APPENDIX C

UNIVERSITY OF NORTH CAROLINA

REQUEST FOR AUTHORIZATION TO ESTABLISH A NEW DEGREE PROGRAM

INSTRUCTIONS: Each proposal should include a 2-3 page executive summary. The signature of the Chancellor is required. Please submit one hard copy and an electronic copy of the proposal to the Office of the Senior Vice President of Academic Affairs at UNC General Administration.

Date: _____08/26/2013_____

Constituent Institution: _ **East Carolina University**_____

CIP Discipline Specialty Title: **Biomedical Engineering** _____

CIP Discipline Specialty Number: _14.0903_ Level: B _____ M __**X**_ 1st Prof _____ D _____

Exact Title of the Proposed Degree: **Biomedical Engineering** _____

Exact Degree Abbreviation (e.g. B.S., B.A., M.A., M.S., Ed.D., Ph.D.): ____**M.S.**_____

Does the proposed program constitute a substantive change as defined by SACS? Yes _____ No _**X**_

The current SACS Substantive Change Policy Statement may be viewed at:
http://www.sacscoc.org/pdf/081705/Substantive%20Change%20policy.pdf

If yes, please briefly explain.
Proposed date to establish degree program: *Month* _ **August**____ *Year* ____**2014** _____

Are there plans to offer all or a portion of this program to students off-campus or online? Yes _____ No _ **X**____

If yes, complete the form to be used to request establishment of a distance education program and submit it along with this request.

Note: If a degree program has not been approved by the Board of Governors, its approval for alternative, online, or distance delivery must wait until BOG program approval is received. (400.1.1[R], page 3)

[1]This Appendix C supersedes the preceding Appendix C entitled, "Request for Authorization to Establish a New Degree Program," adopted May 6, 2009.

Master of Science in Biomedical Engineering
Executive Summary

We propose to create a master of science in biomedical engineering degree which will be offered on campus through the Department of Engineering. Biomedical engineering is a discipline that integrates the engineering sciences with biology and medicine. This interdisciplinary degree with thesis requirement will include courses in advanced biomedical engineering, life science, mathematics and biostatistics for a total of 32 credit hours.

The field of biomedical engineering has seen a dramatic escalation in activity over the past 20 years leading to the development of a wide variety of medical devices, medical procedures, and a basic understanding of biological processes. The proposed program targets an emerging and advanced technological field and integrates with key components of the ECU mission statement: *to serve through education, to serve through research and creative activity, and to serve through leadership and partnership*. **East Carolina University is the only university within the 17 UNC institutions that offers academic programs in engineering, medicine, dentistry, nursing, allied health and business on one campus**. The proximity of the facilities and a congenial, collaborative spirit among faculty provide a unique environment for multidisciplinary educational and research experiences in this rapidly-growing discipline. The Department of Engineering will build on existing collaborations with the College of Nursing, College of Allied Health Sciences, Brody School of Medicine, School of Dental Medicine, Thomas Harriot College of Arts and Sciences, College of Health and Human Performance and ECU's Warrior Training Program focusing on device/equipment design and the application of advanced technologies to solve complex problems in the life sciences and medicine. The educational objectives of the proposed program are to educate and train students to meet the challenges of biomedical discovery and apply engineering principles to advance health care in eastern North Carolina.

The proposed master of science in biomedical engineering program will be a two-year program with a minimum of 32 semester hours of coursework and thesis. Advanced undergraduate engineering students will have the opportunity to apply to an integrated bachelor's/master's in biomedical engineering in their junior year. Approximately 14 semester hours of the coursework will come from the Department of Engineering with emphasis on key engineering proficiencies, with an additional 6 semester hours thesis credit. Building on the research strengths of the Brody School of Medicine, School of Dental Medicine, College of Nursing, Thomas Harriot College of Arts and Sciences, College of Allied Health Sciences and College of Health and Human Performance students may focus their studies in Cardiovascular Biomedical Engineering or Biomolecular & Tissue Engineering with an emphasis on device design and application. Additional courses will be selected from the Departments of Physiology, Pharmacology, Kinesiology, Biology, Physics, Computer Science, Mathematics, Biostatistics and other disciplines as required to support the research interests of the individual. The program will have a program director and advisor, responsible for the overall program administration.

The program planners have identified three NC institutions (see Table 1), located over 85 miles from ECU, offering related degrees and providing opportunities for collaborative academic and research opportunities. ECU Department of Engineering has initiated discussions with University of North Carolina at Chapel Hill/North Carolina State University (UNC/NCSU) Joint Department of Biomedical Engineering, North Carolina Agricultural & Technical State University (NC A&T), and the Joint School of Nanoscience and Nanoengineering (JSNN) to negotiate collaborative research opportunities and course offerings to benefit all programs. Program planning includes joint research, summer internships, access to unique

equipment and laboratories, synchronous broadcast of courses and seminars to ECU and facilitated admission of master's students to biomedical engineering doctoral programs. (see attached letters from UNC/NCSU Joint Department of Biomedical Engineering and JSNN).

ECU's Department of Engineering offers a bachelor of science in engineering with concentrations in biomedical, bioprocess, mechanical, industrial/systems and electrical engineering (new for academic year 2012-2013). The first ECU engineering class graduated in 2008 and the undergraduate engineering program was ABET accredited in 2009. The biomedical engineering concentration has been taught since 2010. Enrollment in the undergraduate biomedical engineering concentration has increased by 100% since 2010 and is anticipated to increase with the growth of the department (current undergraduate enrollment in the engineering department is +500 students). The strategic plan of the college is for the undergraduate engineering program to grow to +750 students over the next 4-5 years. For the May 2013 graduating class, 19% were biomedical, 10% bioprocess, 14% industrial systems and 57% mechanical engineering. Approximately 34% of the engineering freshmen, class of 2016, indicated an interest in the biomedical engineering concentration. In addition, 58% of the biomedical engineering concentration graduates are employed in concentration specific industries and 33% have pursued graduate education. With the growth of the undergraduate biomedical engineering program, faculty from the Brody School of Medicine, School of Dental Medicine, Department of Kinesiology, Department of Physical Therapy and College of Nursing are currently collaborating with biomedical engineering faculty to enhance undergraduate education. There is clearly a demand and interest by ECU engineering students and faculty for advanced graduate education in biomedical engineering.

Regional industry is already an important constituent and stake holder in the planning and success of ECU's undergraduate engineering program. The Department of Engineering maintains a collaborative relationship with an Engineering Advisory Board (EAB) comprised of approximately 40 members from industry, consulting firms, academia, and government laboratories. The board meets twice a year to review current and planned programs, student achievement, and provide guidance on future directions of the engineering program. Several of these organizations participate in the department's senior capstone design project, provide student internships and employment.

The primary goal of the proposed program is to provide a foundation in biomedical engineering expertise to provide a trained workforce of leaders to support economic development, industry and academia. The objectives are to engage students to support innovation in health sciences and regional industry, positively influence research productivity, and support interdisciplinary research improving health care and biotechnology. ECU has a history of supporting innovation and translational research. In 2012, ECU was named a charter member of the National Academy of Inventors. The goals of this organization are to advance invention and innovation and translate research to new products and new ideas. Twenty-three ECU faculty were inducted in 2012-2013, including the collaboration of Dr. Jason Yao, Department of Engineering and Dr. Gregg Givens, College of Allied Health Sciences, as co-inventors on a patent application. The master of science in biomedical engineering program will continue to build on established and new collaborative, internal and external partnerships. We anticipate that graduates of the program will support the regional workforce in industry, healthcare, government and academia. The majority of students are expected to be from eastern North Carolina and the surrounding region and able to complete the degree program in four semesters.

I. DESCRIPTION OF THE PROGRAM

A. Describe the proposed degree program (i.e., its nature, scope, and intended audience).

The MS in biomedical engineering will be developed by the ECU Department of Engineering as a collaborative, research based graduate degree which supports the engineering research needs of a range of key university areas of the Brody School of Medicine, the School of Dental Medicine, College of Nursing, College of Allied Health Sciences, Thomas Harriot College of Arts and Sciences, and the College of Health and Human Performance. Biomedical engineering is a discipline that integrates the engineering sciences with biology and medicine. The field of biomedical engineering has seen a dramatic escalation in activity over the past 20 years leading to the development of a wide variety of medical devices, medical procedures, and a basic understanding of biological processes. Engineering approaches are becoming increasingly important in modern biological and medical research and in the development of new technologies that stem from recent discoveries. The National Academy of Engineering recently identified 14 Grand Challenges for Engineering in the 21st Century [1]. Several challenges address biomedical engineering applications to advance personalized health care, engineer better medicines and improve health informatics systems. Noting these challenges, this program will provide a foundation in biomedical engineering expertise to support faculty in diverse areas of the university to improve and develop their research capabilities in areas such as cardiovascular bioengineering, neural engineering, biomechanics, biomaterials, instrumentation and signal processing, computational modeling and data analysis. Additionally, this program will prepare students to enter industry upon graduation or pursue doctoral studies in biomedical engineering or advanced professional degrees.

The degree program will be delivered on campus. The focus of the program is to prepare students who are skilled in the learning and discovery processes to integrate engineering and life sciences for the advancement of human health. Biomedical engineering combines engineering principles and methodology with physical, chemical, and mathematical sciences to solve problems in biology, medicine, behavior, and health. Due to the multidisciplinary characteristic of the field, biomedical engineering has a diverse research impact, often serving as bridge builder between technological and clinical communities.

We envision the program to be a two-year program with a minimum of 32 semester hours of coursework and thesis. Approximately 14 semester hours of the coursework will come from the Department of Engineering and will build key engineering proficiencies, with an additional 6 semester hours thesis credit. Additional courses will be selected from the Departments of Physiology, Pharmacology, Kinesiology, Biology, Physics, Computer Science, Mathematics, Biostatistics and other disciplines as required to support the research interests of individual students and faculty. Up to 6 semester hours of transfer credit will be allowed from engineering courses offered through the UNC/NCSU Joint Department of Biomedical Engineering, NC A&T State University, the JSNN and other approved engineering graduate programs. In addition, for advanced, highly motivated undergraduate students, an integrated bachelor's/master's in biomedical engineering will be offered. For that program, graduate student course work will begin in the students' fourth year of undergraduate study and be completed with one academic year of study beyond the bachelor's degree.

Over the last three years, ten senior biomedical engineering capstone projects have focused on device or equipment design for research projects in the Brody School of Medicine, College of Allied Health Sciences, National Aeronautics and Space Administration, Centers for Disease Control and Prevention, local health care providers and entrepreneurs. In addition, core engineering faculty are actively

collaborating with faculty in the College of Nursing, Department of Cardiovascular Sciences and Department of Communication Sciences and Disorders. The program planners anticipate continued collaborative opportunities for graduate level research projects and employment following graduation. The engineering faculty continues to actively seek university, industry and government partners to facilitate networking opportunities, technology transfer and innovation.

B. List the educational objectives of the program.

The program will:

- Produce graduates with advanced biomedical engineering skills to serve state and regional industries, hospitals, government agencies, and national and international industries.
- Produce graduates with the background and technical skills in biomedical engineering to work professionally in biomedical related industry, research and laboratory operations.
- Prepare graduates for personal and professional success with awareness and commitment to their ethical and social responsibilities, both as individuals and in team environments.
- Prepare graduates who are capable of entering and succeeding in advanced and terminal degree programs in fields such as engineering, science, medicine and dentistry.

To accomplish these program objectives, graduates of the program will be able to:

- Explain the mathematical and physical foundations of biomedical engineering and demonstrate these principles in the design of biomedical instruments, the analysis of biological systems, and the technological advancement necessary for improved health care outcomes.
- Apply biomedical engineering knowledge in an ethically responsible manner.
- Question and critically evaluate alternate assumptions, approaches, procedures, tradeoffs, and results related to engineering and biological problems.
- Apply knowledge of mathematics, physical sciences, life sciences and engineering to formulate and study or solve engineering and biomedical problems, including problems at the interface of engineering, medicine, and biology.
- Plan and perform experiments and analyze and interpret experimental measurements collected on physical and living systems.
- Design electronic, mechanical and/or computer-based devices and software for applications including medical instrumentation, physiological measurement and signal processing, prosthesis development, and engineering simulation of living systems.
- Communicate effectively using appropriate technology and information resources to document procedures, analyze engineering problems and solutions, and present project results.

C. Describe the relationship of the program to other programs currently offered at the proposing institution, including the common use of:

1. Courses
2. Faculty
3. Facilities, and
4. Other resources

East Carolina University is the only university within the UNC system that offers academic programs in engineering, medicine, dentistry, nursing,allied health and business on one campus. The proposed MS in biomedical engineering does not compete with any other graduate program at East Carolina University. Rather, it enhances and complements the resources available to programs and colleges throughout the university. The proximity of the facilities and

a congenial, collaborative spirit among faculty provide a unique environment for multidisciplinary educational and research experiences in this rapidly-growing discipline.

1. Courses

Approximately 14 semester hours of the coursework will come from the Department of Engineering, with an additional 6 semester hours thesis credit and additional graduate level courses from the Departments of Physiology, Pharmacology, Computer Science, Biology, Physics, Mathematics, Biostatistics and other disciplines to support the research of individual students and faculty. The chairs of these departments have indicated that they have adequate capacity in the existing didactic courses to accommodate the anticipated number of students in this new degree program.

2. Faculty

A core engineering faculty group from the Department of Engineering will be responsible for the planning, course offerings and research projects of the proposed program. Collaborative joint faculty from the Brody School of Medicine, School of Dental Medicine, College of Allied Health Sciences, Thomas Harriot College of Arts and Sciences, College of Nursing and the College of Health and Human Performance have committed to support the core engineering faculty. (see ECU Faculty Letters of Support)

3. Facilities

This program will take advantage of the proximity and combined strengths of the technical and engineering sciences in the Department of Engineering; and the biological and medical sciences in the Brody School of Medicine, School of Dental Medicine, College of Nursing, College of Allied Health Sciences, College of Health and Human Performance, Thomas Harriot College of Arts and Sciences, College of Business, East Carolina Diabetes and Obesity Institute, East Carolina Heart Institute, Leo W. Jenkins Cancer Center and The Harriet and John Wooten Laboratory for Alzheimer's and Neurodegenerative Diseases Research. These departments, schools, colleges and institutes are located on the East Carolina University campus with easy access to faculty and students.

4. Other resources

Research opportunities are growing in the areas of biomedical imaging, cell and tissue engineering, cardiovascular sciences, neural engineering, metabolism, orthopedics, rehabilitation and cancer. The presence of additional graduate students and faculty focused on biomedical engineering problems, working in close collaboration with research faculty in ECU's various colleges and schools will broaden the ECU biomedical research portfolio and provide credibility and capacity to seek externally funded projects that are currently intractable. In addition, access to Vidant Medical Center and regional health care related industries will provide opportunities to support and advance health care in eastern North Carolina.

D. Identify opportunities for collaboration with institutions offering related degrees and discuss what steps have or will be taken to actively pursue those opportunities where appropriate and advantageous.

The program planners have identified three NC institutions (see Table 1) offering related degrees and providing opportunities for collaborative academic and research opportunities. ECU Department of Engineering has initiated discussions with UNC/NCSU Joint Department of Biomedical Engineering, NC A&T State University and the JSNN to negotiate collaborative

research opportunities and course offerings to benefit all programs. All three institutions are located over 85 miles from ECU.

Table 1 – Summary of Biomedical Engineering graduate programs offered in North Carolina

University/School	MS	Location	Concentrations	Public/ Private	Collaboration Opportunities
UNC/NCSU Joint Department of Biomedical Engineering	Biomedical Engineering	Chapel Hill, NC, Raleigh, NC	Rehabilitation, Biomedical imaging, Microsystems, Pharmacoengineering	Public	**Facilitate admissions to PhD program**
North Carolina Agricultural & Technical State University	Bio engineering	Greensboro, NC	Biomaterials, Biomechanics, Bioimaging, Biosignals, Biosensors	Public	**Provide additional online course offerings.**
Joint School of Nanoscience and Nanoengineering	Nano engineering	Greensboro, NC	Nanoengineering	Public	**Provide laboratory access and collaborative research opportunities**

Early in the planning of this degree program, the associate head of biomedical engineering for the UNC/NCSU joint program in biomedical engineering was contacted regarding information on enrollment and graduation rates. This information was used to estimate student enrollment (Section II.C). More recently, Hayden Griffin , PhD, chair of engineering and Barbara Muller-Borer, associate professor of engineering, spoke with Nancy Allbritton, MD, PhD, chair UNC/NCSU Joint Biomedical Engineering Department and Shawn Gomez, PhD, director of graduate studies. The demand for the master of science and doctoral programs in biomedical engineering were discussed. Currently, applicants to both master of science and doctoral programs are accepted and admitted to the UNC/NCSU graduate program. However, the demand for the doctoral program is greater than the master's program (i.e., 25 doctoral vs. 12 master's applicants in 2012). Due to the current economic climate no funding is appropriated to support tuition or stipends at the master's level. The master's of science students are self-supporting and this has resulted in the decline in enrollment at the MS level. The continued interest and demand in a master of science in biomedical engineering at UNC/NCSU underscores the need to provide advanced master's level graduate studies in biomedical engineering. ECU's program will focus on the MS level, and we anticipate that this decision will be beneficial for ECU's enrollment for students who currently do not plan to complete the PhD but desire advanced graduate studies.

To initiate exploration of collaborative opportunities, Drs. Allbritton and Gomez suggested a pilot program for the 2013-2104 academic year to video broadcast the graduate biomedical engineering seminar series to ECU. This seminar series includes invited guest lectures and student presentations. The pilot program would assist both universities in identifying collaborative research and/or teaching opportunities and expand educational outreach to eastern NC. This pilot program would be coordinated with the schedules for senior undergraduate engineering students and ECU engineering and joint faculty. This pilot program

would also assist in providing a foundation for developing a specific course or special topics course in the new MS curriculum. We anticipate this pilot program would help to promote additional video broadcast courses, such as biomedical imaging, to supplement the ECU master's program. Status of the pilot video broadcast project is pending.

Drs. Griffin and Muller-Borer met with Dean James Ryan, PhD, JSNN, former Chair Leonard Uitenham, PhD, and current Chair Stephen Knisley, PhD, Department of Chemical, Biological and Biomedical Engineering, NC A&T State University. An overview of the proposed master of science in biomedical engineering program was provided and opportunities for collaboration were discussed. Specific collaborative opportunities identified at these institutions include:

- JSNN – Joint research, summer internships and access to unique equipment and laboratories in nanomaterials, nanobioelectronics and computational nanotechnology. Graduates of ECU's MS program would be competitive for the PhD in Nanoengineering offered at the JSNN. (see letter of support)
- NC A&T State University - Graduate level courses in biomaterials available by synchronous broadcast via NC A&T State University, University of Pittsburgh and University of Cincinnati (NSF Engineering Research Center partners). MS research collaboration opportunities with ECU Health Science faculty.

NC A&T State University, affiliated with the Joint School of Nanoscience and Nanoengineering, offers graduate courses via distance education. ECU graduate students will have the opportunity to register as non-degree seeking students at NC A&T State University and take up to 6 s.h. of transfer engineering graduate courses to supplement course offerings.

It is anticipated that a number of graduates of ECU's MS program will continue their academic and research careers by matriculating into engineering PhD programs and/or professional degree programs at each of these institutions.

II. JUSTIFICATION FOR THE PROGRAM - NARRATIVE STATEMENT

A. Describe the proposed program as it relates to:

1. Institutional mission

This unique program targets an emerging and advanced technological field and integrates with key components of the ECU mission statement: *to serve through education, to serve through research and creative activity, and to serve through leadership and partnership*. The proposed MS in biomedical engineering is consistent with and supports these components. This program:

- Offers a unique graduate education option preparing engineers and scientists to meet the challenges of biomedical discovery and applications of engineering to medicine in service to the people of North Carolina, their health and their welfare.
- Provides opportunities for partnership and enhances new and emerging research opportunities for the faculty with the Brody School of Medicine, School of Dental Medicine, College of Allied Health Sciences, Thomas Harriot College of Arts and Sciences, College of Nursing and the College of Health and Human Performance, regional and local industry, government, and defense system organizations.
- Focuses on development of technology professionals in a key engineering field and promotes development of strong linkages and interactions with the industrial, business, and public sector organizations of eastern North Carolina.

2. Strategic plan

The proposed master of science program specifically addresses the following ECU Strategic Directions and related sub-elements as presented in ECU Tomorrow [2]:

Education for a new century: We will be responsive to the changing demands of the economy, offering excellent undergraduate and graduate programs that provide the global skills and knowledge necessary for success in the twenty-first century.

Economic Prosperity in the East: We will invest in academic programs that give individuals the right skills and tools needed to compete and thrive in a twenty-first-century workplace. We will provide ongoing educational and learning opportunities to support the continued development of a competitive workforce for North Carolina.

ECU will increase investment in innovation and research: We will lead in innovation in health sciences and information technology and seek to develop products that compete in the growing knowledge-based economy. We will focus on developing applied, translational, and externally focused research that emphasizes the economic and physical health of our citizens.

Health Care and Medical Innovation: ECU will save lives, cure diseases, and positively transform the quality of health care for the region and state. ECU will expand our research in health sciences with a particular emphasis on the health concerns of the region and state. We will expand biomedical and health-related research funding to $75 million annually.

Biomedical engineering is a twenty-first century career field. The proposed program meets the demands of the economy, providing a graduate program which allows ECU graduates to excel and compete in the global economy. In addition, this degree has substantial positive impact on improving the resources for the regional community to improve health care and economic development. Engineering is a global business field, and graduates of the proposed program will be well-prepared to participate in this global endeavor, impacting developing new technologies in the biomedical field.

The MS in biomedical engineering will have a strong impact on health care and innovation. This program will positively influence research productivity, support innovation in health sciences, support interdisciplinary research improving health care and biotechnology, and support overall improvement of the health of our citizens. Funding opportunities for biomedical engineering research are available through the National Science Foundation, National Institutes of Health, Department of Defense and private foundations, and funding for this interdisciplinary effort will be sought from all sources noted. According to the American Institute for Medical and Biological Engineering (AIMBE) Academic Council, universities with bioengineering programs receive the largest part of funding from the NIH and significant funding from NSF, the federal Small Business Administration, Department of Defense and Department of Energy [3]. Engineering faculty are currently involved in interdisciplinary efforts with faculty and graduate students on the ECU campus. Outcomes of these research efforts will result in biomedical engineering devices, products and innovations to enhance the engineering workforce and economic development in North Carolina. Engineering faculty currently involved in multidisciplinary collaborative projects with faculty on ECU's Health Science Campus include:

- Dr. Jason Yao and Dr. Gregg Givens, College of Allied Health Sciences, co-inventor on patent application, "Internet-based Multi-user Diagnostic Hearing Assessment Systems Having Client-server Architecture with User-based Access Levels for Secure Data Exchange".
- Dr. Ricky Castles and Dr. Mary Ann Rose, College of Nursing. Project to develop an accelerometer-based body position sensor for hospitalized morbidly obese patients.

- Dr. Sunghan Kim and Dr. Paul DeVita, Department of Kinesiology. Project to identify markers of instability and balance and develop therapeutic feedback system for patients with diabetic neuropathy.
- Dr. Sunghan Kim and Dr. T. Bruce Ferguson, Department of Cardiovascular Sciences. Diagnostic imaging and signal analysis.
- Drs. Barbara Muller-Borer and Alan Kypson, Department of Cardiovascular Sciences. Co-PIs on industry sponsored research program to evaluate biocompatible surgical materials. Industry sponsor, Pioneer Surgical Orthobiologics, Greenville, NC
- Drs. Barbara Muller-Borer, Brian Cabarrus and Wiley Nifong, Department of Cardiovascular Sciences. Collaborators on NSF-SBIR research program to evaluate intravital fiber optic imaging system. Industry sponsor, Wasatch Photonics, RTP, NC.
- Dr. Stephanie George and Dr. John Cahill, Department of Cardiovascular Sciences. Project to develop MR and computational analysis techniques to assess pulmonary hypertension.

3. Responsiveness to local, regional, or statewide needs

As the population ages, the need for advanced medical tools, devices and diagnostics increases along with the need to improve our understanding of disease states. Thus, as the needs increase so does the demand for biomedical engineers. Due to their unique background, biomedical engineers have one foot grounded in the medical field and one foot grounded in engineering principles. By straddling these fields, biomedical engineers form a bridge upon which medical need, clinical practice, creativity, innovation, collaboration and research can travel freely from one side to the other. Graduates of the proposed program will have a direct impact on advancing health and health care to those living in eastern North Carolina.

According to the Bureau of Labor Statistics, the employment growth for biomedical engineering will increase by 62% over the next ten years illustrating an increasing demand for trained graduates in this field and shown in Table 2 [4]. In addition the Labor Market Information Division of the Employment Security Commission of North Carolina lists biomedical engineering as the fastest growing occupation, with a 77% predicted increase in biomedical engineering jobs from 2008-2018 [5]. Taking a snapshot of the statewide labor market, in October 2012, 4% - 10% of the biomedical engineering jobs advertised on the website ENGINEERJOBS.com were located in North Carolina. The NCBiotech Company Directory available through the North Carolina Biotechnology Center website lists 31, 29 and 382 bioscience companies in the Eastern, Southeastern and Triangle regions of North Carolina (respectively)[6]. Many of these companies are focused on developing products for regenerative medicine, cardiovascular disease, diabetes , drug delivery and medical devices. Thus, there is a demand within the state of North Carolina for biomedical engineers.

Table 2 - SOURCE: U.S. Bureau of Labor Statistics, Employment Projections program [4].

Occupational title	SOC Code	Employment, 2010	Projected employment, 2020	Change, 2010-20	
				Number	Percent
Biomedical Engineer	17-2031	15,700	25,400	9,700	62

Regional industry is already an important constituent and stake holder in the planning and success of ECU's engineering program. The Department of Engineering maintains a collaborative relationship with an EAB comprised of approximately 40 members from industry, consulting firms, academia, and government laboratories. The board meets twice a year to review current

and planned programs, student achievement, and provide guidance on future directions of the engineering program. The board is extremely active, and the department chair maintains contact with the board throughout the year. Members of the **ECU Engineering Advisory Board** include individuals from:

- East Carolina University Brody School of Medicine *
- Vidant Health, Greenville, NC *
- MX Biodevices, Greenville, NC *
- RTI Biologics, Inc. (formerly Pioneer Surgical Orthobiologics, Inc.), Greenville, NC *
- Metrics, Inc., Greenville, NC
- East Group, Greenville, NC
- Pitt County Development Commission, Greenville, NC
- DSM Pharmaceuticals, Greenville, NC *
- DSM-Dyneema, LLC, Greenville, NC
- NAACO Materials Handling Group, Greenville, NC
- North Carolina's Eastern Region, Kinston, NC
- BD Medical, Research Triangle Park, NC *
- GSK, Inc., Research Triangle Park, NC *
- Pharmaceutical Calibrations and Instrumentation, Raleigh, NC
- Triangle Biosystems, Durham, NC *
- North Carolina Biotechnology Center, Research Triangle Park, NC
- Merck & Co., Inc., Wilson, NC *
- Pfizer, Sanford, NC *
- Covidien, Raleigh, NC
- PCS Phosphate, Aurora, NC
- Duke University Fuqua School of Business, Durham, NC
- NASA Langley Research Center, Hampton, VA *
- Centers for Disease Control and Prevention, Atlanta, GA *

* Biomedical engineering employers

It is evident that biomedical engineering organizations are well represented on the EAB and we plan to expand this representation with the growth of the new graduate program. Members of the EAB will serve as program advisors. A number of the EAB members are from healthcare-related industries, providing senior capstone project and internship opportunities. All senior undergraduate engineering students enroll in a two semester capstone project. The objectives are to engage students in innovative, interdisciplinary projects in the health sciences and biotechnology areas. Biomedical engineering capstone projects and sponsors include:

- "Development of a Tactile Input Device for Use in Balance Studies", Leslie Allison, PhD, ECU, College of Allied Health Sciences, Department of Physical Therapy.
- "Design of an Injection Trainer", Dr. Ed Bartlett, Orthopaedics East, Greenville, NC.
- "Design of a Mechanical Labor and Delivery Bed for Low Resource Settings", Center for Disease Control, Atlanta, GA.
- "Modulated Lighting of Approach/Avoidance Inclinations", Dr. Alan Pope, National Aeronautics and Space Administration, Langley Research Center, Hampton, VA.
- "Push-up Pal", Matthew Mahar, PhD, ECU, College of Health and Human Performance, Department of Kinesiology.
- "Plantar Flexion Device", Timothy Gavin, PhD, ECU, College of Health and Human Performance, Department of Kinesiology.

- "Development of the Structure and Steering of a Manual Mobility and Exercise Device: Citty Stepper", Mark Dumas, MD, Kinston, NC.
- "Limits of Stability Testing, Prototype Improvement/Redesign", Leslie Allison, PhD, ECU, College of Allied Health Sciences, Department of Physical Therapy.
- Electrical Stimulation Instrument for 2D and 3D Cell Culture", Barbara J. Muller-Borer, PhD, ECU, Departments of Engineering and Cardiovascular Sciences.
- "Development of an acoustic dust generator for rodent inhalation studies of nanomaterials", Dianne Walters, PhD, ECU, Brody School of Medicine, Department of Physiology.

Four biomedical engineering capstone projects have been identified for fall 2013, to include projects in the Departments of Physiology, Emergency Medicine, Pathology and Psychology. In addition, students are encouraged to complete an internship or participate in a research laboratory experience. ECU undergraduate students have completed internships at Hospira, Inc., Rocky Mount, NC, Pharmaceutical Calibration Incorporated, RTP, NC, BSOM, DSM and RTI Biologics, Inc. (formerly Pioneer Surgical Orthobiologics, Inc.), Greenville, NC. We anticipate continued collaborative opportunities for graduate level research projects and employment following graduation. The engineering faculty continues to actively seek university, industry and government partners to facilitate networking opportunities, technology transfer and innovation.

4. Student demand. Discuss the extent to which students will be drawn from a pool of students not previously served by the institution

With the anticipated growth in employment for biomedical engineers, the Department of Labor reports a graduate degree is recommended or required for many biomedical engineering entry-level jobs [7]. As noted by the National Science Foundation and summarized in Table 3, enrollment in biomedical engineering graduate programs, which increased by 7.5% between 2009 and 2010, continues to be one of the fastest growing science and engineering fields and has experienced the most rapid growth over the last decade (165%), from approximately 3,200 graduate students in 2000 to 8,500 students in 2010 [8]. Currently, a master of science in biomedical engineering degree is offered at three public and two private North Carolina universities. These institutions accept 15% to 24% of qualified applicants applying to their respective degree programs. It is clear that the gap between graduate program admissions and work place needs is significant.

TABLE 3 - Nationwide graduate enrollment in engineering by field: 2000–10, [8].

												% change	
												2000	2009
Field	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	–10[b]	–10
Aerospace engineering	3,407	3,451	3,685	4,048	4,089	4,170	4,482	4,616	4,902	5,266	5,540	65	5.2
Architecture[a]	ne	ne	ne	ne	ne	ne	ne	4,601	5,905	6,804	6,795	-	-0.1
Biomedical engineering	**3,197**	**3,599**	**4,338**	**5,301**	**5,807**	**6,067**	**6,482**	**6,904**	**7,339**	**7,904**	**8,497**	**165**	**7.5**
Chemical engineering	7,056	6,913	7,414	7,516	7,452	7,173	7,261	7,584	7,892	8,188	8,668	25	5.9
Civil engineering[a]	16,451	16,665	17,713	18,890	18,561	18,114	17,802	16,071	16,931	18,638	19,559	20	4.9
Electrical engineering	33,611	36,100	39,948	41,763	38,995	37,450	38,265	40,588	41,164	41,218	41,336	25	0.3
Industrial engineering	12,119	12,940	14,033	14,313	13,852	13,650	13,829	14,474	15,692	15,825	15,205	25	-3.9
Mechanical engineering	15,235	15,852	17,139	18,393	17,852	17,373	17,919	18,347	19,585	21,243	22,509	50	6.0
Metallurgical/materials engineering	4,377	4,721	4,992	5,131	5,059	5,160	5,268	5,314	5,539	5,863	6,274	45	7.0
Other engineering	8,659	9,252	10,406	12,022	11,899	11,408	11,733	13,177	12,907	13,728	14,858	70	8.2

ECU's Department of Engineering offers a bachelor of science in engineering with a concentration in biomedical, bioprocess, mechanical, industrial/systems and electrical engineering (new for academic year 2012-2013). Undergraduate students declare a concentration major at the end of their sophomore year and begin concentration specific courses in their junior year. The first ECU engineering class graduated in 2008 and the undergraduate engineering program was ABET accredited in 2009. The biomedical engineering concentration has been taught since 2009-2010. Enrollment in the undergraduate biomedical engineering concentration has doubled from 10 students in 2009 to 20 in 2012 and is anticipated to increase with the growth of the department (current undergraduate enrollment in the engineering department is over 500 students). Approximately 34% of engineering freshmen, class of 2016, indicate an interest in the biomedical engineering concentration. For the May 2013 graduating class, 19% were biomedical, 10% bioprocess, 14 % industrial systems and 57% mechanical engineering. Currently the strategic plan of the university is for the undergraduate engineering program to grow to +750 students over the next 4-5 years.

The first ECU graduating class with a biomedical engineering concentration graduated in 2011. For the 2011 and 2012 graduates, 58% are employed in concentration specific industries. Employers include Novartis, Merck, Hospira, Inc, and RTI Biologics, Inc. (formerly, Pioneer Surgical Orthobiologics, Inc.). In addition, 33% of the students have pursued graduate degrees at California Polytechnic State University, NC State University, and George Mason University. As of May 2013, 75% of the class of 2013, biomedical engineering concentration, had confirmed industry employment at Hospira, Inc. Rocky Mount, NC, ASMO Greenville, NC, and US government. A 2011 ECU biomedical engineering concentration alumnus will matriculate into the biomedical engineering doctoral program at the Virginia Tech-Wake Forest School of Biomedical Engineering and Sciences in fall 2013.

Currently, a master of science in biomedical engineering degree is offered at three public (NC A&T State University and UNC/NC State) and two private (Duke University and Wake Forest University/VA Tech) North Carolina universities. According to the American Society for Engineering Education the number of students graduating with a master of science in biomedical engineering from these universities (2008-2012) includes [9]:

- NC A&T State University – 0 (6 graduates in 2013, self report)
- UNC/NCSU - 15
- Duke University - 159
- Wake Forest/VT - 23

All of these graduate programs are located in central or western North Carolina. Except for UNC/NCSU which has focused on growing their doctoral program, enrollment and graduation rates at the master's level have remained constant at these universities during this five-year period. To better understand the demand for this graduate program several other biomedical engineering master of science programs, similar in size and academics to ECU's engineering program were surveyed. Master of science in biomedical engineering graduation rates (2008-2012) for these programs were:

- Mercer University, GA – 16
- University of Alabama Birmingham – 41
- Virginia Commonwealth University – 53

These numbers are similar to those at NC universities and suggest a strong need for a master of science in biomedical engineering. It should be noted that none of these programs are located in eastern North Carolina. Approximately 47% of the current ECU engineering students are from

eastern North Carolina and 60% of the ECU Engineering alumni are from eastern North Carolina. Therefore, there is a need to be fulfilled within the state of North Carolina for the training of biomedical engineers, particularly in eastern North Carolina. East Carolina University has an advantage, both nationally and regionally, as the only university within the 17 University of North Carolina institutions that offers academic programs in engineering, medicine, dentistry, business, nursing and allied health on one campus. This proximity of complementary programs provides an unequaled opportunity for collaboration and professional growth of faculty, staff, and students. The proposed program is intended to meet the student and employer demands for advanced education and research training for biomedical engineers within eastern North Carolina, the state and nation.

5. Employment opportunities. Document need for proposed degree recipients in the region, the state, or nationally

Employment in the United States is projected to grow from 143.1 million jobs in 2010 to more than 163.5 million in 2020, an increase of nearly 20.5 million jobs [7]. About 877,000 of these new jobs will require a doctorate or a professional degree for entry, and about 431,000 will require a master's degree for entry [10]. The Bureau of Labor Statistics reports that a bachelor's degree is required for entry-level engineering positions. A graduate degree is necessary for senior level positions or to teach at the college level. However, unlike other engineering specialties, the Department of Labor reports a graduate degree is recommended or required for many biomedical engineering entry-level jobs. According to the U.S. Department of Labor, the number of biomedical engineering jobs is expected to increase much faster than the average for all other occupations [11]. As previously noted, the employment growth for biomedical engineering is expected to increase by 62% over the next ten years according to the Bureau of Labor Statistics [4]. In addition, the Labor Market Information Division of the Employment Security Commission of North Carolina lists biomedical engineering as the fastest growing occupation with a 77% predicted increase in biomedical engineering employment in 2008-2018. As noted by the National Science Foundation and summarized in Table 3, enrollment in biomedical engineering graduate programs, which increased by 7.5% between 2009 and 2010, continues to be one of the fastest growing science and engineering fields and has experienced the most rapid growth over the last decade (165%). "Because of the growing interest in this field, the number of degrees granted in biomedical engineering has increased greatly. Many biomedical engineers, particularly those employed in research laboratories, need a graduate degree to be competitive" [12]. A recent search for biomedical engineering jobs on the job-site Monster.com, showed that 55% of the biomedical engineering jobs advertised required a bachelor's degree while 30% required a master of science degree. Local and regional industrial, clinical, and academic partners previously listed (see Section II.A.3, Engineering Advisory Board) provide a source and resource for employment opportunities for biomedical engineering professionals, and promote networking, continuing education and career advancement for graduates.

B. Discuss potential program duplication, program competitiveness, and opportunities for collaboration in the delivery of the program

1. Identify similar programs offered by public and private universities elsewhere in North Carolina. Indicate how the proposed new degree program differs from other programs like it within UNC. If the program duplicates other UNC programs, explain:
   a. Why the proposed program is necessary or justified, and
   b. How all or portions of the curriculum might be offered collaboratively with another UNC institution.

A summary of MS in biomedical engineering or similar programs offered at North Carolina public and private universities is listed below. All programs listed are located 85 miles or more from Greenville, NC, and only one program currently offers courses via distance education. The graduate programs at the UNC/NCSU Joint Department of Biomedical Engineering, NC A&T State University, and the JSNN are accessible for collaborative academic, research and laboratory opportunities for ECU students and faculty. East Carolina University's Department of Engineering is currently exploring collaborative course and research opportunities with these programs. ECU students may choose to register as non-degree seeking students at these NC universities or other approved engineering programs and take up to 6 s.h. of transfer engineering graduate courses to supplement course offerings. Furthermore, it is anticipated that a number of graduates of the MS program will continue their academic and research careers by matriculating into engineering PhD programs and/or professional degree programs at these NC institutions. The proposed MS curriculum (see Section III.D, required courses, page 21) does not substantially duplicate course offerings by other MS in biomedical engineering programs and would allow students to supplement course offerings via distance education or transfer credits. This arrangement is important for out of cycle students and provides electives in areas such as advanced biomaterials and nanoengineering. The following summaries describe the related programs of the UNC system or private universities.

UNC SYSTEM SUMMARY

University of North Carolina at Chapel Hill (Location: Chapel Hill, NC, 111 miles from ECU)
North Carolina State University (Location: Raleigh, NC, about 85 miles from ECU)
Program: MS in Biomedical Engineering
The University of North Carolina at Chapel Hill/North Carolina State University Joint Department of Biomedical Engineering was established in 2003. The four engineering cores include rehabilitation engineering, biomedical imaging, pharmacoengineering and microsystems engineering. Courses are offered on the UNC or NCSU campus. Courses are not offered by distance education.

North Carolina Agricultural and Technical State University (Location: Greensboro, NC, 160 miles from ECU)
Program: MS in Bioengineering
NC A&T University, in collaboration with the University of Pittsburgh, University of Cincinnati, and Germany's Hannover School of Medicine, Indian Institute of Technology Madras, California State University at Los Angeles, Guilford Technical Community College, and Edmonds Community College, has developed an educational and research program in bioengineering. The master of science in bioengineering emphasizes advanced study in two specialization areas: (i) biomaterials and biomechanics, and (ii) bioimaging, biosignals and biosensors. Some courses are offered by distance education and could be made available to ECU students.

Joint School of Nanoscience and Nanoengineering (Location: Greensboro, NC, 160 miles from ECU)
Program: MS in Nanoengineering
The Joint School of Nanoscience and Nanoengineering (JSNN) was formed as a collaborative project of North Carolina A&T State University and The University of North Carolina at Greensboro. The JSNN's research and educational programs focus on Nanoscience and Nanoengineering. Courses are offered on the JSNN campus and state-of-the-art equipment is available for training and research. Courses are not offered by distance education.

University of North Carolina at Charlotte (Location: Charlotte, NC, 240 miles from ECU)
Center for Biomedical Engineering and Science (CBES)
Program: No MS degree offered within Center
The CBES at the University of North Carolina at Charlotte was established in 2005 to include research faculty in the Colleges of Engineering, Arts & Sciences, Health & Human Services and Computing & Informatics, OrthoCarolina, Carolina's Medical Center and Presbyterian Hospital. The research focus of the CBES includes medical therapies & technologies, molecular engineering & design and biomechanics & mobility research. The Department of Mechanical Engineering offers one course in biotechnology and bioengineering.

PRIVATE UNIVERSITIES

Programs at the following private colleges and universities were also surveyed.
Duke University (Location: Durham, NC, 110 miles from ECU)
Program: MS in Biomedical Engineering
Major research programs include biomechanics, biomolecular and tissue engineering, electrobiology and biomedical imaging. Courses are offered on the Duke University campus. Courses are not offered by distance education.

Virginia Tech -Wake Forest University (Location: Winston-Salem, NC, 200 miles from ECU)
Program: MS in Biomedical Engineering
The joint graduate degree program in biomedical engineering is offered through Virginia Polytechnic Institute and State University (Virginia Tech) and Wake Forest University in the School of Biomedical Engineering and Sciences. Areas of concentration include biomechanics, cell & tissue engineering, medical imaging & medical physics. The program was established in 2003. Courses are offered on the Wake Forest and Virginia Tech campuses. Courses are not offered by distance education.

2. If the program is a graduate or first professional degree, compare it with other similar programs in public and private universities in North Carolina, in the region, and in the nation. Where appropriate, describe how all licensure or professional accreditation standards will be met, including required practica, internships, and supervised clinical experiences.

N/A

C. Enrollment (baccalaureate programs should include only upper division majors, that is, juniors and seniors).

Headcount enrollment

Show a four-year history of enrollments and degrees awarded in similar programs offered at other UNC institutions (using the format below for each institution with a similar program); indicate which of these institutions you consulted regarding their experience with student demand and job placement. Indicate how their experiences influenced your enrollment projections.

Institution: **University of North Carolina at Chapel Hill and North Carolina State University Joint Department of Biomedical Engineering ***
Program Title: **Master of Science in Biomedical Engineering**

	(2007-2008)	(2008-2009)	(2009-2010)	(2010-2011)
Enrollment	16 FT 3 PT	5 FT 13 PT	NA	9 FT 12 PT
Degrees-awarded	7	2	6	0

An average of 78 applicants/year applied to the biomedical engineering master of science program from 2007 – 2011, with an average of 8 full time applicants/year accepted into the program. Job placement data for graduates were not available. A majority of the students applying to the department pursue a PhD curriculum. The number of PhD students is not represented in the chart.

Institution: **North Carolina A&T State University Department of Biomedical Engineering ***
Program Title: **Master of Science in Bioengineering**

	(2008-2009)	(2009-2010)	(2010-2011)	(2011-2012)
Enrollment	NA	NA	7	8
Degrees-awarded	NA	NA	0	0

An average of 12 applicants per year applied in the first two years of instruction. There were no graduates of the program at the time of inquiry and no data available on job placement. The program accepts undergraduate majors from chemical engineering, mechanical engineering, industrial engineering, biology, chemistry and physics.

*UNC institutions consulted regarding experience with student demand and job placement

As previously noted, ECU's Department of Engineering currently offers a bachelor of science in engineering with a concentration in biomedical engineering. Enrollment in this undergraduate engineering concentration has doubled from 10 students in 2009 to 20 in 2012 and is anticipated to increase with the growth of the department. Approximately 34% engineering freshmen, class of 2016, indicated an interest in the biomedical engineering concentration. Based on the number of applicants and enrollment at NC A&T State University and UNC/NCSU, as well as requests for an MS in biomedical engineering by current and former ECU students, and anticipated job demand in NC the projected enrollment for the proposed program is shown below.

Please indicate the anticipated first year and fourth year steady-state enrollment (head count) for the proposed program.

Year 1: Full Time ___4____ Part-time ___2____ Total ___6____

Year 4: Full-time ___20___ Part-time ___4____ Total ____24___

III. PROGRAM REQUIREMENTS AND CURRICULUM

A. Program Planning

1. List the names of institutions with similar offerings regarded as high quality programs by the developers of the proposed program.

   - UNC/NCSU Joint Department of Biomedical Engineering
   - North Carolina Agricultural & Technical State University
   - Virginia Tech -Wake Forest University School of Biomedical Engineering and Sciences
   - Mercer University
   - Virginia Commonwealth University
   - University of South Carolina
   - The University of Alabama Birmingham

2. List institutions visited or consulted in developing this proposal. Also discuss or append any consultants' reports or committee findings generated in planning the proposed program.

- UNC/NCSU Joint Department of Biomedical Engineering
- North Carolina Agricultural & Technical State University
- Joint School of Nanoscience and Nanoengineering

B. Admission. List the following:

1. Admissions requirements for proposed program (indicate minimum requirements and general requirements).

A faculty committee within the Department of Engineering will review applications and make recommendations regarding admissions to the Departmental Director of Graduate programs. This information will be conveyed to the Graduate School. Admission procedures will follow the graduate school process and criteria.

In addition, the faculty committee will award graduate assistantships. Criteria to be used for awarding graduate assistantships will include:

- GPA and overall academic performance in current or most recent undergraduate or graduate program
- Performance in standardized graduate exams such as the GRE
- Strength of recommendation letters
- Experience and potential for teaching if the position is for a TA
- Appropriateness of degree(s) and field(s) of interest for funding coming from a grant if the focus is research oriented.
- Assessment of a statement of purpose for graduate study to be provided with the application

General Admission Requirements:
Students applying for admission to the MS in biomedical engineering program must meet the general requirements of admission set forth in the *East Carolina University Bulletin, Graduate Catalog*.

Applicants may be admitted to the MS in biomedical engineering program under unconditional or provisional admission. In addition, for advanced, highly motivated undergraduate students, we will offer an integrated bachelor's/master's in biomedical engineering. For this program, graduate student course work will begin in the students' fourth year of undergraduate study and be completed with one academic year of study beyond the bachelor's degree.

Unconditional Admission Requirements:
Applicants for study in biomedical engineering should have a bachelor's degree in engineering and a minimum 3.0/4.0 grade point average in the last two years of undergraduate study. The following minimum preparation is recommended:

- Biology- one semester
- Mathematics- calculus through differential equations, probability and statistics
- Physics- two semesters
- Chemistry- one semester
- Engineering - one course in basic electrical engineering,
- Engineering - an introductory course in three of the following five areas:
    i. materials science or biomaterials,
    ii. mechanics or fluid mechanics,
    iii. transport or heat and/or mass transfer,
    iv. instrumentation
    v. systems physiology

- Engineering research or design experience

Provisional Admission:
Applicants may be granted provisional admission if they do not qualify for unconditional admission. In particular, students entering from disciplines other than engineering may find it necessary to take preparatory undergraduate and/or graduate level courses that serve as prerequisites. Students admitted to the MS in biomedical engineering program are expected to have undergraduate preparation in biology, mathematics, physics, and chemistry as previously listed. Based on the specific research area, students may be asked to take additional courses in organic chemistry, genetics, biochemistry, linear systems, computer programming, analog and digital electronics, solid or fluid mechanics and thermodynamics. It should be noted that preparatory courses that are for undergraduate credit only may not be applied toward credit hours required for a graduate degree.

Integrated Bachelor's/Master's of Science in Biomedical Engineering
This program is to be initiated while undergraduates are completing the BS degree and is intended for outstanding undergraduates who have worked with a thesis advisor during their undergraduate studies. It is anticipated that a full year of study beyond completion of undergraduate requirements will be required to complete this program. Students may apply to the program after completion of a minimum of 81 eligible undergraduate credit hours, and can enter the program after completion of a minimum of 97 eligible undergraduate credit hours (a minimum of 128 credit hours is required for BS degree). Applicants must have substantially completed their general education requirements, and expect to complete their undergraduate degree in 4 years. The minimum GPA at the time of admission and entry to the program is 3.5. Students applying to the integrated bachelor's/master's in biomedical engineering program will go through the regular graduate application process with the following exceptions: (1) "Integrated BS/MS" will be indicated on the application, and (2) in the personal statement, the student will indicate why they are interested in BME graduate education and the integrated program. In addition to regular criteria, the admissions committee will evaluate whether the applicant has demonstrated the maturity necessary for success in an integrated, highly competitive program.

2. Documents to be submitted for admission (listing or attach sample).

The required documents will follow East Carolina University's graduate school guidelines:

- Completed standard graduate school application form
- Official undergraduate transcripts
- Two letters of reference
- Personal Statement
- GRE scores
- TOEFL scores if applicable (Students for whom English is not the primary language must submit scores from the Test of English as a Foreign Language (TOEFL), the International English Language Testing System (IELTS), or Pearson Test of English (PTE))

C. Degree requirements. List the following:

1. Total hours required. State requirements for Major, Minor, General Education, etc.
   A minimum of 32 semester hours including six (6) thesis hours is required. No minors are proposed.

The degree requirements are similar to the institutions with similar master of science in biomedical engineering programs (see Section III.A.1 for list of programs). Minimum requirements range from 30 – 32 semester hours and 3 – 9 thesis hours. Most programs assign 0 credit hours for required seminar and introductory courses.

2. Other requirements (e.g. residence, comprehensive exams, thesis, dissertation, clinical or field experience, "second major," etc.).
   a. Research-based written thesis
   b. Oral defense of thesis
   c. Public presentation of thesis research

For graduate programs only, please also list the following:

3. Proportion of courses open only to graduate students to be required in program
   All required and elective courses must be at the graduate level.

4. Grades required

   Grades for graduate students are recorded as:

   A, excellent
   B, average
   C, below average
   F, failure
   I, Incomplete
   S, (Satisfactory progress in thesis or dissertation research) A special grade reserved for thesis and dissertation courses. The grades in these courses are not included in meeting the cumulative grade point average of 3.0 required for graduation.
   U, (Unsatisfactory progress in thesis or dissertation research) A special grade reserved for thesis and dissertation courses. The grades in these courses are not included in meeting the cumulative grade point average of 3.0 required for graduation.
   W, withdrawal

   a. In order to remain in good academic standing, graduate students must maintain a minimum cumulative GPA of 3.0 .
   b. A grade of A or B is required for all biomedical engineering courses (see Section III.D below for list of required courses).
   c. A grade of C is allowed for course work in departments outside of engineering.
   d. A graduate student automatically goes on probation when his/her cumulative GPA falls below 3.0 (“B”).
   e. A grade of F will constitute grounds for dismissal
   f. The grade of "I" is given for a deficiency in the quantity of work done in a course. "I" grades must be resolved within one calendar year or a grade of "F" will be automatically assigned. No exceptions to this policy will be allowed. No student will be allowed to graduate with an incomplete on his or her record.

5. Amount of transfer credit accepted

   A maximum of 20% (i.e., six (6) credit hours) with a grade of “B” or better will be allowed which is in compliance with ECU Graduate School’s policy. Up to six (6) credit hours of graduate course work with a grade of “B” or better taken at ECU as an undergraduate student may be transferred to the MS in biomedical engineering program provided it was not counted to fulfill undergraduate requirements. No graduate credit will be allowed for excess credits completed in an undergraduate classification at another institution.

6. Language and/or research requirements
   - Language:
     For admission into the program students must submit TOEFL scores if applicable (Students for whom English is not the primary language must submit scores from the Test of English as a Foreign Language (TOEFL), the International English Language Testing System (IELTS), or Pearson Test of English (PTE).)
   - Research requirements (previously noted):
     a. Research-based written thesis
     b. Comprehensive defense of thesis
     c. Public presentation of thesis research
7. Any time limits for completion

East Carolina University's Graduate School's policy of a six-year time limit will be adhered to. Students are expected to graduate in two years.

D. For all programs, list existing courses by title and number and indicate (*) those that are required. Include an explanation of numbering system. List (under a heading marked "new") and describe new courses proposed.

Curriculum development is in the planning stage and discussions have included the joint faculty listed (Section IV.A). Discussions with engineering and joint faculty have included:

- access to graduate level courses offered in their schools and departments.
- collaborative research opportunities in funded laboratories.

With regards to course numbers, the first number is the level with 5, 6 and 7 being graduate level.

Required courses for all students admitted to the MS in biomedical engineering program include:
***Introduction to Biomedical Engineering Research**
***Biomedical Engineering – 4 courses**
***Life Science – 1 course**
***Biostatistics – 1 course**
***Mathematics - 1 course**
***Technical Elective - 1 course**
***Thesis**

Existing Courses:

Life Science (1 course)*

- PHYL 6330 Human Physiology (5 s.h.)
- PHLY 7701 Graduate Cellular Physiology (3 s.h.)
- BIOL 6071 Human Gross Anatomy (4 s.h.)
- BIOL 6300 Neurophysiology (3 s.h.)

Biostatistics/Statistics (1 course)*

- BIOS 7021 Biostatistics for Health Professionals (I) (3 s.h.)
- BIOS 7501 Experimental Design (3 s.h.)
- MATH 5031 Applied Statistical Analysis (3 s.h.)
- MATH 5801 Probability Theory (3 s.h.)
- PHAR 7777 Biometry (3 s.h.)

Mathematics (1 course)*

- MATH 5101 Advanced Calculus I (3 s.h.)

- MATH 5102 Advanced Calculus II (3 s.h.)
- MATH 5110 Elementary Complex Variables (3 s.h.)
- MATH 5121 Numerical Analysis in One Variable (3 s.h.)
- MATH 6401 Introduction to Partial Differential Equations I (3 s.h.)
- MATH 6411 Ordinary Differential Equations I (3 s.h.)
- PHYS 5311 Mathematical Physics (3 s.h.)

Technical elective (1 course)*

- EXSS 6200 Biomechanics (3 s.h.)
- PHYS 6720 Physics of Medical Imaging (3 s.h.)
- PHYS 6715 Biomedical Physics (3 s.h.)
- PHYS 7715 Biomedical Optics (3 s.h.)
- BIOL 7880, 7781 Bioinformatics (3 s.h.)

Other existing graduate-level courses may be taken as technical electives when approved by the program director.

New Courses

- BIME 6000, Introduction to BIME Research (2 s.h.) Fall semester. P: Admission to the MS in biomedical engineering program or consent of program director. Introduction to biomedical ethics, library systems, thesis and research publications, review and critique of current literature.*

- BIME 7000, Thesis Research (3 s.h.) May be repeated and count for a maximum of 6 s.h.*

BIME Courses (4 BIME courses required)*

- BIME 6200, Biomedical Instrumentation/Measurements (3 s.h.) P: Admission to the MS in biomedical engineering program or consent of program director. General principles of signal acquisition, amplification processing, recording, and display in medical instruments. System design, construction, and evaluation techniques will be emphasized.

- BIME 6250, Biomedical Signal Processing (3 s.h.) P: Admission to the MS in biomedical engineering program or consent of program director. The course will cover principles underlying the processing of one and two dimensional signals, including Fourier transforms, sampling, quantization, correlation, and filtering. Matlab projects, with an emphasis on biomedical signals.

- BIME 6300, Cardiac Electrophysiology (3 s.h.) P: Admission to the MS in biomedical engineering program or consent of program director. Electrophysiological behavior of cardiac muscle. Emphasis on quantitative study of cardiac tissue with respect to propagation and the evaluation of sources. Effect of junctions, inhomogeneities, and anisotropy.

- BIME 6350, Cardiovascular Biomechanics (3 s.h.) P: Admission to the MS in biomedical engineering program or consent of program director. The mechanical behavior of the cardiovascular system will be explored in a quantitative manner.

- BIME 6400, Biomaterials (3 s.h.) P: Admission to the MS in biomedical engineering program or consent of program director. Topics include basic material types and functions, tissue response mechanisms, and considerations for long term usage.

- BIME 6450, Biomolecular Engineering (3 s.h.) P: Admission to the MS in biomedical engineering program or consent of program director. Topics include the application of natural processes into bio-inspired devices, such as biosensors, research tools, new materials, pharmaceuticals, transducers, and the design of interfaces for biological components with conventional engineering materials.
- BIME 6500, Introduction to Tissue Engineering (3 s.h.) P: Admission to the MS in biomedical engineering program or consent of program director. An overview of selected topics in the field of tissue engineering including cell sourcing and maintenance of differentiated state, culture scaffolds, cell-biomaterials interactions, and surgical implantation for therapies to repair or replace cells, tissue, and organs damaged by disease, trauma, or congenital conditions.
- BIME 6700, Selected Topics in Biomedical Engineering (3 s.h.) P: Admission to the MS in biomedical engineering program or consent of program director. The course will address a current body of knowledge in biomedical engineering with a research orientation.

Building on the research strengths of the Brody School of Medicine, School of Dental Medicine, College of Allied Health Sciences and College of Health and Human Performance students may opt to focus their studies in one of the following areas:

- **Cardiovascular Biomedical Engineering**
  - BIME 6350 (Cardiovascular Biomechanics)
  - BIME 6300 (Cardiovascular Electrophysiology)
  - BMED 6200 (Biomedical Instrumentation) or BIME 6250 (Biomedical Signal Processing)
- **Biomolecular & Tissue Engineering**
  - BIME 6500 (Introduction to Tissue Engineering)
  - BIME 6450 (Biomolecular Engineering)
  - BIME 6400 (Biomaterials)
  - BMED 6200 (Biomedical Instrumentation)

IV. FACULTY

A. (For undergraduate and Master's programs) List the names, ranks and home department of faculty members who will be directly involved in the proposed program. The official roster forms approved by SACS may be submitted. For Master's programs, state or attach the criteria that faculty must meet in order to be eligible to teach graduate level courses at your institution.

Department of Engineering Faculty

- O. Hayden Griffin, Jr., PhD, Professor and Chair of Engineering, Department of Engineering
- Barbara J. Muller-Borer, PhD, Associate Professor, Biomedical Engineering, Department of Engineering
- Stephanie George, PhD, Assistant Professor, Biomedical Engineering, Department of Engineering
- Sunghan Kim, PhD, Assistant Professor, Biomedical Engineering, Department of Engineering
- Loren Limberis, PhD, Associate Professor, Bioprocess Engineering, Department of Engineering
- Jason Yao, PhD, Associate Professor, Electrical Engineering, Department of Engineering
- Tarek Abdel-Salem, PhD, Professor, Mechanical Engineering, Department of Engineering
- Ricky Castles, PhD, Assistant Professor, Electrical Engineering, Department of Engineering

- Amanda Funai, PhD, Visiting Assistant Professor, Electrical Engineering, Department of Engineering
- Zhen Zu, PhD, Teaching Assistant Professor, Electrical Engineering, Department of Engineering

Joint Faculty

- Waldemar de Rijk, PhD, DDS, MS, Unit Chief and Clinical Associate Professor, Biomedical Materials Sciences, School of Dental Medicine
- Bobby M. Collins, DDS, MS, Section Chief Oral and Maxillofacial Pathology, School of Dental Medicine
- Robert Lust, PhD, Chair, Department of Physiology and Interim Associate Dean for Research & Graduate Studies, Brody School of Medicine
- Wiley Nifong, MD, Associate Professor, Department of Cardiovascular Sciences
- Kenneth De Ville, PhD, JD, Professor, Department of Bioethics and Interdisciplinary Studies
- Daniel Goldberg, PhD, JD, Assistant Professor, Department of Bioethics and Interdisciplinary Studies
- Joe Houmard, PhD, Professor, Director of Human Performance Laboratory, Department of Kinesiology
- Zachary Domire, PhD, Associate Professor, Department of Kinesiology
- Zhibin Huang, PhD, Assistant Professor, Department of Physics

In addition, the MS in biomedical engineering program integrates well with the MS in biomedical sciences and interdisciplinary doctoral program in biological sciences (IDPBS) biomedical sciences concentration. Both graduate programs are offered in the Brody School of Medicine. These graduate programs emphasize basic science, medical, pharmaceutical, and biotechnology research. The proposed MS in biomedical engineering program will complement these research areas, and expand course selection for graduate students both in engineering and in the above disciplines. Drs. Muller-Borer and George are faculty in the IDPBS program. Dr. Muller-Borer is the graduate program director for the IDPBS biomedical science concentration.

Currently, faculty from the School of Dental Medicine, Department of Kinesiology, Department of Physical Therapy, Department of Cardiovascular Sciences, Department of Physiology and College of Nursing collaborate with biomedical engineering faculty to enhance undergraduate education. This includes:

- Lectures in biomaterials (Drs. deRijk and Collins, School of Dental Medicine)
- Lectures in biomechanics (Dr. Domire, Department of Kinesiology, Dr. Allison, Department of Physical Therapy)
- Lectures in biomedical device applications (Dr. Sam Sears, Department of Psychology and Cardiovascular Sciences)
- Introduction to basic science, robotics and biomechanics laboratories (Dr. Muller-Borer, Department of Engineering and Cardiovascular Sciences, Dr. Nifong, Department of Cardiovascular Sciences, Dr. Domire, Department of Kinesiology, Dr. Allison, Department of Physical Therapy)
- Senior capstone project sponsors (Dr. Muller-Borer, Department of Cardiovascular Sciences, Dr. Walters, Department of Physiology, Brody School of Medicine, Dr. Allison, Department of Physical Therapy, Dr. Rose, College of Nursing)
- Undergraduate research opportunities (Dr. Muller-Borer, Department of Engineering and Cardiovascular Sciences, Dr. Virag, Department of Physiology, Brody School of Medicine, Drs.

Rosenbaum, Oppelt and O'Rourke, Department of Comparative Medicine, Brody School of Medicine)

- Multidisciplinary faculty research projects (Department of Kinesiology, Department of Cardiovascular Sciences, College of Nursing)

Criteria that faculty must meet in order to be eligible to teach graduate level courses
All tenure-track faculty who hold the appropriate terminal degree for the discipline in which they hold their appointments are deemed to be members of the graduate teaching faculty upon their initial appointments. Qualifications for graduate teaching faculty members include:

- Highest earned degree in the field.
- Professional certifications or licensure as specified by the code unit.
- Demonstrated evidence of success or the potential for successful graduate teaching.
- Evidence of professional growth, e.g., completion of continuing education, participation in relevant seminars, or other professional activity. In some instances, especially for clinical faculty, extensive professional experience, high productivity, or successful competition for research/creative activity support may substitute for the highest degree.

Graduate teaching faculty members may teach masters' or doctoral classes as appropriate for their background, certification, and experience and may be the fourth member of a master's committee upon certification of appropriate experience or expertise by the unit administrator.

B. (For doctoral programs) List the names, ranks, and home department of each faculty member who will be directly involved in the proposed program. The official roster forms approved by SACS may be submitted. Provide complete information on each faculty member's education, teaching and research experience, research funding, publications, and experience directing student research including the number of theses and dissertations directed.

C. Estimate the need for new faculty for the proposed program over the first four years. If the teaching responsibilities for the proposed program will be absorbed in part or in whole by the present faculty, explain how this will be done without weakening existing programs.

The impact of the program on the Department of Engineering will be to increase the teaching demands on the biomedical engineering faculty, and several electrical, mechanical and bioprocess engineering faculty. New faculty have recently been hired in the Department of Engineering to meet the educational demands of the growing undergraduate engineering program (i.e., one visiting assistant professor and one teaching assistant professor). These strategic new hires in biomedical and electrical engineering faculty and future faculty hires will reduce undergraduate teaching demands on the graduate faculty. In addition, future faculty searches focused on electrical and mechanical engineering expertise provide an opportunity to recruit faculty with subspecialty interests in biomedical engineering. These faculty positions will help to alleviate the increased undergraduate teaching demands and/or supplement graduate courses. Finally, the presence of engineering graduate students will establish a resource for teaching assistants, supporting faculty and contributing to the success of the program.

D. Explain how the program will affect faculty activity, including course load, public service activity, and scholarly research.

A significant advantage of the MS in biomedical engineering program will be to provide additional research and collaborative opportunities for existing faculty and enable ECU to recruit and retain highly qualified new faculty. New collaborative relationships established with the Brody School of Medicine, School of Dental Medicine, College of Nursing, College of Allied Health Sciences, College of Health and Human Performance, Thomas Harriot College of Arts and Sciences, College of Business, East Carolina Diabetes and Obesity Institute, East Carolina Heart Institute, Leo W.

Jenkins Cancer Center and The Harriet and John Wooten Laboratory for Alzheimer's and Neurodegenerative Diseases Research will have a positive impact on scholarly activity and public service in the Department of Engineering and across the university.

ECU has a history of supporting innovation and translational research. In 2012, ECU was named a charter member of the National Academy of Inventors. Twenty-three ECU faculty were inducted in 2012-2013, including Jason Yao, PhD from the Department of Engineering. Other engineering faculty currently involved in multidisciplinary collaborative projects with faculty on ECU's Health Science Campus include:

- Dr. Jason Yao and Dr. Gregg Givens, College of Allied Health Sciences, co-inventor on patent application, "Internet-based Multi-user Diagnostic Hearing Assessment Systems Having Client-server Architecture with User-based Access Levels for Secure Data Exchange".
- Dr. Ricky Castles and Dr. Mary Ann Rose, College of Nursing. Project to develop an accelerometer-based body position sensor for hospitalized morbidly obese patients.
- Dr. Sunghan Kim and Dr. Paul DeVita, Department of Kinesiology. Project to identify markers of instability and balance and develop therapeutic feedback system for patients with diabetic neuropathy.
- Dr. Sunghan Kim and Dr. T. Bruce Ferguson, Department of Cardiovascular Sciences. Diagnostic imaging and signal analysis.
- Drs. Barbara Muller-Borer and Alan Kypson, Department of Cardiovascular Sciences. Co-PIs on industry sponsored research program to evaluate biocompatible surgical materials. Industry sponsor, Pioneer Surgical Orthobiologics, Inc., Greenville, NC.
- Drs. Barbara Muller-Borer, Brian Cabarrus and Wiley Nifong, Department of Cardiovascular Sciences. Collaborators on NSF-SBIR research program to evaluate intravital fiber optic imaging system. Industry sponsor, Wasatch Photonics, RTP, NC.
- Dr. Stephanie George and Dr. John Cahill, Department of Cardiovascular Sciences. Project to develop MR and computational analysis techniques to assess pulmonary hypertension.

Research efforts in these areas are either ongoing through existing grants or are in development. Faculty members in the proposed program are currently preparing competitive grant applications for initial submission in the 2013-2014 academic years. It is anticipated that external grant funding will provide graduate assistant support contributing to the success of the program. New projects includes:

Jason Yao, PhD, Associate Professor, Electrical Engineering, Department of Engineering

- PI, "*Collaborative Research: Cyber-Physical Tools for the MOOC Age: Personalized Hands-On Electrical Engineering Learning Experiences for Distributed Education",* $150,063. NSF-ECR program, 1/1/2014 – 12/31/2016.
- PI, "*Timely Assessment of Cochlear Integrity in Combat Theater,"* Department of Defense, $259,158. pending.
- Co-PI, "*Cubesat ground station: NCER subcontract,"* AgCarolina Financial $4,998.00. (PI: Eban Bean, PhD, ECU Department of Engineering) pending.

Barbara J. Muller-Borer, PhD, Associate Professor, Biomedical Engineering, Department of Engineering

- Collaborating Investigator, "*Peroxisomal-Mitochondrial Interactions in Human Skeletal Muscle and Obesity*" National Institutes of Health RO1 (PI, Ron Cortright, PhD, ECU Department of Kinesiology) $1,465,450.000, in revision.

- Co-PI, *"Intramyocardial EphrinA1-Fc Reduces Acute Injury and Chronic Remodeling"*. National Heart, Lung and Blood Institute R21, (PI: Jitka I. Virag, PhD, ECU Department of Physiology) $300,000, in revision.
- Collaborating Investigator, *"Pilot Study on Disparities of Peri-Partum Cardiomyopathy*", ECU Center for Health Disparities (PI, Long Cao, MD, ECU Department of Cardiovascular Sciences), $75,000, pending.

Stephanie M. George, PhD, Assistant Professor, Biomedical Engineering, Department of Engineering

- PI, "*MR and Computational Analysis of the Pulmonary Artery and Right Ventricle in Pulmonary Hypertension*", American Heart Association Beginning Grant-in-Aid Mid-Atlantic Affiliate, $153,115, pending.
- PI, "*Hemodynamic Investigation of Pulmonary Hypertension using MRI and CFD*", NIH Heart, Lung, and Blood Institute, $440,396, pending.
- PI, *"MR-Guided Differentiation of Pulmonary Hypertension in Sickle Cell Patients*", ECU Center for Health Disparities, $ 223,911, pending.
- PI, "*Biomedical Engineering in Simulations, Imaging, and Modeling (BME-SIM)* ", NSF – REU, $360,000, pending

Ricky T. Castles, PhD, Assistant Professor, Electrical Engineering, Department of Engineering

- Collaborating Investigator, "*ECU Connects! Expanding the STEM Pipeline through long-term partnerships between schools and industry*". NSF Math Science Partnership Grant Program. $1,378,264, 36 months 2013-2016, pending.
- PI, "*Advancing Personalized Learning- Using Physiological Sensors to Evaluate the Effectiveness of Novel Instruction in Engineering Statics* ", NSF – REU, $300,000, pending

It should be noted that, Dr. George and Dr. Castles are each preparing NSF-Research for Undergraduate proposals (August 2013 submission). It is anticipated that awarding of these programs will facilitate recruiting of competitive graduate students to this master of science program.

As noted in Section IV.C, the MS in biomedical engineering program will impact the course load of the engineering faculty. The Department of Engineering is proactively addressing this situation through strategic new faculty hires (i.e. Drs. Funai and Zu) for the undergraduate engineering program.

V. LIBRARY

A. Provide a statement as to the adequacy of present library holdings for the proposed program to support the instructional and research needs of this program.

The J.Y. Joyner Library on east campus and William E. Laupus Health Sciences Library on west campus provide library resources and services to support the research, teaching, and service goals of East Carolina University. Joyner Library is the largest library on the ECU campus. Access Engineering is a currently subscribed database at Joyner Library and provides a rich collection of ebooks, videos, and other literature in the Bioengineering field. In addition, ECU Library resources provide online access to tens of thousands of journals, reference materials, e-books, and databases. A unique library guide link for engineering has been established, "Engineering: a guide to library resources". This link provides faculty, students and staff with access to engineering resources, i.e. handbooks, journal articles, reference books, technical reports and patents and other valuable resource material. Current journal subscriptions and books are sufficient to start the proposed program including the *Journal of Biomechanics,* the *Journal of*

Magnetic Resonance Imaging, *Medical and Biological Engineering and Computing*, several *IEEE Transactions* series, and the *Journal of Neural Engineering*. A few additional subscriptions (for example, *Journal of Biomechanical Engineering*) may need to be added over the first five years.

The William E. Laupus Health Sciences Library connects the education, research, and clinical programs of ECU's Division of Health Sciences, Eastern Area Health Education Center (EAHEC), and health care practitioners in eastern North Carolina with quality health information. The Laupus Library serves the Brody School of Medicine, the College of Nursing, the College of Allied Health Sciences, and the School of Dental Medicine. Library services are also extended to the region's health care providers. The library delivers information services and resources to health providers at Vidant Medical Center in Greenville and Vidant Health system affiliates across eastern North Carolina. In 2006, Laupus Library moved to the new Health Sciences Building on ECU's medical campus. The library shares this 300,000 square foot state-of-the-art educational center with the College of Allied Health Sciences and the College of Nursing. The four-story 72,000 square foot library provides study space, a computer lab, media production and consultation services, reference services, circulating and historical collections.

Laupus Library collects current information in the biomedical engineering subject area, mostly in electronic format to increase ease of use and access. Laupus Library works with Joyner Library to ensure that all electronic holdings appear across all our shared resource platforms, so that medical and engineering-specific materials can be found regardless of which library is the student's starting point. Laupus Library also promotes and teaches classes on how to most efficiently use databases such as PubMed and Web of Science so that students can learn how to retrieve quality information.

B. State how the library will be improved to meet new program requirements for the next four years. The explanation should discuss the need for books, periodicals, reference material, primary source material, etc. What additional library support must be added to areas supporting the proposed program?

Resources in the J.Y. Joyner Library and William E. Laupus Health Sciences Library have been assessed and deemed adequate for commencement of the proposed program. Additional future needs will be captured through regular library polls asking faculty for suggestions on new books and resources to add to their collections.

C. Discuss the use of other institutional libraries.

East Carolina University cooperates with libraries through interlibrary loan and shared resources programs. This provides access to reference material from libraries including the University of North Carolina at Chapel Hill, North Carolina State University, North Carolina A&T University and Duke University.

VI. FACILITIES AND EQUIPMENT

A. Describe facilities available for the proposed program.

College of Technology and Computer Science, Department of Engineering
The Department of Engineering manages several conveniently located laboratory spaces in the Science and Technology Building.
Room 355 (670 sq. ft.) is equipped with a complement of advanced electronics fabrication and test equipment including:

- MSO4054B 500 MHz mixed-signal oscilloscope;
- Tektronix AFG3022B 25 MHz;
- dual-output arbitrary waveform generator;

- Tektronix P5205 high-voltage differential probe and ADA400 differential preamplifier;
- TCP0030 current probe;
- Agilent 34410A digital multimeter.

Room 243 (903 sq. ft.) is a multipurpose laboratory, with several fully equipped electronics test benches, including:

- Agilent E3631A triple-output power supplies;
- Agilent 34410A digital multimeters;
- Agilent 33220A, 20 MHz arbitrary waveform generators;
- Agilent 5000 series oscilloscopes.

In addition, the adjacent Room 247 contains a full complement of Agilent oscilloscopes, multimeters, wave generators, power supplies, and personal computers with LabView and Electronics Workbench Multisim.

The Biosensors Research Laboratory available for faculty research and development, located in Room 350 (1200 sq. ft.) is equipped with high-end electronic measurement and test equipment. Specific equipment includes:

- Agilent MSO6034A oscilloscope;
- 1682A logic analyzer;
- 6622A power supply;
- 34410A digital multimeter;
- 33220A function generator;
- Cadence P-SPICE;
- Electronics Workbench Multisim;
- soldering stations;
- wireless communication modules (Bluetooth, Zigbee) and development tools;
- medical sensors;
- personal computers;
- LPKF print circuit board rapid-prototype machine;
- Microchip Integrated Development Tools;
- Software licenses for LabVIEW, MATLAB, Solidworks, and NI-ELVIS.

The Bioprocess Engineering Laboratory, located in room 130 & 131 (1990 sq. ft.) is used for teaching and faculty research. Current courses in upstream bioprocessing (wet-lab techniques, bacterial cultures in both shaker flasks and benchtop bioreactors, and cell harvesting) and downstream processing (distillation, extraction, affinity chromatography) are taught in this laboratory each semester. The major equipment housed in the laboratory available for teaching and research includes:

- two 5L and two 2L benchtop bioreactors (Sartorius BioStat Aplus);
- GE AKTA Purifier system;
- Beckman Coulter Avanti J-E centrifuge;
- Hirayama HICLAVE, top loading autoclave;
- Tuttnauer Brinkmann 2540E , front loading autoclave;
- table-top shaker/incubator;
- Thermo Orions Star series pH meter;
- Fisher Model 100 sonic dismembrator;
- Perkin Elmer Lambda 45 UV/VIS spectrophotometer;
- bath sonicator;

- Mettler Toledo analytical balance;
- stir/hot plates;
- Labconco Freeze Zone 4.5 lyophilizer;
- Promega Glomax 20/20 luminometer;
- Promega, Modulus fluorometer;
- three-door chromatography cabinet;
- protein and DNA electrophoresis equipment;
- thermal cycler;
- TA Instruments AR-2000 stress-controlled Rheometer;
- Olympus BX-51 reflected light microscope with 12MP digital camera for bright field/dark field/fluorescence;
- ramé-hart Model 250 Standard Contact Angle Goniometer/Tensiometer for contact angle and surface tension measurements;
- tools and equipment to conduct molecular biology research (micropipettes, table-top centrifuge, etc.).

To support the Department of Engineering, the College of Technology and Computer Science maintains a fabrication laboratory, room 130, with state-of-the-art tool-room size machining and fabrication equipment, including (but not limited to): a Haas Vertical milling machine, Haas Horizontal milling machine, a variety of welders, vertical and horizontal band saws, a brake and shear, drill presses, workbenches, vices, a wide assortment of hand tools, a phototachometer, an extensometer, a shear test fixture, durometers, and hardness testers. The fabrication area also supports welding, from metal inert gas (MIG) to tungsten inert gas (TIG) and plasma cutting.

The Material Testing Lab is equipped with an Instron electromechanical testing system to test a wide range of materials in tension or compression. This laboratory also contains force gauges, hardness testers, strain gauges, and various ergonomic measurement tools, such as the Bertec Force Plate.

Brody School of Medicine
Major laboratory equipment is available in the Brody Medical Sciences Building (3S-16, 400 sq. ft.), including: a laminar flow hood, chemical hood, CO_2 water-jacketed incubators, centrifuge with rotors, laboratory refrigerator and freezer, an inverted, upright and dissecting microscopes, distilled water source, balance, and pH meter.

The Tissue Culture Facility located in 279 Warren Life Science Building (LSB 279, 800 sq. ft.) offers additional laboratory space. Major equipment includes four bench top work areas with adjacent laminar flow hoods, one chemical hood, CO_2 water-jacketed incubators, tabletop centrifuge with rotors, laboratory refrigerator, two laboratory freezers (-20° C, -80° C), a Dewar liquid nitrogen cell storage system, inverted and upright light microscopes, a digital camera with C-mount, and distilled water source. Additional equipment in this laboratory, i.e., syringe pump and high-voltage power supply (Gamma High Voltage Research), supports nano-electrospinning research.

The Brody School of Medicine maintains Core Facilities to support campus-wide research efforts. These facilities include:

- The Flow Cytometry-Confocal Microscopy Core Facility is a research support resource in the Brody School of Medicine Biotechnology Program. This multi-user shared instrumentation resource is located on the 4th floor of the Brody Medical Science building. The facility has two bench top flow analyzers (Becton Dickinson FACScan), a four-color cell sorter, Becton Dickinson FACSVantage SE, with high-speed sorting capability, a polychromatic flow

cytometry system, Becton Dickinson LSR II, and a Zeiss LSM 510 Laser-scanning Confocal Microscope coupled to an inverted (Axiovert) microscope.

- Zeiss PALM Laser Capture Microdissection System. The PALM MicroBeam System is a non-contact sampling technique for medical and biological materials for recovery of DNA, RNA and protein. This system combines laser microdissection with a laser-assisted transfer.
- Zeiss LSM 700 Laser-scanning Confocal Microscope coupled to an inverted (Axiovert) microscope and on stage incubation system for live cell and time-lapse imaging (new facility, 8/2013). This multi-user shared instrumentation resource is located on the 3rd floor of the Brody Medical Science building.
- Phosphor-Imaging/Fluorescence Imaging (PhIFI) core facility houses a fully equipped Amersham/ GE Healthcare Typhoon 9410 Imager for 2D imaging of phosphorescent, chemiluminescent and fluorescent gel and array data. The Typhoon 9410 is capable of detecting, imaging and quantifying five different forms of emission: phosphor autoradiography, chemiluminescence, blue-excited fluorescence, green-excited fluorescence, and red-excited fluorescence.
- Electron microscope laboratory with JEOL 1200EX TEM; CCD camera and Leica UC6 Ultramicrotome
- Histology laboratory with Microm HM505E Cryostat, Microm HM340E digital advance rotary microtome, Citadel 1000 Tissue Processor for paraffin embedding, and Sequenza Immunostaining System , to provide research support in histology and immunohistochemistry
- Metabolomics laboratory, with LINCOplex 200, for protein expression profiling, gene expression profiling and diagnostics
- Genome sequencing core facility, the Genome Sequencer FLX System is an automated DNA sequencing system capable of preparing, amplifying and sequencing a library of DNA fragments in a massively parallel fashion.

Additional shared resources include (but are not limited to) centrifuges, electrophoresis equipment, various imaging systems, chromatography systems, an ultrasound machine, microscopes, and spectrophotometers.

B. Describe the effect of this new program on existing facilities and indicate whether they will be adequate, both at the commencement of the program and during the next decade.

The MS in biomedical engineering is an interdisciplinary program and it is anticipated that students will be involved in courses and research projects located in the Department of Engineering and in the Brody School of Medicine, School of Dental Medicine, College of Allied Health Sciences, Thomas Harriot College of Arts and Sciences, College of Nursing and the College of Health and Human Performance. The impact of additional students should be minimal as most of the graduate programs are small and additional students could easily be accommodated in didactic classes and integrated into existing laboratory space.

C. Describe information technology and services available for the proposed program

The computing needs of biomedical engineering graduate students will be supported by the College of Technology and Computer Science (TECS), the High Performance Computing laboratory and Information Technology and Computing Services (ITCS). The laboratories previously listed, and any office space, are equipped with the computers needed to perform data analysis or other research related tasks.

TECS provides an array of support including software, hardware, and technical services support. This includes the infrastructure to provide cluster computing and remote display of graphically intensive applications with VMware View and Vcloud Director. Technical services also support desktops on demand, virtual servers on demand and network attached storage space.

ITCS supports additional student computing needs through two unique services: high performance computing and the Virtual Computing Lab. The high performance computing capabilities offered by ITCS are optimized for solving some of the advanced computational problems that arise in engineering research. The Virtual Computing Lab, located at NC State University, provides remote access to a variety of advanced software packages. ITCS provides this access through ECU's network.

East Carolina University's SGI Origin 350 (Zeus) provides high-performance computing (HPC) with hardware and software solutions specifically optimized for complex technical research computing tasks. The independent, modular scalability of CPUs, I/O bandwidth, system bandwidth, memory, storage, and graphics provide a resource for solving larger and more complex problems than can be solved with traditional desktop computing solutions.

East Carolina's SGI Altix 4700 high performance computer has 64 dual-core Montecito processors, 128 GB of memory and 14 TB of disk space. The Altix 4700 is comprised of interchangeable compute, memory, I/O and special purpose blades for 'plug and solve' configuration flexibility. The Altix is a ccNUMA system which means that the address space is shared between all processors. This shared memory cluster environment is most suitable for the scientific and engineering calculations performed by East Carolina researchers.

D. Describe the effect of this new program on existing information technology and services and indicate whether they will be adequate, both at the commencement of the program and during the next decade.

The faculty associated with the proposed program will mentor graduate research using the equipment and facilities described. This equipment, and the associated laboratory space are already in place and are actively used in current research.

VII. ADMINISTRATION

Describe how the proposed program will be administered, giving the responsibilities of each department, division, school, or college. Explain any inter-departmental or inter-unit administrative plans. Include an organizational chart showing the "location" of the proposed new program.

The proposed program will be housed in the Department of Engineering in the College of Technology and Computer Science. The program will be administered by a department chair who will report to the Dean of the College of Technology and Computer Science. The department chair will manage the budget and resources, recruit faculty, and assign teaching and service responsibilities. Other graduate program directors in the college are shown in the organizational chart in Figure 1.

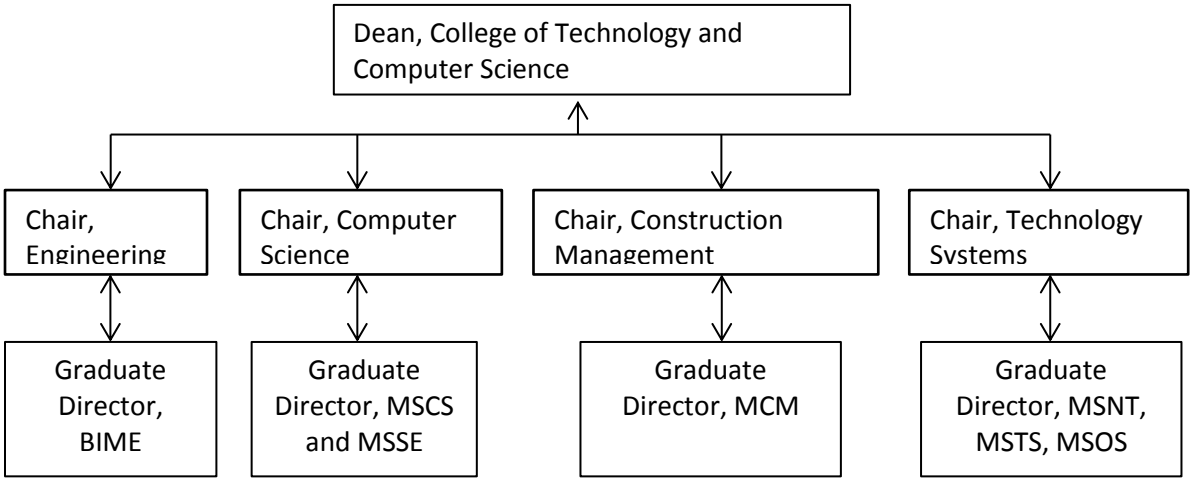

Figure 1 – Organizational structure of the College of Technology and Computer Science

Biomedical engineering faculty and clinical/industrial advisors (see Section II.A.3, Engineering Advisory Board) will review course and program development.

VIII. ACCREDITATION AND LICENSURE

A. Indicate the names of all accrediting agencies normally concerned with programs similar to the one proposed. Describe plans to request professional accreditation.

No separate accreditation will be pursued for this degree program beyond the institutional SACS accreditation. The BS Engineering program is ABET accredited.

B. If the new degree program meets the SACS definition for a substantive change, what campus actions need to be completed by what date in order to ensure that the substantive change is reported to SACS on time? **N/A**

C. If recipients of the proposed degree will require licensure to practice, explain how program curricula and title are aligned with requirements to "sit" for the licensure exam. **N/A**

IX. SUPPORTING FIELDS

Are other subject-matter fields at the proposing institution necessary or valuable in support of the proposed program? Is there needed improvement or expansion of these fields? To what extent will such improvement or expansion be necessary for the proposed program?

There are no immediate needs to expand programs or to improve programs to support the proposed program.

X. ADDITIONAL INFORMATION

Include any additional information deemed pertinent to the review of this new degree program proposal.

1. ECU faculty - Letters of Support (MS_BME Letters of Support-ECU Faculty.pdf)
2. Industry - Letters of Support (MS_BME Letters of Support-Industry.pdf)
3. Graduate Faculty CVs ((MS_BME Core Faculty CVs.pdf)

XI. BUDGET

Based upon your responses in previous sections, provide estimates of the incremental continuing and one-time costs required to implement the proposed program.

A. Estimates should be provided for the first and fourth years of the program in the following broad categories and be inclusive of applicable employee fringe benefit costs:

1. New Faculty and Instructional Support Staff (including Library)

Projected Expenses	YEAR 1	YEAR 4
Program Costs		
EPA Salaries	$140,000	$235,000
EPA Benefits	$36,368	$61,693
Total Projected Expenses	$176,368	$296,693

This number represents the number of FTE dedicated to the MS in biomedical engineering at an annual yearly salary of $90,000 each. There will be 4-5 faculty involved in this effort, each spending a fraction of their time teaching in this program. In addition, a postdoctoral research associate at a salary of $50,000 is requested to support the program in year 1. An additional 0.5 FTE faculty position and one postdoctoral research associate is requested in year 3. It is the intention of the Department of Engineering to support postdoctoral research associates through extramural grant funding.

The Department of Engineering currently has 24 FTE faculty positions, with ten of the current faculty supporting the biomedical engineering concentration indirectly. Strategic new hires in biomedical and electrical engineering faculty and future faculty hires will be used to support the MS program. Faculty resources are sufficient for initiation of the MS program.

2. New Non-Academic Administrative Support Positions.

Projected Expenses	Year 1	Year 4
SPA & CSS Salaries	$65,000	$65,000
SPA & CSS Benefits	$17,451	$17,451
Graduate Assistant Salaries	$30,000	$75,000
Graduate Assistant Benefits	$2,295	$5,738
Total Projected Expenses	$114,746	$163,189

The SPA & CSS salaries are necessary to support one full time SPA research laboratory assistant ($50,000) and a half-time SPA person ($15,000) to serve as administrative support for graduate admissions, assistantships, and other related duties. The Department of Engineering is requesting two graduate assistantships in year 1 ($30,000) with an increase to five graduate assistantships in year 4 ($75,000). The majority of graduate assistants will be supported with extramural grant funds generated by faculty. Current undergraduate enrollment in the engineering department is +500 students and the strategic plan of the college is for the undergraduate engineering program to grow to +750 students over the next 4-5 year. Enrollment in this undergraduate biomedical engineering concentration has doubled from 10 students in 2009 to 20 in 2012 and is anticipated to increase with the growth of the department. The growth in the undergraduate program will positively impact financial resources for the Department of Engineering and recruitment for the graduate program. We are not requesting any tuition remissions. The target student population is primarily from North Carolina.

3. Recurring Operational Expenses (e.g., supplies, materials, telephone, travel, insurance, library or software subscriptions, equipment maintenance, etc.)

Projected Expenses	Year 1	Year 4
Supplies	$40,000	$60,000
Faculty Development/Travel	$1,500	$4,000
Library	$7,425	$29,700
Facilities	$42,120	$93,085
Equipment & Technology	$50,000	$80,000
Total Projected Expenses	$141,045	$266,785

Supplies and equipment will be purchased for instructional purposes and laboratories. Funds for faculty development and travel will be supplemented by the Department of Engineering's operating funds. It is anticipated that additional travel and training will be necessary to recruit students, educate faculty on new equipment and assist with collaborative research/educational programs with partner institutions.

4. One-time expenses for facilities renovations or additions, equipment purchases, library materials, etc.

B. Based on the campus' estimate of available existing resources or expected non-state financial resources that will support the proposed program (e.g., federal support, private sources, tuition revenue, etc), will the campus:

1. Seek enrollment increase funds or other additional state appropriations (both one time and recurring) to implement and sustain the proposed program? **NO** If so, please elaborate.

2. Require differential tuition supplements or program-specific fees? **NO** If so, please elaborate.
   a. State the amount of tuition differential or program-specific fees that will be requested.
   b. Describe specifically how the campus will spend the revenues generated.
   c. Does the campus request the tuition differential or program-specific fees be approved by the Board of Governors prior to the next Tuition and Fee cycle?

C. If additional enrollment increase funding or other state appropriations elaborated above <u>are not forthcoming</u>, can the program still be implemented and sustained and, if so, how will that be accomplished? Please elaborate.

Considering the current strength of the undergraduate concentration in biomedical engineering and the growth in the related biomedical engineering jobs forecasted by the Bureau of Labor Statistics, a decline in program enrollment is unlikely. Current employment and labor projections in biomedical engineering related areas are very strong. If the decision was made to cut resources at the university or college level, possibly by reducing the graduate assistantships, the program would still be viable. The Master of Science in biomedical engineering programs offered at the two NC universities in closest geographical distance to ECU (i.e. UNC/NC State Joint Program in Biomedical Engineering and Duke University) accept self-supporting Master of Science students only. Reduction of the number of ECU assistantships may effectively reduce the "quality" of the students in the program since the best students may seek assistantships at other universities outside NC. If additional faculty positions in the Department of Engineering were denied, the projected size of the program could be reduced. In addition, the potential for

research efforts in biomedical engineering would be reduced overall if faculty numbers are not increased.

XII. EVALUATION PLANS

All new degree program proposals must include an evaluation plan which includes:

A. Criteria to be used to evaluate the quality and effectiveness of the program, including academic program student learning outcomes.

1. Student GPA
2. Student retention
3. Successful completion of thesis proposal
4. Successful completion of thesis
5. Graduation rate
6. Student evaluation of courses
7. Placement of graduates
8. Publications and presentations by students

B. Measures (metrics) to be used to evaluate the program (include enrollments, number of graduates, and student success)

The data generated by the criteria in A will be collected and analyzed by the program director.

C. The plan and schedule to evaluate the proposed new degree program prior to the completion of its fourth year of operation.

The department chair will meet with the program director in the spring semester of each year to review the criteria for evaluation and make necessary adjustments for the fall semester of the next academic year. This evaluation will parallel the assessment and evaluation plan already in place at the university.

XIII. REPORTING REQUIREMENTS

Institutions will be expected to report on new program productivity as a part of the biennial low productivity program review process.

This proposal to establish a new degree program has been reviewed and approved by the appropriate campus committees and authorities.

Chancellor: _____Date:_____

References

1. National Academy of Sciences on behalf of the National Academy of Engineering **2012**, Grand Challenges for Engineering. Retrieved from http://www.engineeringchallenges.org/
2. ECU Tomorrow: A Vision for Leadership and Service (**2012**). Retrieved from http://www.ecu.edu/mktg/ecu_tomorrow
3. American Institute for Medical and Biological Engineering (AIMBE) Academic Council. Retrieved from http://www.aimbe.org
4. Lockard, C. B., & Wolf, M. (**2012**). Occupational employment projections to 2020. *Monthly Labor Review Online*, 135(1), 84–108. Retrieved from http://www.bls.gov/opub/mlr/2012/01/
5. North Carolina Department of Commerce Division of Employment Security. (**2012**) Retrieved from http://eslmi23.esc.state.nc.us/projections/EmploymentOutlook.asp?version=aopengp&AreaType=01&Area=000037&PeriodID=09
6. North Carolina Biotechnology Center (**2012**). Retrieved from http://www.ncbiotech.org/
7. Sommers, D., & Franklin, J. C. (**2012**). Overview of projections to 2020. *Monthly Labor Review Online,* 135(1), 3–20. Retrieved from http://www.bls.gov/opub/mlr/2012/01/
8. National Science Foundation/National Center for Science and Engineering Statistics, NSF-NIH Survey of Graduate Students and Postdoctorates in Science and Engineering. **May 2012**. Retrieved from http://www.nsf.gov/statistics/infbrief/nsf12317/
9. American Society for Engineering Education (**2012**). Retrieved from http://www.asee.org/papers-and-publications/publications/college-profiles
10. Grad Edge – Insights and Research on Graduate Education, Council of Graduate Schools, **March 2012**, Retrieved from http://www.cgsnet.org
11. United States Department of Labor, Bureau of Labor Statistics, Occupational Outlook Handbook, **March 2012**. Retrieved from http://www.bls.gov/ooh/fastest-growing.htm
12. American Institute for Medical and Biological Engineering, "Bureau of Labor Statistics Sees Rapid Growth in Biomedical Engineering Jobs". **February 2010**, Retrieved from http://www.aimbe.org/in-the-news-bureau-of-labor-statistics-sees-rapid-growth-in-biomedical-engineering-jobs/).

Attachments:

1. ECU Faculty Letters of Support (MS_BME Letters of Support-ECU Faculty.pdf)
2. Industry Letters of Support (MS_BME Letters of Support-Industry.pdf)
3. Graduate Faculty CVs ((MS_BME Core Faculty CVs.pdf)