Proposal for the Initiation of a New Instructional Program Leading to an MS, MEng, PhD Degree in Bioengineering
Oregon State University
College of Engineering
School of Chemical, Biological and Environmental Engineering
CPS Proposal #92511
February 2015

1. Program Description

a. Proposed Classification of Instructional Programs (CIP) number.

CIP #: 14.0501

Title: Bioengineering and Biomedical Engineering

Definition: A program that prepares individuals to apply mathematical and scientific principles to the design, development and operational evaluation of biomedical and health systems and products such as integrated biomedical systems, instrumentation, medical information systems, artificial organs and prostheses, and health management and care delivery systems.

Source: US Department of Education, National Center for Educational Statistics, CIP 2010 ed.

b. Brief overview (1-2 paragraphs) of the proposed program, including its disciplinary foundations and connections; program objectives; programmatic focus; degree, certificate, minor, and concentrations offered.

Bioengineering is an interdisciplinary field that applies engineering principles and quantitative methods to the advancement of knowledge at the molecular, cellular, tissue, organ, and system levels, and to the development of new biologicals, materials, devices, and processes. While OSU offers a BS degree in Bioengineering and has significant bioengineering research activity, graduate level training in bioengineering is not currently available. We propose the creation of a new interdisciplinary graduate program in Bioengineering. Degrees to be offered include Masters of Science (MS), Masters of Engineering (MEng), and Doctor of Philosophy (PhD). A graduate minor in Bioengineering will not be offered. The program will be administered within the School of Chemical, Biological, and Environmental Engineering and the College of Engineering. Participating faculty outside of the College will be able to serve as mentors/advisors for graduate students. The main objective is to provide students with graduate training in bioengineering, including broad exposure to the discipline through coursework, seminars, as well as a focused research experience. The program will provide students with resources and faculty expertise to conduct advanced studies in the core areas of biomaterials, biomedical devices and instrumentation, human performance engineering, medical imaging, and systems and computational biology.

Table 1. Proposal Summary

NEW: Graduate Degree Program

Program Title:
Bioengineering

- *Degree Types:* **Master of Science (MS), Master of Engineering (MEng), and Doctorate of Philosophy (PhD)**
- *Program Type:* **Graduate**
- *Academic Home:* [No Change]
  School of Chemical, Biological, and Environmental Engineering
  College of Engineering
- Contacts:
  - **Jim Sweeney (7-6799); Jim.Sweeney@oregonstate.edu**
  - **Adam Higgins (7-6245); adam.higgins@oregonstate.edu**
  - **Joseph McGuire (7-6306); joseph.mcguire@oregonstate.edu**
- Options:
  - Undergraduate Options: **NA**
  - Graduate Options: **None**
- Graduate Areas of Concentration: **Biomaterials; Biomedical Devices and Instrumentation; Human Performance Engineering; Medical Imaging; Systems and Computational Biology**
- Minors:
  - Undergraduate Minors: **NA**
  - Graduate Minors: A graduate minor in Bioengineering will not be offered
- CPS #: **92511**
  https://secure.oregonstate.edu/ap/cps/proposals/view/92511
- CIP #: **14.0501 (Same as the existing undergraduate BS degree program)**
- SIS #: **XXXX – (To be assigned by the Registrar's Office)**
- College Code: **16**
- Course Designator: **BIOE** (existing)
- Courses: **Five (5) New courses to be developed**
- Program Total Credit Hours: **MS, MEng (45 minimum); PhD (108 minimum)**
- Delivery Mode and Locations: **On-Campus (Face-to Face) OSU-Main**
- Enrollment (Anticipated): **10-20 students per year**
- Graduates (Anticipated): **10-20 students per year**
- Accreditation: **None**
- Certification: **None**
- Program Uniqueness: **Yes**
  - Oregon University System: **Yes**
  - State of Oregon: **Yes**
- Final Approval by: **Higher Education Coordinating Commission**
- Proposed Effective Term: **Fall Term 2016 (Banner: 201601)**
- 5-Year Follow-Up Review: **AY 2021-22**

c. Course of study – proposed curriculum, including course numbers, titles, and credit hours.

Students enrolled in the MEng and MS degree programs will complete at least 45 graduate credits. For students in the MS program 12 of those credits must be thesis credits (BIOE 503). Students enrolled in the PhD program will complete at least 108 graduate credits. At least 36 of those credits must be non-blanket coursework, and at least 36 must be thesis credits (BIOE 603).

Students in all Bioengineering graduate programs (MEng, MS and PhD) will be required to complete the program core curriculum for a total of 15 credits (Table 2). The remaining credits required for completion of the degree program will be electives, and may include courses in science, mathematics, engineering or other topics (e.g., entrepreneurship). An abundance of courses are currently offered at OSU that could fulfill the elective requirements, including several courses related to bioengineering offered within the College of Engineering (COE) (Table 3). In addition, the College of Veterinary Medicine recently initiated a new graduate program in Comparative Health Sciences, which will include various course offerings that could serve as electives for Bioengineering graduate students. These include existing courses in Animal Models (VMB 521) and Molecular Tools (VMB 671), as well as new courses in Bioinformatics, Epidemiology, Genomics and Immunology. We have also initiated discussions with representatives from Veterinary Medicine about the possibility of creating a new course to provide hands-on training for working with animals in biomedical research.

All students will submit a program of study during their first quarter in the program specifying the elective courses they plan to take to complete their degree requirements. Programs of study will be reviewed by a committee of BIOE program faculty to ensure that the program has sufficient breadth and depth in the context of the student's planned research activities.

Table 2. Core courses

I. Physiology for Engineers – BIOE 5## (4 credits) Integration of engineering principles and human physiology in the following areas: mechanics of the musculoskeletal system; transport phenomena in the pulmonary, cardiovascular, renal and gastrointestinal systems; bioelectricity in the nervous system. II. Cellular and Molecular Bioengineering - BIOE 5## (3 credits) Fundamentals of mammalian cell biology, with an emphasis on biomedical applications and engineering approaches to study and manipulate cells. III. Bioengineering Analysis – BIOE 5## (3 credits) Fundamentals of mathematical modeling of biomedical systems. IV. Drug and Medical Device Regulations in Technology Development – BIOE 5## (2 credits) Advanced study of regulation of pharmaceutical products and medical devices by the Food and Drug Administration, including requirements for drug and device approval, current good manufacturing practices, current good laboratory practices, quality control and assurance, and compliance. V. Bioengineering Seminar – BIOE 507 (1 credit per term, total of 3 credits required) Current topics in bioengineering research, including ethics and issues related to commercialization of biomedical technologies.

The four core courses denoted as BIOE 5## will be developed and delivered as new graduate standalone courses. The Bioengineering Analysis course will be entirely new, but the remaining core courses will build on existing course offerings in the BIOE undergraduate program. Physiology for Engineers will leverage material from BIOE 340 (Biomedical Engineering Principles), Cellular and Molecular Bioengineering will leverage material from BIOE 459/559 (Cell Engineering), and Drug and Medical Device Regulations in Technology Development will leverage material from BIO 470/570 (Regulation of Drugs and Medical Devices). After creation of the 500 level graduate standalone courses, the corresponding 500 level components of the 400/500 slash courses will be eliminated.

Table 3. Existing courses within COE related to bioengineering.

BIOE 520. Social Justice, Ethics and Engineering (3)
BIOE 551. Biomaterials and Biointerfaces (3)
BIOE 557. Bioreactors I (3)
BIOE 562. Bioseparations (3)
BIOE 599. Special Topics: Bioconjugation (3)
BIOE 599. Special Topics: Surface analysis (3)
CE 590. Selected Topics in Transportation Engineering: Driving Simulator (3)
CHE 581. Selected Topics: Microreactor Engineering (3)
CS 519. Topics in Computer Science: Algorithms for Computational Molecular Biology (3)
CS 584. Human Factors Programming Languages (4)
ECE 573. Microcontroller System Design (4)
IE 545. Human Factors Engineering (4)
IE 546. Human-Machine Systems Engineering (3)
IE 548. Cognitive Engineering (3)
ME 513. Bio-Inspired Design (4)
MFGE 531. Meso-Scale Manufacturing (3)
NE/RHP/MP 536. Advanced Radiation Detection and Measurement (4)
NE/RHP/MP 535. Radiation Shielding and External Dosimetry (4)
NE/RHP/MP 537. Digital Radiation Measurement and Spectroscopy (3)
ROB 599. Special Topics: Human Control Systems (4)

d. Manner in which the program will be delivered, including program location (if offered outside of the main campus), course scheduling, and the use of technology (for both on-campus and off-campus delivery).

The program will be delivered on the OSU campus. There are no immediate plans for off campus instruction. However, we will explore the possibility of working with OHSU and nearby hospitals (e.g., Good Samaritan) for delivery of clinical instruction.

e. Ways in which the program will seek to assure quality, access, and diversity.

The program will be reviewed by the Graduate School five years after initial approval and every 10 years thereafter, in a manner consistent with the Guidelines for Review of Graduate Programs published by the OSU Graduate Council.

The program will seek to recruit students nationally and internationally. The program will be advertised through traditional channels such as brochures, mailing and our

website. Underrepresented students will be encouraged to apply for admission in all recruiting materials and efforts are made to provide financial aid to all qualified underrepresented students. Mailing lists from the McNair Scholars Directory, the California Forums for Diversity in Graduate Education, the Society for the Advancement of Chicano and Native American Students and other appropriate sources will be used to advertise the degree offerings.

Graduate admission requirements are a B.S. or B.A. degree in engineering or science, and an undergraduate grade point average (GPA) of 3.00 (on a 4-point scale) for the last graded 90 quarter or 60 semester credit hours. The minimum GRE score is 1100 (combined verbal and quantitative). For international students, the minimum TOEFL score is 580 (or iBT of 18 on each section). GRE exams are required for all applicants except those with degrees from the College of Engineering at OSU.

f. Anticipated fall term headcount and FTE enrollment over each of the next five years.

We anticipate a relatively small cohort of students to enroll in the Bioengineering graduate program in the Fall of 2016 because comprehensive recruiting efforts will not begin until the following academic year. Some of the students in this first cohort may elect to switch into the Bioengineering graduate program from other engineering programs at OSU (e.g., Chemical Engineering, Mechanical Engineering, etc). Overall, we anticipate 5 students in each program (MEng, MS and PhD) in this first cohort.

As a result of more comprehensive recruiting efforts, we expect an increase in the size of the second cohort enrolling in the Fall of 2017. Thereafter, we expect to enroll approximately 8 new students per program (MEng, MS and PhD) each year for the next 5 years+. Based on historical data in the Chemical Engineering graduate program we also expect about half of MS graduate to remain for completion of a PhD. These headcount enrollment projections are detailed in Table 4 (relatively few students are expected to enroll at less than full-time, so headcount and FTE are expected to be about the same)[1].

Table 4. Anticipated enrollment and degrees produced from 2016 to 2022.

Year (fall term)	2016	2017	2018	2019	2020	2021	2022
Students Entering Program							
MEng	5	8	8	8	8	8	8
MS	5	8	8	8	8	8	8
PhD	5	8	8	10.5	12	12	12
Total Enrollment							
MEng	5	13	16	16	16	16	16
MS	5	13	16	16	16	16	16
PhD	5	13	21	31.5	45	47	48
Graduates							
MEng	0	0	5	8	8	8	8
MS	0	0	5	8	8	8	8
PhD	0	0	0	0	0	5	8

[1] Assumes initial cohort enrollments as described above (5 into each program in 1st year), then 8 into each program as direct admits each year, and that half of MS graduates (once these start to occur) will then pursue the PhD degree.

Note that we have assumed a negligible effect of attrition on enrollment numbers. This assumption is based on data from the Chemical Engineering graduate program, which has an attrition rate over recent years of only ~2%.

g. Expected degrees/certificates produced over the next five years.

The anticipated number of degrees produced over the next several years is summarized in Table 4. On average, about 2 years are required for completion of an MS degree and 5 years are required for a PhD (based upon observed trends in similar OSU degree programs, especially ChemE). In the first 5 years after initiation of the BIOE graduate program, we expect to award about 29 MS degrees, 29 MEng degrees and 5 PhD degrees. In the long term (2023 and beyond), we expect that about 8 students from each Master's level program (MEng, MS) will graduate every year, and that annual PhD program graduates will grow to about 12 per year[2].

h. Characteristics of students to be served (resident/nonresident/international; traditional/nontraditional; full-time/part-time; etc.)

The students to be served are primarily expected to be full-time, traditional students. It is expected that the student population will be about 75% US and 25% international, although the mix will depend heavily upon the INTO enrollment.

i. Adequacy and quality of faculty delivering the program.

Over a period of several years there has been increasing involvement in bioengineering research among a number of OSU engineering faculty whose earlier research had been mainly focused on applications outside of biology and medicine. A large number of faculty are now working in interdisciplinary teams as well as independently on funded bioengineering projects (a sample of these are listed in Appendix 1). They also have a number of proposals currently pending, with the largest among these having been jointly prepared by multiple program faculty, describing inter-departmental and inter-institutional bioengineering research. In Fall 2013 these faculty were joined by eight new faculty hires in the College of Engineering, all with expertise and interests in bioengineering. Currently, there are over 30 faculty members in the College, as well as several in other schools and colleges across campus, who have expressed interest in participating in the BIOE graduate program. Altogether, current faculty expertise is enabling advanced studies in the core areas of biomaterials, biomedical devices and instrumentation, human performance engineering, medical imaging, and systems and computational biology, as described below. These areas of concentration will not be transcript visible.

[2] Assumes enrollment trends described above; and the MEng and MS students take 2 years to graduate, direct PhD admits take 5 years, and MS graduates entering the PhD program take 3 additional years beyond the MS.

Biomaterials

Focus areas: bioactive and biocompatible surface coatings, advanced surface analysis, mechanical properties of solids and complex fluids, implant biocompatibility and biomechanics, nanomaterials

Participating faculty: Jay Kruzic (MIME), Brian Bay (MIME), John Parmigiani (MIME), Liney Arnadottir (CBEE), Joe Baio (CBEE), Greg Herman (CBEE), Joe McGuire (CBEE), Skip Rochefort (CBEE), Karl Schilke (CBEE), Travis Walker (CBEE), Stacey Harper (CBEE)

Biomedical Devices and Instrumentation

Focus areas: biosensors, microfluidics, biomedical device design and manufacturing, biological signal processing, medical robotics, point of care diagnostics

Participating faculty: Alan Wang (EECS), John Conley (EECS), Pallavi Dhagat (EECS), Larry Cheng (EECS), Mario Magana (EECS), Patrick Chiang (EECS), Cindy Grimm (MIME), Kendra Sharp (MIME), Sundar Atre (MIME), Brian Paul (MIME), Bill Smart (MIME), Vinod Narayanan (MIME), Ravi Balasubramanian (MIME), Jonathan Hurst (MIME), Adam Higgins (CBEE), Goran Jovanovic (CBEE), Elain Fu (CBEE)

Human Performance Engineering

Focus areas: rehabilitation engineering, design of accessible transportation systems, minimizing human error in health care delivery, biomechanics, ergonomics

Participating faculty: Ken Funk (MIME), Javier Calvo-Amodio (MIME), Chin Eseonu (MIME), Katherine Hunter Zaworski (CCE), David Hurwitz (CCE), Mike Pavol (College of Public Health and Human Sciences), Sam Logan (College of Public Health and Human Sciences), Marc Norcross (College of Public Health and Human Sciences), Laurel Kincl (College of Public Health and Human Sciences)

Medical Imaging

Focus areas: development of advanced radiation detectors, Monte Carlo modeling of radiation dose

Participating faculty: Krystina Tack (NERHP), Abi Farsoni (NERHP), Todd Palmer (NERHP), David Hamby (NERHP)

Systems and Computational Biology

Focus areas: biological systems modeling, immune system modeling, gene regulation and modeling of gene regulatory networks

Participating faculty: David Hendrix (EECS/BB), Steven Ramsey (EECS/CVM), Mario Magaña (EECS), Molly Megraw (BPP/EECS), Thomas Sharpton (MB/ST), Andriy Morgun (Pharmacy)

j. Faculty resources – full-time, part-time, adjunct.

Consistent with other interdisciplinary programs, participating faculty will represent several disciplines and will be primarily tenure-track/tenured appointments with significant assignments to research and scholarship (see Appendix 1). Several faculty

members from different schools within the College of Engineering, as well as outside the college, have expressed interest in participating in the program by mentoring graduate students.

The graduate program will be managed by a director and a committee representing faculty in multiple units within the College of Engineering, as well as outside of the College as necessary. The director and committee members will contribute to management of the graduate programs as a part of the "Service" requirement of their position description.

k. Other staff.

The graduate program will be administered in the School of Chemical, Biological and Environmental Engineering using existing support staff.

l. Facilities, library, and other resources.

The resources necessary for delivery of the interdisciplinary graduate program in Bioengineering at OSU are already in place within the participating units, including classrooms, seminar rooms, computer facilities, research laboratories and graduate student offices. No changes in the needed library resources or library use are required.

m. Anticipated start date.

September 15th, 2016.

2. Relationship to Mission and Goals

a. Manner in which the proposed program supports the institution's mission and goals for access; student learning; research, and/or scholarly work; and service.

The proposed Bioengineering graduate program will support OSU's mission and goals through education, research and service by providing graduates with interdisciplinary training in bioengineering. The proposed program will create an organizational infrastructure to facilitate development of a community of students and faculty across bioengineering and other life sciences units on campus. It will be complementary to existing graduate programs focusing on health sciences, molecular/cellular biology, pharmacy and other bioscience-based fields, and is expected to synergistically bolster these programs through enhanced interdisciplinary collaboration. The addition of this Bioengineering graduate program will facilitate growth of bioscience-based industries in Oregon and support OSU's commitment to improve human health and well-being.

b. Connection of the proposed program to the institution's strategic priorities and signature areas of focus.

Phase II of OSU's strategic plan (http://oregonstate.edu/leadership/strategic- plan) seeks to advance three signature areas of distinction: Advancing the Science of Sustainable Earth Ecosystems; Improving Human Health and Wellness; and Promoting Economic Growth and Social Progress. As stated in the plan, improving human health and wellness depends on "building more holistic and interdisciplinary approaches to healthy aging, chronic infectious disease control, new drug development, mental health, and disease prevention to enhance the human lifespan, decrease health care costs, and maintain a healthy population." The proposed bioengineering graduate program

strongly aligns with this signature area of distinction. In addition, we expect that creation of this new graduate program will lead to growth of bioscience-based industries in Oregon through development of new technologies and strengthening of the bioengineering workforce. The proposed graduate program in Bioengineering also directly aligns with the final signature area of distinction, "Promoting Economic Growth and Social Progress."

c. Manner in which the proposed program contributes to Oregon University System goals for access; quality learning; knowledge creation and innovation; and economic and cultural support of Oregon and its communities.

See need section below

d. Manner in which the program meets broad statewide needs and enhances the state's capacity to respond effectively to social, economic, and environmental challenges and opportunities.

See need section below

3. Accreditation

a*. Accrediting body or professional society that has established standards in the area in which the program lies, if applicable.*

There are no plans to accredit the graduate degrees in Bioengineering.

b. Ability of the program to meet professional accreditation standards. If the program does not or cannot meet those standards, the proposal should identify the area(s) in which it is deficient and indicate steps needed to qualify the program for accreditation and date by which it would be expected to be fully accredited.

Not applicable.

c. If the proposed program is a graduate program in which the institution offers an undergraduate program, proposal should identify whether or not the undergraduate program is accredited and, if not, what would be required to qualify it for accreditation.

The undergraduate program in Bioengineering is accredited by the Accrediting Board of Engineering and Technology (ABET).

d. If accreditation is a goal, the proposal should identify the steps being taken to achieve accreditation. If the program is not seeking accreditation, the proposal should indicate why it is not.

Accreditation of the degrees is not a goal. ABET does not allow accreditation of undergraduate and graduate degrees at the same institution in the same program.

4. Need

a. Evidence of market demand.

From 2001 to 2010, the US bioscience industry grew by 6.4%, despite an overall drop in private sector employment of 2.9% during the same time period [Batelle/BIO State Bioscience Industry Development 2012, www.bio.org/sites/default/files/v3battelle-bio_2012_industry_development.pdf]. This growth is largely due to new technologies

and advancements that have spawned new businesses. According to the US Bureau of Labor Statistics, employment in bioscience-based industries is projected to grow even more significantly over the next decade, at a rate much faster than average. Employment of biomedical engineers in particular is projected to grow by 27%. [US Bureau of Labor Statistics, Occupational Outlook Handbook, www.bls.gov/ooh/architecture-and-engineering/biomedical-engineers.htm]

This growth is particularly apparent in Oregon where employment in bioscience-based industries increased by nearly 31% from 2001 to 2010. There are over 700 bioscience industry establishments in Oregon providing more than 13,000 jobs. The largest bioscience subsectors in Oregon are Bioscience-Related Distribution (4446 jobs), Medical Devices and Equipment (3962 jobs) and Research, Testing and Medical Laboratories (3659 jobs). There was strong job growth in all bioscience industry subsectors from 2001 to 2010, including 53% growth for Research, Testing and Medical Laboratories and 31% growth for Medical Devices and Equipment. [Batelle/BIO State Bioscience Industry Development 2012, www.bio.org/sites/default/files/v3battelle-bio_2012_industry_development.pdf]

According to the Oregon Bioscience Association, the industry is at an inflection point and is poised for significant growth into the future. This inflection point is bolstered by several recent events that will promote growth of the bioscience industry in Oregon, including Phil and Peggy Knight's donation of $500 million to kick start a $1 billion cancer research initiative at Oregon Health and Sciences University (OHSU), expanded bioscience business incubator laboratory space and the opening of the OHSU/OSU Collaborative Life Sciences Building on Portland's south waterfront.

OSU has also seen an expanded capacity for bioscience innovation over the last decade. In addition to a BS degree program in Bioengineering (ABET-accredited under program criteria for Biomedical Engineering), there is significant research as well as graduate coursework throughout the COE that relates to developing devices and technologies that combine life sciences with engineering principles to improve human health, wellness and quality of life. There have been large investments in faculty lines across several COE schools, with eight tenure track positions filled by individuals with expertise in bioengineering over the past year alone. In addition, OSU has in recent years brought about a significantly enhanced institutional capacity for innovation, industry partnering, prototype development, scale-up and commercialization.

As a result, we are currently in a very strong position to launch a new Bioengineering graduate program. We envision a program that will produce graduates with interdisciplinary training that will contribute to the growing bioscience-based industry in Oregon, as well as stimulate economic growth through creation of new companies based on translation of university research. In addition to providing interdisciplinary training that integrates the biosciences and engineering, our program will leverage OSU's recent investment in commercialization resources to educate students about the processes required to translate their research to practice, including: (i) workshops customized to the needs of research group clusters connected along comprehensive themes; (ii) alliance with the College of Business and its Integrated Business Project; (iii) the use of fabrication facilities at the Microproducts Breakthrough Institute and the

Materials Synthesis and Characterization Facility; and in selected cases, (iv) OSU Advantage programs that help guide new technologies to market.

OSU's strength in Veterinary Medicine also creates opportunities for graduate training focused on clinical translation of bioengineering research. The use of research animals is required by the FDA as well as regulatory authorities worldwide in order to demonstrate safety and efficacy of biomedical technologies. We have initiated discussions with representatives from the College of Veterinary Medicine about developing and delivering new courses that provide classroom and hands-on training in the care and use of animals in research. This coverage would include the ethics of animal research as well as hands-on training in unique aspects of anatomy for selected animal models, animal handling, blood collection and injections, catheter placement, and basic elements of anesthesia, analgesia, patient monitoring, and post-operative care. This training, coupled with the Regulation of Drugs and Medical Devices course that is a part of the proposed core curriculum (see Table 2), would empower students to design animal studies and navigate the regulatory requirements for bringing biomedical technologies to market.

Currently, graduate students interested in bioengineering must choose one of the existing engineering programs and complete courses that neither align with nor capture the multi-disciplinary nature of modern bioengineering research. In addition, the vast preponderance of undergraduates with interest in pursuing graduate study in bioengineering (mainly from OSU but also OIT, PSU, UO, others) must leave the State. Thus, it is not surprising that current OSU undergraduates strongly support the creation of a new BIOE graduate program (see attached letter). As evidence of the strong demand for graduate training in bioengineering in the Northwest, the UW Bioengineering program receives over 300 applicants per year, and can only accept about 6% of those applicants. Establishment of a graduate program in bioengineering will provide an environment for collaborative research and training along interdisciplinary themes, and will serve to attract and retain talented students in the State.

In its 2013 Policy Guide the Oregon Bioscience Association (Oregon Bio) outlined the significant role bioscience plays in the Oregon economy, and the need for Oregon policy makers to effectively compete with the aggressive efforts of other states to attract and retain bioscience-based research, therapeutic, and manufacturing companies. In this regard they identified improvement of Oregon's competitive business environment – by creating jobs, rewarding innovation, supporting company recruitment and fostering commercialized research – as their number one policy priority. Establishment of MEng, MS and PhD degree programs in Bioengineering is fully supportive of these state-level developments and will:

- provide an environment for collaborative research and training along interdisciplinary themes;
- provide our graduate students with educational resources to enable them to recognize how their research can be used for an economic benefit, as well as understand the processes that are required for its translation to practice;
- contribute to the growth and vitality of the bioscience- based industry in Oregon through a new source of human capital; and

- help keep new bioscience-based technologies in Oregon.

Outside of OSU, at this early stage we have discussed our intention to develop a new Bioengineering graduate program with Dennis McNannay (Executive Director, Oregon Bio), Rod Ray (CEO, Bend Research and Chair, OSU College of Engineering Advisory Board), and several other members of the Oregon bioscience industry, and have received an enthusiastic response. Letters of support from Dennis McNannay and Rod Ray are appended to this proposal.

b. If the program's location is shared with another similar OUS program, proposal should provide externally validated evidence of need (e.g., surveys, focus groups, documented requests, occupational/employment statistics and forecasts).

The proposed BIOE graduate program will be unique at OSU. The following programs at OSU have some similarities, but focus on biological and biomedical sciences rather than engineering: Molecular and Cellular Biology (PhD), Applied Biotechnology (PSM), Comparative Health Sciences (MS, PhD). Within COE, there are also programs in Radiation Health Physics (MS, PhD) and Medical Physics (MS, PhD), but these programs do not provide the interdisciplinary breadth of the proposed BIOE graduate program. The Health Physics program focuses on ensuring safe use of radiation for a variety of applications, including energy production, medical uses of radiation, transportation safety, industrial measurements, etc. The Medical Physics program examines and applies nuclear/radiation sciences to medicine, in both radiation therapy and diagnostic imaging. In contrast, the proposed Bioengineering graduate program will provide broad interdisciplinary training that integrates the biosciences, physical sciences, mathematics and engineering for development of new biologicals, materials, devices and processes.

c. Manner in which the program would serve the need for improved educational attainment in the region and state.

See 4a

d. Manner in which the program would address the civic and cultural demands of citizenship.

The graduates of the proposed Bioengineering graduate program will be trained to integrate bioscience and engineering principles, allowing them to contribute to the development of processes and technologies that address issues of high social importance, including the delivery of effective and affordable health care.

5. Outcomes and Quality Assessment

a. Expected learning outcomes of the program.

The learning outcomes for the Bioengineering graduate program include scholarship, mastery of subject material and ethical conduct, as described in detail below.

Graduate Learning Outcomes for Ph.D., M.S., and M.Eng. Programs in Bioengineering:

Ph.D. Outcomes	MS Outcomes	MEng Outcomes
Outcome 1: Scholarship The student will be able to identify and conduct original research resulting in a significant contribution to knowledge in the fields spanned by Bioengineering and to effectively communicate this work to a technically literate audience. This will be assessed using the Ph.D. Qualifier Examination, Ph.D. Thesis and Final Oral Examination ("Defense").	**Outcome 1: Scholarship** The student will be able to conduct original research and assemble a creative new body of work in the fields spanned by Bioengineering and to effectively communicate this work to a technically literate audience. This will be assessed using the M.S. Thesis and Final Oral Examination.	**Outcome 1: Scholarship** The student will be able to assemble a presentation synthesizing aspects of core knowledge in the fields spanned by Bioengineering and to effectively communicate this work to a technically literate audience. This will be assessed using the M.Eng. Final Oral Examination, which will take place during the last quarter that the student is enrolled in the M.Eng. program.
Outcome 2: Mastery of Subject Material The student will be able to think critically, creatively and to address technical problems in the fields spanned by Bioengineering. This will be assessed through satisfactory completion of the graduate program of study, as well as course summaries written by the instructors.	**Outcome 2: Mastery of Subject Material** The student will be able to think critically, creatively and to address technical problems in the fields spanned by Bioengineering. This will be assessed through satisfactory completion of the graduate program of study, as well as course summaries written by the instructors.	**Outcome 2: Mastery of Subject Material** The student will be able to think critically, creatively and to address technical problems in the fields spanned by Bioengineering. This will be assessed through satisfactory completion of the graduate program of study, as well as course summaries written by the instructors.
Outcome 3: Ethical Conduct Students will be educated in ethical and responsible conduct in research and professional activities. This will be assessed through satisfactory completion of the graduate seminar (BIOE 507), as well as ethical completion of the Ph.D. Qualifier Examination and the Ph.D. Thesis and Final Oral Examination.	**Outcome 3: Ethical Conduct** Students will be educated in ethical and responsible conduct in research and professional activities. This will be assessed through satisfactory completion of the graduate seminar (BIOE 507), as well as ethical completion of the M.S. Thesis and Final Oral Examination.	**Outcome 3: Ethical Conduct** Students will be educated in ethical and responsible conduct in professional activities. This will be assessed through satisfactory completion of the graduate seminar (BIOE 507), as well as ethical completion of the M.Eng. Final Oral Examination.

b. Methods by which the learning outcomes will be assessed and used to improve curriculum and instruction.

Mapping Guide for the Ph.D. Degree – ***Bioengineering***

The main activities are listed for each outcome. Other activities may also support the outcomes, but data will only be collected for those listed below. The data collected will be reviewed annually and used for continuous improvement of the curriculum and instructional practices.

	Learning Outcomes and Evidence: *Graduate students in the Ph.D. program will demonstrate*		
	Outcome 1: Scholarship Identify and conduct original research, scholarship or creative endeavors; communicate with peers	Outcome 2: Mastery of Subject Field The student will be able to think critically, creatively and to address technical problems in field	Outcome 3: Ethical Conduct Conduct professional activities in an ethical and responsible manner
Activities ↓			
1. Completion of Coursework		Completion of Program of Study; Course Summaries for Core Courses in BIOE grad program (see Table 2)	
2. Seminar Series			Completion of Program of Study showing participation in BIOE 507 seminar
3. Ph.D. Qualifier Exam	Filled individual examiner's rubrics and committee summary rubric	Filled individual examiner's rubrics and committee summary rubric	Filled individual examiner's rubrics and committee summary rubric
4. Ph.D. Thesis and Final Oral Exam	Filled individual examiner's rubrics and committee summary rubric		Filled individual examiner's rubrics and committee summary rubric

Mapping Guide for the M.S. Degree – ***Bioengineering***

The main activities are listed for each outcome. Other activities may also support the outcomes, but data will only be collected for those listed below. The data collected will be reviewed annually and used for continuous improvement of the curriculum and instructional practices.

	Learning Outcomes and Evidence: *Graduate students in the M.S. program will demonstrate*		
	Outcome 1: Scholarship	Outcome 2: Mastery of Subject Field	Outcome 3: Ethical Conduct
Activities ↓	Identify and conduct original research, scholarship or creative endeavors; communicate with peers	The student will be able to think critically, creatively and to address technical problems in field	Conduct professional activities in an ethical and responsible manner
1. Completion of Coursework		Completion of Program of Study; Course Summaries for Core Courses in BIOE grad program (see Table 2)	
2. Seminar Series			Completion of Program of Study showing participation in BIOE 507 seminar
3. M.S. Thesis and Final Oral Exam	Filled individual examiner's rubrics and committee summary rubric		Filled individual examiner's rubrics and committee summary rubric

Mapping Guide for the M.Eng. Degree – ***Bioengineering***

The main activities are listed for each outcome. Other activities may also support the outcomes, but data will only be collected for those listed below. The data collected will be reviewed annually and used for continuous improvement of the curriculum and instructional practices.

	Learning Outcomes and Evidence: *Graduate students in the M.Eng. program will demonstrate*		
	Outcome 1: Scholarship	Outcome 2: Mastery of Subject Field	Outcome 3: Ethical Conduct
Activities ↓	Conduct literature research on a Bioengineering related process and assemble an oral presentation summarizing the process; communicate with peers	The student will be able to think critically, creatively and to address technical problems in field	Conduct professional activities in an ethical and responsible manner
1. Completion of Coursework		Completion of Program of Study; Course Summaries for Core Courses in BIOE grad program (see Table 2)	
2. Seminar Series			Completion of Program of Study showing participation in BIOE 507 seminar
3. Final Oral Exam	Filled individual examiner's rubrics and committee summary rubric		Filled individual examiner's rubrics and committee summary rubric

c. Program performance indicators, including prospects for success of program graduates (employment or graduate school) and consideration of licensure, if appropriate.

Various performance indicators will be collected including:

- Number of applicants, offers and acceptance rates
- Academic qualifications of applicants and accepted students
- Retention and graduation rates
- Employment upon graduation
- Student satisfaction from exit interviews
- Employer satisfaction

d. Nature and level of research and/or scholarly work expected of program faculty; indicators of success in those areas.

The majority of faculty to be included in the program have extramurally funded research and produce high quality scholarship (see Appendix 1). The number and quality of peer-reviewed scholarship and the availability of research funding will be the primary indicators of success. Performance parameters continually collected by the College of Engineering include:

- Scholarly publication
- Participation in professional meetings, conferences and workshops
- External funding for research
- Number and magnitude of proposals written
- Participation in professional societies, committees, boards, and commissions
- Commercial development including disclosures, patents and start-up companies

These indicators are evaluated each year in the faculty member's annual review.

6. Program Integration and Collaboration

a. Closely related programs in other OUS universities and Oregon private institutions.

The most closely related program in the state of Oregon is the Biomedical Engineering graduate program (MS and PhD) at the Oregon Health & Science University. The proposed BIOE graduate program would complement the current BME program at OHSU (see below), while also providing more opportunities for current Oregon undergraduates (from OIT, OSU, PSU, UO, etc.) to pursue a graduate degree in bioengineering within the state.

b. Ways in which the program complements other similar programs in other Oregon institutions and other related programs at this institution. Proposal should identify the potential for collaboration.

We have discussed our intention to develop the new graduate program with several OHSU representatives including Dan Dorsa (VP for Research), Joe Gray and Owen

McCarty (Chair and Vice Chair, Department of Biomedical Engineering), and Michael Chapman (Department of Biochemistry and Molecular Biology). It is clear the research themes at the two schools are unique and complement each other. The research activities at OHSU are focused squarely on engineering for unmet clinical needs while the bioengineering research threads at OSU encompass a wider range of bioscience-based technologies beyond the focus of clinical need. We agreed to work together in the coming months to ensure continued complementarity in thematic offerings at each institution, and to explore new opportunities for collaboration. In this regard we discussed the potential for enhanced interinstitutional connections that a formal program at OSU would bring, especially with respect to access to OSU facilities for engineering design, device fabrication and technology development, and access to OSU bioengineering undergraduates in meeting "broader impacts" criteria for joint, OHSU-OSU NSF grants for research and graduate training.

c. If applicable, proposal should state why this program may not be collaborating with existing similar programs.

As mentioned above, we have discussed our plans to create a new Bioengineering graduate program with several OHSU representatives. Our proposed program will be complementary to the existing Biomedical Engineering program at OHSU, and we anticipate that creation of a formal program at OSU will enhance collaborative opportunities with OHSU. We plan to continue to explore opportunities for collaboration during and after the launch of the Bioengineering graduate program at OSU.

d. Potential impacts on other programs in the areas of budget, enrollment, faculty workload, and facilities use.

The creation of a Bioengineering graduate program at OSU is not expected to affect the budget, enrollment, faculty workload or facilities use of any other programs in Oregon outside of OSU. The only potential impact is competition with the OHSU Biomedical Engineering program for graduate student applicants. However, as described in section 4a, there are many more applicants to BIOE/BME graduate programs in the Northwest than available positions.

The impact at OSU will be modest because recent faculty hires provide the increased capacity needed to deliver the new BIOE graduate program, and to support the growth of existing programs in the COE. In the last four years 41 new tenured/tenure-track faculty members were hired in the College and several searches are currently underway to add additional tenure-track faculty members.

Some graduate students who would otherwise choose to enroll in a traditional engineering program (e.g., Mechanical Engineering, Electrical Engineering, Chemical Engineering, etc) might instead choose to enroll in the new BIOE graduate program. However, this is not expected to reduce enrollment in other programs below current levels. In fact, growth of both existing engineering programs and the new BIOE graduate program is expected as a result of increased research activity within the College. As new faculty members win research grants to support graduate students, enrollment in graduate programs is expected to increase.

Some faculty time will of course be required to deliver the BIOE program core (see Table 2). As described in section 1i, we currently have the faculty expertise and capacity to deliver the core. We expect to be able to deliver the core courses without diverting faculty time from existing teaching activities by leveraging new faculty members who have either not yet been assigned teaching duties or who have been given temporarily reduced teaching loads as they establish their research programs. As an example, the five courses in BIOE program core could be delivered entirely using new faculty in the School of CBEE. There is currently a search underway for a new BIOE faculty member to start in Fall 2015; the individual who fills this position could teach two courses in the core (e.g., Cellular and Molecular Bioengineering; Bioengineering Analysis). Joe Baio, a CBEE faculty member who began in 2013, was offered a reduced teaching load in his first two years as a part of his startup package. Once this reduced teaching load expires in 2015 he could teach one of the core courses (e.g., Drug and Medical Device Regulations in Technology Development). In addition, Jim Sweeney recently joined CBEE as School Head. He has experience with teaching various BIOE courses at both the graduate and undergraduate level and could teach the Physiology for Engineers course. The remaining 1 credit BIOE seminar course is not a major time commitment and could be taught by a different BIOE program faculty member each year. Outside of CBEE, other Schools in the COE have also added new faculty members who have expertise in Bioengineering, providing additional options for delivery of the BIOE program core.

BIOE graduate students will also be required to take elective courses such as those listed in Table 3. Existing OSU course offerings provide ample options for elective courses, and no additional course development will be needed to support the BIOE graduate program. The only potential impact on faculty time is a modest increase in enrollment in existing graduate courses that could serve as BIOE electives.

Faculty time will also be required to manage the BIOE graduate program. Once again, we expect that faculty participation in management of the BIOE graduate program will not divert time from existing service activities. Overall, we expect an increased capacity for faculty service activities as a result of recent hires, as well as currently open positions to be filled in the Fall. Some of this increased service capacity will be used for management of the BIOE graduate program.

No significant effects on the budgets of other programs at OSU are anticipated.

7. Financial Sustainability (attach the completed *Budget Outline*)

a. Business plan for the program that anticipates and provides for its long-term financial viability, addressing anticipated sources of funds, the ability to recruit and retain faculty, and plans for assuring adequate library support over the long term.

We anticipate that the vast majority of graduate students will either be supported as GTAs or GRAs. Each School within the COE will be able to offer GTA positions to bioengineering graduate students using their existing budget, using criteria established by the School (e.g., ability to TA core undergraduate courses within the School). Funding for GRA positions will come from research grants. The costs of student recruiting visits, program promotion and management of the Bioengineering program

website will be paid using the existing budget within the School of Chemical, Biological and Environmental Engineering. The costs for these activities are estimated at $10,000 per year.

As described in section 6.d. above, the College of Engineering has added 41 new faculty members in the last 4 years, and searches for several additional faculty members are underway; these new faculty members provide the increased capacity needed to deliver the new BIOE graduate program. The annual cost in terms of faculty time for delivering the new BIOE graduate program core courses (15 credits) is estimated at about $190,000. This estimate is based on an assumed $90,000 academic year salary, 40% OPE and a typical teaching load of about 10 credits per year. The number of faculty lines required to deliver the core is approximately 1.5. There will also be some cost associated with the service activities of the BIOE graduate program director. Assuming the director dedicates 10% of his or her time to program related service duties over the entire year (including summer), the cost of these service activities will total approximately $17,000 (salary plus OPE).

For the program to be successful, there will also need to be some administrative and advising support. We expect, for example, that the CBEE Operations Manager will need to devote approximately 15% of her annual effort to this program (in concert with her existing efforts already devoted to support of the existing CBEE graduate degree programs). This equates to $14,000 (salary plus OPE) annually. We do not anticipate the need for TAs to support courses in the BIOE program core. The expected enrollment for any given new course is less than 30 students per year, as shown in Table 4.

No additional library support is anticipated (please see the enclosed library evaluation).

b. Plans for development and maintenance of unique resources (buildings, laboratories, technology) necessary to offer a quality program in this field.

Facilities and resources across and in support of the College of Engineering and across campus (e.g., Microproducts Breakthrough Institute, Center for Genome Research and Biocomputing, etc) are more than adequate to support the proposed graduate programs in Bioengineering. A new engineering building, Johnson Hall, is currently under construction with a target completion date of Fall 2016. This building will include several BIOE research laboratories, faculty offices and graduate student offices (approximately 72+ new graduate student desks). Beyond existing and new graduate student desks in CBEE in Gleeson and Johnson Halls, some students in the new program will also be dispersed through the college and across campus into existing spaces based upon their research areas and advisors. No additional facilities or resources will be required.

c. Targeted student/faculty ratio (student FTE divided by faculty FTE).

The targeted student to faculty ratio is about 1.5 BIOE MS/MEng and 1.5 BIOE PhD students per faculty member. Because of the interdisciplinary nature of the program, participating faculty may also advise students enrolled in other graduate programs. With this in mind, the target student/faculty ratio is consistent with the COE strategic

plan, which sets expectations of 3 M.Eng./M.S. students and 4 Ph.D. students per research active faculty by 2025.

d. Resources to be devoted to student recruitment.

Student recruitment involves both program promotion, as well as recruiting visits for students who have applied and been accepted into the program. Resources for program promotion include the costs of brochures, mailing, and webpage maintenance. In the first two years of the new BIOE graduate program, we anticipate relatively high promotion costs of about $18,000 per year in order to create promotional materials, build a new website for the program as well as more comprehensive efforts to promote the launch of the program (including top student recruitment and visits). The College of Engineering has committed $50,000 over the next two years to support the launching and promotion of the new Bioengineering graduate program (See Liaison Letter from COE). In the long term, the costs of program promotion and student recruitment are estimated at about $10,000 per year. This cost will be paid by the School of Chemical, Biological and Environmental Engineering.

8. **External Review** *(if the proposed program is a graduate level program, follow the guidelines provided in External Review of new Graduate Level Academic Programs in addition to completing all of the above information)*

Professor Dave Castner – Department of Bioengineering, University of Washington

Professor Ashutosh Chilkoti – Department of Biomedical Engineering, Duke University

Professor Tejal Desai – Department of Bioengineering and Therapeutic Sciences, UCSF, and Chair, Joint Graduate Program in Bioengineering, University of California, San Francisco and Berkeley

Professor Kevin Healy – Department of Bioengineering and Department of Material Science and Engineering, University of California, Berkeley

Professor Andres Garcia – Director of Bioengineering Graduate Program, Georgia Institute of Technology

Dr. Anna Belu – Senior Principal Scientist at Medtronic, Inc., Editor in Chief of Biointerphases