengineering MS curriculum is in place and key adjunct faculty are identified to offer the BS/MS degree option.
2. The strong interest in and demand for a MS degree program from present and prospective students will provide recruiting leverage for the School of Engineering and the University;

Since the curriculum for the proposed MS degree program is in place for 2012-13, rapid approval will have an immediate positive impact on the present applicant pool for the Class of 2012. The new BS/MS program could be advertised through the School of Engineering and admissions web sites in time to affect students' decisions. If approved before the Fall of 2012, current Bioengineering Seniors (a total of 28 including an exchange student from Sweden) will have an option to enroll in the new MS program.

LIST OF COURSES

List the course to be offered in the program, including which currently exist and which are new.

Upper division BIOE undergraduate courses eligible for graduate credit (if not claimed for BS credit):

BIOE 153 Biomaterials Science (4 units)
BIOE 154 Introduction to Biomechanics (4 units)
BIOE 155 Biological Transportation Phenomena
BIOE 157 Introduction to Biofuels Engineering (2 units)
BIOE 163 (L&L) Bio-device Engineering (5-unit)
BIOE 172 (L&L) Tissue Engineering I (5-units)
BIOE 173 Tissue Engineering II (4-units)
BIOE 175 (L&L) Biomolecular Engineering I (5-units)
BIOE 176 Biomolecular Engineering II (4-units)

(Max. 9 units of upper division BIOE classes are allowed to count towards the MS elective requirement)

Graduate Core: (6-units) *same as other Engineering majors*

Math Core Courses (6 units):

AMTH 201 & 202 or AMTH 210 & 211; and one additional 2-unit AMTH course

Required BIOE Courses: (9 units)

BIOE 270 Molecular and Cellular Bioengineering (4-units)
BIOE 270 L Molecular and Cellular Bioengineering Lab (1-unit)
BIOE 272 Fundamentals in Tissue Engineering (2-units)
BIOE 275 Physiology and Disease Biology (2-units)

Elective BIOE Courses: (24 units)

BIOE 200 Graduate Research Seminar (1 unit)
BIOE 207 Medical Device Invention: from ideas to business plan (2 units)
BIOE 249 Topics in Bioengineering (also ENGR 249) (2 units)
BIOE 250 Introduction to Bioinformatics and Sequence Analysis (2 units)
BIOE 254 Intro to Biomechanics (cross-listed with MECH 254) (4 units)
BIOE 256 Introduction to Nano-Bioengineering (2 units)
ENGR 257 Introduction to Biofuels (2 units)

BIOE 258 Synthetic Biology & Metabolic Engineering (2 units)
BIOE 266 Advanced Nano-Bioengineering (2 units)
BIOE 268 Biophotonics and Bioimaging (2 units)
BIOE 269 Stem Cell Bioengineering (2 units)
BIOE 274 Microfluidics for biomedical applications (also BIOE 174) (4 units)
BIOE 280 Special Topics in Bio-therapeutic Engineering (2 units)
BIOE 282 BioProcess Engineering (2-units)
BIOE 289 Medical Imaging (cross-listed with ELEN 642)
BIOE 297 Directed Research (<= 6 units)
BIOE 397 Master's thesis *research* (9 *units*)

LIST OF FACULTY

List the faculty who will be members of the program and what their responsibilities will be.

Bioengineering core faculty:

1. Yuling Yan, Associate Professor, Director of the Bioengineering Program
2. Zhiwen Jonathan Zhang, Associate Professor
3. Unyoung Kim, Assistant Professor
4. Prashanth Asuri, Assistant Professor

Bioengineering adjunct faculty:

5. Paul Cosingny, Senior Manager, Abbott Vascular
6. Paul Davison, VP for Research, Advanced Energy
7. Rajeev Kelkar, Term Lecturer, Med_Device
8. Gerardo Noriega, Managing Director of GVMED
9. Vidyodhaya Sundaram, Term Lecturer
10. Dan Zarraga, GenenTech Scientist

Affiliate Faculty and Advisors:

1. John Birmingham, Associate Professor, Chair of Physics Dept.

2. Steve Chiappari, Applied Mathematics
3. Jack Gilbert, Professor, Chair of Chemistry,
4. Tim Hight, Associate Professor, Mechanical Engineering
5. Margaret McLean, Senior Lecturer, Director of Bioethics and Associate Director, Ethics Center
6. Nam Ling, Professor, Computer Engineering
7. Craig Stephens, Professor, Biology
8. Sally Wood, Professor, Electrical Engineering
9. Aleksandar Zecevic, Professor, Electrical Engineering; Associate Dean of Engineering

Bioengineering Advisory Board:

1. Paul Davison, Vice President, Advanced Energy, Conmed/Linvatec
2. Michael K. Helms, Director of Strategic Research Development, Stanford University School of Medicine
3. Krzysztof Izdebski, Chairman, Pacific Voice and Speech Foundation
4. Thane Kreiner, Executive Director Howard and Alida Charney, University Professor of Science and Technology for Social Benefit
5. Ron Schilling, Mi3 Venture Partners
6. Carl Simpson, Director, Coronis Ventures
7. James A. Spudich, Douglass M. & Nola Leishman Professor of Cardiovascular Disease, Depts. of Biochemistry and Developmental Biology, Stanford University School of Medicine

All of the core and adjunct faculty will serve as instructors, advisors and/or research mentors for bioengineering graduate students. The core bioengineering faculty along with the adjunct/affiliated faculty members listed above will teach the required core and elective courses, and they will also organize bioengineering research seminars, supervise master's thesis work or directed research projects and facilitate students' professional developments.

There are a number of ongoing faculty research projects that bioengineering students will find engaging. Dr. Yan is an Associate

Professor, currently leading the Bioengineering program. Her current research focuses on basic and translational aspects of voice research (continuation of an NSF funded project during 2004-07) that include the development of new imaging modalities to study laryngeal dynamics and function with associated approaches for the analysis and modeling of voice production in normal and diseased conditions. She is also participating in a multi-PI project funded by NIH on the development of optical molecular switch probes and novel detection and analytical methods for applications in high-contrast, single molecule imaging in cells and tissues. Dr. Kim investigates the application of integrated microfluidic systems for multiple applications in diagnostics as well as experimental science. Dr. Asuri's research interests are interdisciplinary in nature, integrating tools and concepts from material science, cellular bioengineering, and stem cell biology, to engineer instructive cellular microenvironments that effectively instruct stem cell fate for applications in tissue engineering and regenerative medicine. Dr. Zhang is currently working on several NIH funded research projects spanning topics from protein engineering to drug discovery. Dr. Stephens is full Professor in the Biology Department, former Chair of the department (2005-08), and currently Director of the Public Health major. His research, which is funded by the NSF, focuses on microbial genomics and molecular biology. Dr. Birmingham is an Associate Professor in the Department of Physics. He studies neuromodulation and sensory feedback in an invertebrate motor control network using both physiological and computational approaches. Dr. Gilbert is Professor and Chair of Chemistry and has research interests in physical organic chemistry and synthetic methodology.

The Bioengineering graduate major represents the next critical step towards establishing truly comprehensive curricula that will significantly improve the quality and scope of interdisciplinary education at the interface of engineering, physical science, biology and chemistry at SCU.

APPENDIX A: CHECKLIST OF POSSIBLE RESOURCE REQUIREMENTS OR IMPLICATIONS

Does the proposed program change entail any of the following? Please check the appropriate box for each item below and include with proposal:

Yes	No	
	x	Increase, decrease, or reallocation of revenue from tuition or fees. *If yes, consult University Finance Office.*
	x	Increase, decrease, or reallocation of existing budgets. *If yes, consult University Finance Office.*
	x	Reassignment of endowment income or designated gift accounts. *If yes, consult University Finance Office.*
	x	Increase or decrease in faculty or staff positions or costs. *If yes, consult University Finance Office.*
	x	Financial impact on another University program or service, including but not limited to a requirement for increased support from that program or service. *If yes, consult affected program or service.*
	x	New or modified office, instructional, or support space. *If yes, consult Planning and Projects (Facilities).*
	x	Building modifications or infrastructure changes (examples: HVAC, increased power, telecommunications, deionized water, parking). *If yes, consult Planning and Projects (Facilities).*
	x	New environment requirements (examples: hazardous waste treatment, exhaust treatment, biological or radiological monitoring and reporting). *If yes, consult Planning and Projects (Facilities).*
	x	Increased physical plant operating expenses (examples: electricity, water, natural gas, waste water, custodial services, building maintenance). *If yes, consult Planning and Projects (Facilities).*
	x	New library or media services collections, programs, or services. *If yes, consult Library or Media Services.*
	x	Additional computer, network, or telecommunications equipment, capacity, or service. *If yes, consult Information Technology.*

APPENDIX B: STATEMENTS OF SUPPORT

1. Letter of support from Dean Mungal
2. Letter of support from Carl Simpson, advisory board member of the Bioengineering Program and entrepreneur and pioneer in the medical device industry.

Santa Clara University

January, 17th, 2012

Santa Clara University
Academic Affairs Committee

Dear Committee Members,

This letter is written in very strong support of the creation of a Bioengineering Department and the creation of a Master's Degree in Bioengineering within the School of Engineering. Our Bioengineering Program is currently housed under Electrical Engineering, but has clearly now outgrown its host.

The Bioengineering field appeals to a new generation of students attracted by the life-changing developments and new career opportunities emerging from research at the interface of engineering, biology and medicine. Bioengineering addresses the growing needs of an aging population, quality of life issues, and touches upon the ethics of life and living. Bioengineering has also promoted increased interdisciplinary work between the College of Arts & Sciences and the School of Engineering. SCU's Jesuit values have played an important role in the execution of our program to date.

I am quite confident that the proposed expansion of the current curriculum will lead to further improvement of this rapidly growing program in terms of the quality of interdisciplinary education and for opening up diverse and meaningful careers in this fast growing field for our undergraduates and graduate students. It should be noted that, as a focus of biotech and biomedical technology, the Bay Area has approximately 800 Biotech/BioEng companies employing over 85,000 workers. Additionally, there are over 4,000 FDA registered medical companies in California, which are several folds ahead of other states.

The proposal lists the advantages and feasibility of creating a Department of Bioengineering and the benefit of offering a Master's degree program in Bioengineering, but I will also review some compelling points here:

1. Since 2008, the number of Bioengineering (BIOE) undergraduate students at SCU has quadrupled from 34 to 136. Bioengineering is outgrowing Electrical Engineering now, and has comparable student enrollment statistics as other engineering majors at SCU.
2. Bioengineering has achieved a critical mass of student enrollment within just 3 years of its launch, a rate of growth that is unparalleled at SCU. The students in this rapidly expanding and exciting area of engineering need a formal home department.
3. Establishing a Department of Bioengineering would facilitate further and sustained growth and allow the program to compete better with other Bioengineering programs in the Bay Area. Sustaining the growth of Bioengineering through formation of a department will help the School of Engineering meet its goal of 15% of all undergraduate enrolment at SCU.

School of Engineering, Office of the Dean
500 El Camino Real, Santa Clara, California 95053-0590
408-554-4600 FAX 408-554-5474 http://www.scu.edu/engineering

4. A formal Department of Bioengineering will also help to build long-term relationships with local companies and improve both internship and job prospects for Bioengineering students.
5. Survey data suggests there is strong demand from our Bioengineering students for a 5-year BS/MS degree program.
6. Likewise, many professionals from local industry have indicated a desire to supplement their current education training with specialized knowledge in the field of Bioengineering. This demand can be seen from applications for a space for a professional Master's degree in Bioengineering offered by UCB/UCSF, which attracts some 300 applicants for about 20 positions.
7. Housing a graduate program in a formal department of Bioengineering will likely improve the chance for securing external funding/training grants from Federal agencies. A graduate program in Bioengineering will also complement faculty research efforts, as students can contribute to and expand the breadth of funded research.

I believe that this proposal is timely, building upon the rapid success of our current Bioengineering Program, and will produce a rich core of Bioengineers who will engage the field in a unique way, marked by our values of competence, conscience and compassion, while being prepared to address the ethical issues the field now faces, and will continue to face, as new technological advances emerge.

This proposal has my full support and I look forward to the success of its graduates and the increased collaboration among faculty across the campus.

Please do not hesitate to contact me if any additional information is required.

Sincerely,

Godfrey Mungal
Dean of Engineering
Sobrato Professor of Engineering

January 22, 2012

I am writing this letter in support of a Master's Degree in Bioengineering and as a separate department in the School of Engineering.

I am a graduate of SCU with a Masters in Electrical Engineering and an MBA. I combined this graduate education and a strong undergraduate background in the biological and medical sciences to self educate as a Biomedical Engineer. I am currently on the SCU School of Engineering Industry Advisory Board and an advisor to the BIOE program.

I was part of a team of founders to start the first medical device company in late 1970's in Silicon Valley. Advanced Cardiovascular Systems was one of the first companies in the world to develop therapeutic devices for treating coronary artery disease…the technology was termed Coronary Angioplasty. The success of ACS spawned the medical device business in the valley. I am currently a medical device entrepreneur with experience in helping develop over 25 companies in this field.

The medical device business in the valley is the perfect marriage of investment capital, advanced educational systems and an extensive infrastructure of well educated employees. The development of new medical technologies requires a futuristic thinking of how to solve imposing disease states. It has to operate in the forefronts of discovery and research to bring new therapies to our patients, practicing physicians and medical personal.

In the early 1980's the field of Bioengineering was in a state of infancy and hiring such trained employees was out of the question. To build a medical device business we needed to hire people with varied engineering skills and medical backgrounds and train them to develop the necessary skills. Now the valley is rich with such skills, solving medical challenges with the infrastructure to bring new medical therapies to the world.

The medical device business and the biotech business have its largest concentration in the world in the Bay Area. Because of this success, the need to train future employees has grown even further to learn sophisticated engineering and medical knowledge to meet the growth and maintain our competitive edge solving clinical needs throughout the world.

The local Universities are the key to solving some of these issues of knowledge and growth. When I received my Masters in Engineering and an MBA from SCU I was a full time employee in the valley. These programs centered on mornings and evenings, where necessary to maintain a full time job and expand my education. As we all know high technology education is a requirement of maintaining a competitive position in our fields.

While at ACS I advised and wrote letters of recommendation to 100's of employees to enhance their education at Santa Clara in engineering and business. The University does certainly see the value of their graduate educational programs to employees of the valley. With this rapid development of the Biotech business in the valley the expansion of BIOE into a graduate and a separate department is the next step to provide the educational tools this industry needs to be a continual leader in the world.

It is with this background in the medical device business and my association with SCU that I give my full support for developing and enhancing these programs. An education in the medical engineering and sciences requires increased and full collaboration among the faculty across the campus.

Please do not hesitate to contact me if any additional information is required.

Sincerely,

Carl Simpson

Medical Device Entrepreneur

APPENDIX C: STUDENT SURVEY COMMENTS

Freshmen & Sophomores

A 5-year master degree program is something I would seriously consider.

I was already planning on getting a MS for BIOE so to do it all here at SCU in 5-years would be great.

It would be nice to have the option to a 5-year masters program!

I am currently a freshman and if this gets approved in time, I would be interested in joining this program

However, I'm going to be a junior next year, but I feel like this would be a wonderful opportunity for future classes!

Although I am a sophomore and will not be able to do this, I think it would be a very good option to have. It would help graduating students to get better jobs. If I have the time and enough classes, I would like to do this.

Will this year's freshmen (class of 2014) be able to do this?

I think a 5 yr program would be great, but it would have to start in the next two years in order for me to participate, as I am currently a sophomore.

I am seriously considering this. Would it be worth staying an extra year?

This seems appealing and it would be very nice to have the option available, but since I am a freshman, I am still unaware as to what direction I want to go in the field - still possibly thinking pre-med?

The program would be very tempting, but currently I am more interested in pursuing a graduate degree at another university for a change of pace and scenery.

Would like to see a wider range of classes & topics to allow for greater specialization.

Juniors & Seniors

I think it's a great idea and if I would be able to do this as a junior I probably would.

I would greatly consider participating in this program if given the chance.

I think this would be a great opportunity for the bioengineers at this school. It would help with job opportunities.

I think it would greatly benefit all BIOE students & would interest all.

Hopefully more courses are offered through that are directly related to BIOE.

Depends how the program changes with the addition of the master program.

With such a competitive job market, this is a good idea for students to sharpen their skills and move toward their goals with a bit more time than usual.

I am definitely interested. I need to take a year or two off before I go to medical school, so it would be great for me. However…I can't pay for it. If I could also be a TA (which I think I'd be great at) to pay for my grad school education, I think I can say for sure that I'd do it. Please contact me if you have any additional info. Also, I have extra space in my schedule, so I can possibly finish in less than one year. Let me know!!

Unfortunately, I am not that interested in my major so I do not plan on going to grad school for it. A 5-year master degree would probably be a great addition to our school though.

I think a 5-year program would be great however I would only want to do it if the program is well thought out and solid.

Since it does not apply to me, it's hard to be certain of my feelings towards the idea. I think it would be a good addition, however, to the program.

Already have other plans. Sounds like a good idea though.

BMES Members

I'm looking forward to it. When can we start the program? Please let us know.

I'm planning for a Ph.D., so I'd need to go somewhere else.

Would you be able to enroll in the program as a junior or senior?

APPENDIX D: PERSISTENT PROGRAMMATIC NEEDS FOR DEPARTMENT OF BIOENGINEERING

Based on recent course schedules, faculty appointment policies implementation, faculty workload document, senior project policies, research units policies.

BIOE courses offered in a year:

Undergraduate

Assumption: a 4 or 5 unit lecture course = 1 course; a lab with TA = 0.25 course; a course section = 1 course; senior design project instruction: 1.5 course, and senior design projects per team = 0.25 course.
Total undergraduate courses = 26 courses (includes 12 lab sections = 3 courses with TAs).
Projected assuming a cautious course growth rate of about 50% in near future ~= 39 courses.

Graduate (Program at planning stage and with an anticipated start in the Fall of 2012)

Assumption: a 4-unit course = 1 course; a 2-unit course = 0.67 course; 24 units of research = 1 course; independent study = 0 course.
Projected graduate courses and advising (with enrollment of 30 in 2012) = 20 courses
Projected total enrollment of 50 in 2014: 25 courses

Summary (yearly)

Total BIOE courses (2011-12) 26 courses.
Projected total BIOE courses = 39 undergraduate courses + 25 graduate courses (from Fall 2012)

Persistent Programmatic Needs (Yearly) based on SCU Faculty Appointment Policies Implementation

Step 1:
Total tenure-track faculty (including F/T and P/T administrators) = 4 (From Fall 2011)
Step 2:
Number of undergraduate courses or course sections needed on a continuous basis = 39 – (6 x 4) = 15 course sections.
Step 3:

These courses are BIOE courses which are required as core and electives to maintain program quality for our undergrad and the new graduate (MS) program in planning.
Persistent programmatic needs = 64 course sections.
Step 4:
The current need (undergraduate program only) is met by:
4X Quarterly (fixed-term, part-time) Adjunct Lecturers (each teaches 1 to 4 courses).

Plan (tentative) for near future to meet BIOE persistent programmatic needs:

1 x Tenure-track faculty (6 courses); and
1 x Lecturer (renewable-term) (teaches 7 courses);
8 x Quarterly (fixed-term, part-time) lecturers (each teaches 3 course units on average)