# New Program Proposal
# Master of Science, Bioengineering Science
# South Carolina State University

## Summary

South Carolina State University (SCSU) requests approval to offer a program leading to the Master of Science degree in Bioengineering Science with two tracks: Academic and Industry to be implemented in August 2014. The proposed program is to be offered through traditional, online, and distance instruction. The purpose of the proposed program is to offer a graduate degree program that is interdisciplinary among biology, chemistry, and computer science. The following chart outlines the stages for approval of the proposal; the Committee on Academic Affairs and Licensing (CAAL) voted to recommend approval to the Commission. The full program proposal is attached.

| Stages of Consideration | Date | Comments |
|---|---|---|
| Program Planning Summary received and posted for comment | 11/1/2012 | |
| Program Planning Summary considered by ACAP through electronic review | 12/15/12 | USC Columbia stated that the proposal should address potential overlap with the Master of Science in Biotechnology offered by Claflin University. USC also recommended that the ongoing costs of the program beyond the EPSCoR funding be addressed. Winthrop University supported the program given the NSF financial support. MUSC supported the development of the program but provided five areas that needed to be addressed: clarification of curriculum as it relates to biomedicine, agriculture, and industrial engineering; recommendation of a practicum instead of a thesis; more details about the lab equipment; updated information on the ties for distance education classes with Clemson and USC; and the inclusion of faculty from MUSC, USC, and Clemson in mentoring.<br><br>Staff suggested a change in the implementation date from August 2013 to August 2014; asked for additional details for employment opportunities; asked for a more detailed list of equipment and a schedule for purchases; requested a copy of the agreements with USC, Clemson, and MUSC; and asked for addition details about how the program will be funded after NSF funding ends. |

| Stages of Consideration | Date | Comments |
|---|---|---|
| Program Proposal Received | 9/17/13 | |
| Comments and suggestions from CHE staff to the institution | 10/2/13 | Staff requested a copy of the agreement between SCSU and USC, Clemson, and MUSC for the shared distance education courses and asked for further clarification on the inclusion biomedicine, agriculture, and industrial engineering in the proposed program. |
| ACAP Consideration | 10/17/2013 | Staff reminded SCSU to send a copy of the NSF funded agreement that addressed the collaboration between SCSU and USC, Clemson, and MUSC. |
| Comments and suggestions from CHE staff to the institution | 11/14/13 | Staff requested a revised proposal be submitted that addressed minor edits and questions noted in the document. Staff also again requested a copy of the collaborative agreement. |
| Revised Program Proposal Received | 11/20/13 | |
| Comments received from CAAL members | 1/2/2014 | Commissioner Munns asked for additional information about reallocated funds and the costs of developing new courses. Staff requested this information from the institution. |
| Responses provided to CAAL | 1/8/2014 | Staff distributed the requested information to CAAL (attached). |
| CAAL Consideration | 1/9/2014 | CAAL voted to recommend approval to CHE. |

**Recommendation**

The Committee on Academic Affairs and Licensing recommends that the Commission approve the program leading to the Master of Science degree in Bioengineering Science with Academic and Industry Tracks to be implemented in August 2014.

**Commissioner Munns's Questions and Institutional Responses**
**Regarding New Academic Degree Program Proposals**
**Committee on Academic Affairs and Licensing, January 9, 2014**

**South Carolina State University, M.S., Bioengineering Science**

QUESTION: Pg. 11, the program will require 18 new courses. What is the cost to develop them, is this accounted for in the financial summary, and does the existing faculty have the time and experience to develop the courses?

QUESTION: Pg. 17, the program will require relocation of some existing funding at the level of the rate for 2 or 3 faculty. What programs will lose this funding?

NOTE: Institutional representatives will respond to these questions at the CAAL meeting.

**Proposing Institution:** South Carolina State University

**Program Title:** Master of Science in Bioengineering Science
Academic Track / Industry Track

**Date of Submission:** September 15, 2013

**Signature of Executive Officer:**

Date 9/13 /2013
Thomas Elzey, M.S.P.P.M.
President, South Carolina State University

**Program Contact:**

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## Classification

| | |
|---|---|
| Program Title: | Master of Science in Bioengineering Science |
| Options: | Academic or Industry Track, 40 hours each |
| Academic Unit: | Department of Biological and Physical Sciences |
| Level of degree: | Master of Science |
| Proposed implementation date: | August 2014 |
| CIP code: | 140501 |
| Site: | South Carolina State University, Main Campus |
| Program qualifies for supplemental Palmetto Fellows Scholarship and LIFE Scholarship awards: | Yes _____ No:_ _X_____ |
| Delivery Mode: | Traditional, online, distance |

## Institutional Approval

The following institutional bodies have approved this proposal; their dates of approval are indicated.

Educational Policies Council (5/22/12)
Faculty Senate (5/29/12)
Vice-President of Academic Affairs (5/22/12)
President (5/30/13)
Board of Trustees (9/12/13)

## Purpose of the Program

South Carolina State University proposes a new master's degree program in Bioengineering Science (MBES). The proposed MBES will be housed primarily in the Department of Biological and Physical Sciences. The purpose is to establish a graduate program that is interdisciplinary among biology, chemistry and computer science. It is expected that students from three undergraduate areas - biology, chemistry and computer science will enroll in this master's program. This represents a substantial pool of potential enrollees. The main goal of this program will be to provide a bridge between undergraduate studies and advanced academic or professional degree programs. There will also be an option for students who seek training for industry employment. The program will develop integrative knowledge in biological, biochemical and biomedical engineering and will focus on the biological and non-clinical biomedical sciences and technologies underlying bioengineering problems. The curriculum is concentrated on various combinations of scientific, mathematical, computational, and engineering principles in the analysis and evaluation of bioengineering problems, including applied research in molecular biology, biochemistry, computer science, and biomedical science. The program is in collaboration with University of South Carolina (USC), Medical University of South Carolina (MUSC), and Clemson (CU) and will complement existing programs at those institutions.

The program will include academic (thesis) and industry (nonthesis) tracks. The academic track will prepare students for entry into advanced degree programs leading to professional careers as biologists and biomedical scientists. For students in this track, the MBES will provide opportunities to conduct research with faculty from the collaborating institutions and improve the

success of their subsequent applications for advanced degree programs. The academic track will provide a transition for SC State undergraduates who plan to enter Ph.D. programs and is intended in part to improve the opportunities and success rate of SC State graduates applying for graduate school. It will also increase SC State undergraduates' awareness of graduate school opportunities. The industry track will include training for industry careers in biotechnology, bioengineering and agriculture. Students pursuing this track will serve a one-semester internship at a local industry involved with biotechnology. Two industries have agreed to support internships from students in the program – ArborGen, located in Summerville, SC, and Greenwood Genetics, located in Greenwood, SC. Letters of intent from representatives of these industries are included at the end of this proposal (Part 15, Articulation). This track will enhance employment opportunities in medicine, industry, and agriculture. The program is unique and fills a need at SC State, because no graduate program in the biological sciences or computer science currently exists at SC State and many of its undergraduates enter master's degree programs at out-of-state institutions. It is expected that the great majority of the enrollment in this program will be members of underrepresented minority groups. Representation of these groups in scientific professions will increase as a result.

**Objectives of the Program**

The objectives of the MBES program are:

- to provide an interdisciplinary bridge between biology, computer science, and engineering at the graduate level.
- to address the shortage of underrepresented minorities who pursue the industry employment or the Ph.D. in bioengineering and related fields.
- to increase the number of interdisciplinary and collaborative graduate programs with other research universities in the state.
- to contribute to a well-trained South Carolina workforce in bioengineering sciences.

**Justification**

**Need for the Program**

The MBES program is designed primarily for students who will pursue professional (MD degree), or advanced graduate study (PhD degree) after graduation, and is focused on preparing students for entrance into these programs. Graduating from the MBES program will enhance students' chances of acceptance into advanced graduate programs in biology, molecular biology, and fields of biology that require computer skills (bioinformatics, structural biology), so a wide range of programs will be available to them. In addition, those MBES graduates who pursue professional degrees would be more competitive on admissions examinations. A greater number of minority students entering graduate and professional programs and successfully completing them will serve the overall goal of increasing minority representation in STEM disciplines. In addition to preparing students for advanced graduate study, this program will prepare students for employment in bioengineering/biomedical industries and governmental agencies related to bioengineering and biotechnology. For students who do not continue their education after completing the MBES program, one of the target employment options will be as a biomedical engineer. According to the U.S. Bureau of Labor Statistics (BLS) Occupational Outlook Handbook, 2013, (http://www.bls.gov/ooh/architecture-and-engineering/biomedical-engineers.htm) a master's degree is now recommended for employment as a biomedical engineer, and is likely to become required. The median pay in this field in 2010 was $81,540 per year. Biomedical engineering employment opportunities nationwide are expected to increase by 62% by 2020, much faster than average. A master's degree will improve the graduate's ability to compete for these positions. Compared to the rest of the nation, South Carolina does not have a high number of biomedical engineering jobs, about 110 according to the BLS. Most of these are in the Charleston and Greenville – Spartanburg areas, which have relatively high employment in these areas compared to national data. The demand in South Carolina is likely to grow as new industry is attracted. A relatively high number of biomedical

engineering jobs also exists in North Carolina and Florida, areas of potential employment for graduates. Another potential area of employment is in agricultural and food science technologies, with about 150 jobs in South Carolina, according to the BLS. The BLS projects job growth in this area to be about average (10% by 2020). The outlook for employment for individuals trained in bioengineering sciences in South Carolina looks positive. A search on the website of the SC Department of Employment and Workforce conducted in June 2013 revealed 28 open jobs in the medical and diagnostics laboratory industry group and 26 in the pharmaceutical industry group, both of which would be industries of potential employment for graduates of the proposed program. The need for underrepresented minorities in science and technology fields is expected to increase employment opportunities in South Carolina and nearby states for graduates of the MBES program. Nationally, employment opportunities exist for bioengineering master's degree holders in the defense and security industries, as well as federal agencies including the Department of Defense, the National Institute of Standards and Technology, the National Institutes of Health, the Food and Drug Administration, the U.S. Department of Agriculture, the U.S. Patent and Trademark Organization and various intelligence agencies. According the University of Maryland's website, the demand for bioengineering graduates in these federal agencies was a central factor in the development of an online Master in Bioengineering at the University of Maryland (http://www.bioe.umd.edu/media/release.php?id=57).

**Centrality of the Program to the Mission**

South Carolina State University's proposed MBES degree is entirely consistent with the University's mission statement. These new efforts in bioengineering science described above would merge University goals with twenty-first century technology needs. The MBES degree will advance the overall mission of outreach and economic development as is referenced in the University's mission statement, in part:

> *"SC State University prepares highly skilled, competent and socially aware graduates to enable them to work and live productively in a dynamic, global society. Through technology and traditional methods of teaching and learning, research and service, the University enhances the quality of life of citizens and contributes to the economic development of the state and nation."*

South Carolina State University is a land grant institution with the mission of providing education and service to the citizens of South Carolina. The university does this primarily through affordable quality undergraduate programs, but there are a few graduate programs already in place. The addition of the MBES will increase the graduate programs available, complement an existing Master in Energy and Environmental Science, and provide a bridge for graduates to highly technical industry positions or advanced graduate programs. Consistent with the mission of SC State, this will improve the quality of life for the graduates. It will also contribute to the economic development of the state by improving the quality of the workforce to biotechnology industries that relocate to South Carolina. Most of the students in the program are expected to be drawn from underrepresented minority groups. Representation of minority group members in bioengineering and biotechnology professions and degree programs, where they are currently under represented, will increase as a consequence of M.S. degree holders entering the workforce or advanced degree programs.

**Relationship of the Proposed Program to Related Programs within the Institution**

The proposed program will complement a new M.S. in Energy and Environmental Science that will also be housed in the Department of Biological and Physical Sciences. The MBES will be the first graduate program to integrate the biological, biotechnical, and computer sciences. Other master's programs at SC State neither focus on biology nor integrate the sub-disciplines that contribute to bioengineering sciences. The program will contribute to collaboration and cooperation among faculty from biology and computer science.

**Similar Programs in the State**

M.S. in Biomedical Engineering, USC-Columbia
M.S. Bioengineering, Clemson University
M.S. in Biotechnology, Claflin University

**Similarities and Differences between the Proposed Program and Others in the State, the Region and the Nation**

Elements of master's degree programs at USC and Clemson University (CU) are similar to the proposed program, and some of their courses are included in this program as part of a statewide collaboration. USC offers a Biomedical Engineering master's degree that is narrower in scope than the proposed program because it is limited to medical application rather than including a more general academic, agricultural, or industrial application. The CU Bioengineering program focuses on synthesis of biomaterials, which is not part of the proposed program. The M.S. in Bioengineering at CU is relatively limited with a focus on non-thesis degrees. As with the USC program, the proposed MBES program at SC State would be broader in scope and more general than the CU program. The proposed program is intended to complement the programs at USC and CU, and to broaden the statewide foundation for such programs. One difference between the proposed program and existing ones in the state is that graduates will be prepared to enter a wide range of advance degree programs. Another important difference is that the proposed program includes an industry track for those pursuing employment in biotech and bioengineering industries. Additionally, the HBCU status of SC State would help provide opportunities for minority students in bioengineering sciences. Claflin University in Orangeburg (another HBCU) offers a M.S. degree in biotechnology. The Claflin program differs substantially from the proposed MBES program in that it focuses on forensics with a curriculum that overlaps little with that of the MBES.

An internet search for master's programs in bioengineering returned the one at Clemson and others at Stanford University, the University of California, Berkeley, University of California Los Angeles, and University of Illinois Chicago. These are all Ph.D.-granting institutions, with a different overall mission than SC State. Most of these programs focus on engineering aspects of the field and/or have a strong applied biomedical component, whereas the proposed program emphasizes biological aspects of bioengineering and is primarily for students who intend to pursue higher academic or professional degrees. Other similar programs are strictly biomedical engineering, such as the program at USC, with a narrower focus than the proposed program and an emphasis on medical technology. Nationally, there are few online bioengineering master's programs. A Google search of online bioengineering programs returned one at the University of Maryland (http://www.bioe.umd.edu/home).

**Admissions Criteria Specific to the Program**

To gain admission to the MBES degree, all applicants must meet the requirements for entrance into SC State's Graduate School. These requirements are detailed in the SC State Graduate Catalog, 2012-2014. In addition to general Graduate School admission requirements, the MBES program requires the following:

**1)** Applicants for the MBES program must have a bachelor's degree or higher from an accredited college or university, with competence in a science field related to the chosen area of emphasis. The applicant's undergraduate transcript and GPA must reflect the ability to handle advanced science course work (usually a 3.00 or higher in science courses). Applicant review will occur by a multi-disciplinary team of faculty from the College of Science, Mathematics Engineering and Technology. All applicants must also submit scores from the general GRE; a score of 141(Quantitative Reasoning) and 150 (Verbal Reasoning) or above will be preferred.

**2)** Coursework: one year of Calculus (M153 and 154 or equivalent), Computer Science (C150 or 151 or equivalent), Statistics or Biostatistics (M208 or ENV302 or equivalent), Bioinformatics (CS495

or equivalent), Comparative Anatomy (B201 or equivalent), Vertebrate Physiology (B202 or equivalent) and Genetics (B204 or equivalent). Courses that have not been completed in undergraduate school must be taken within the first year after admission in addition to the required graduate courses.
**3)** Research: All applicants must demonstrate participation in a supervised undergraduate research experience.

**Enrollment**

**Table A – Projected Total Enrollment**

| PROJECTED TOTAL ENROLLMENT | | | | | | |
|---|---|---|---|---|---|---|
| **YEAR** | **FALL** | | **SPRING** | | **SUMMER** | |
| | Headcount | Credit Hours | Headcount | Credit Hours | Headcount | Credit Hours |
| 2014 – 15 | 6 | 54 | 6 | 54 | 6 | 36 |
| 2015 – 16 | 12 | 114 | 12 | 90 | 12 | 72 |
| 2016 – 17 | 14 | 132 | 14 | 108 | 14 | 82 |
| 2018 – 19 | 16 | 152 | 16 | 120 | 16 | 96 |
| 2019 – 20 | 16 | 152 | 16 | 120 | 16 | 96 |

**Basis for the estimates:**
a) This is a two-year program;
b) Six students new to the institution will enroll in the program each year in the first two years, 8 students per year thereafter;
c) New students will enter the program in the fall semester;
d) There will be little if any attrition between academic years;
e) Students will take a full load according to the curriculum below;
f) All students in the program will take summer courses.

Six new students are expected to enroll in the first year. This estimate is based on the pool of biology, chemistry, and mathematics bachelor's degree graduates who intend to go on to professional or graduate school and would benefit from further preparation. Biology and chemistry majors often indicate an interest in a master's degree – they would like to 1) have more time or background before making career decisions, 2) increase their preparation for professional or advanced degree programs or 3) improve their employment options with further training. Many enroll in master's programs in other schools for those purposes, even though they would prefer to stay at SC State. It is anticipated that these students would enroll in the MBES program. Six additional students are expected in the second year. In subsequent years a total of eight new students per year are expected to enroll. Attrition is expected to be low because this is a graduate

program and most students will initially be SC State University biology graduates with known background and qualifications. Enrollment is expected to stabilize at around sixteen.

**Source of Students**
It is anticipated that all enrollment will be new enrollment. It is not expected that graduate students from existing programs will move into the MBES program. Initially, students will come from SC State University undergraduate programs, but others could come from Claflin or other universities.

**Curriculum**

**Outline of Curriculum – 40 Credits**

| **Semester 1** | | **Semester 2** | |
|---|---|---|---|
| **Course** | **credit** | **Course** | **credit** |
| BES 510 – Integrated Bioengineering | 2 | BES 550 – Bioanalytical Instrumentation | 2 |
| BES 520 – Histology | 3 | BES 540 – Human Anatomy | 3 |
| BES 530 – Molecular, Cell & Developmental Biology I | 3 | BES 531 – Molecular, Cell & Developmental Biology II | 3 |
| BES 555 – Seminar I | 1 | BES 555 – Seminar II | 1 |
| **Total** | **9** | **Total** | **9** |

**Summer:**
BES Elective 1 (distance, online), **3 credits**
BES 670 Bioengineering Field Experiences I, **3 credits**

| **Semester 3** | | **Semester 4** | |
|---|---|---|---|
| **Course** | **credit** | **Course** | **credit** |
| BES 655 – Capstone - Seminar | 1 | BES 671 (6 credits) – Bioengineering Field Exp. II (Industry track only) | 6 |
| BES 545 – Engineered Physiology | 3 | or BES 672 (6 credits) – Thesis | |
| BES Elective 2 | 3 | | |
| BES Elective 3 | 3 | | |
| **Total** | **10** | **Total** | **6** |

**<u>Elective Courses and Institutions</u>**

| **Elective Course (choose any 3)** | **Credit** | **Institution** |
|---|---|---|
| BES 600 -- Computational Structural Biology | 3 | USC via distance classroom |
| BES 610 -- Information Flow in Biological Systems | 3 | SCSU |
| BES 620 -- Evolutionary Computation and Genetic Algorithms | 3 | SCSU |
| BES 630 – Biomedical Basis for Engineered Replacements | 3 | SCSU |
| BES 660 -- Tissue Engineering | 3 | CU via distance classroom |
| BES 640 -- Stem Cell Biology | 3 | SCSU |
| BES 650 -- Methods in Bionanotechnology | 3 | SCSU |

**New Courses**
All of the courses below that are offered at SC State University are new courses that have been developed for the MBES program. The two courses cross listed with USC and CU (BES 520 Histology (USC BIOL J530) and BES 660 Tissue Engineering (CU BIO E 801)) are existing courses that will be integrated into the curriculum.

**Course Descriptions** (all courses are 3 credits except BES 671 and BES 672, which are 6 credits each, BES 510, which is 2 credits, and BES 555 and BES 655, which are 1 credit each, as shown in the curriculum above)
**BES 510 Integrated Bioengineering Science Communication** – Topics for this course will include career development, ethics in biotechnology, understanding integrated bioengineering disciplines, science/technical communication, and preparation of manuscripts, grant proposals and scientific presentations.
**BES 520 Histology** (USC BIOL J530) – Basic human microscopic anatomy of tissues, organs and organ systems.
**BES 530/531 Molecular, Cell & Developmental Biology I & II** – The study of cell biology. Topics include how and where intracellular and intercellular molecules control cellular functions such as gene expression, secretion, motility, signaling, cell cycle control and differentiation.
**BES 540 Human Anatomy/Physiology** – The study of the anatomy and physiology of the 11 organ systems in humans. Studies include food processing and nutrient allocation, circulation and respiration, excretion, communication via hormones and nervous transmission, reproduction, behavior, locomotion and support.
**BES 545 Engineered Physiology -** The course covers engineering aspects of medical physiology, building cells, tissues, organs, and organisms. Methods such as genetic engineering, tissue implantation, organ printing, robotized prosthetics, among others are also covered. Biomedical aspects of engineering a physiological system are emphasized
**BES 550 Bio-Analytical Instrumentation** – Lecture course covers the fundamentals of instrumental characterization of biological materials and systems including: confocal microscopy, scanning and transmission electron microscopy, quantitative polymerase chain reaction (PCR), electron and x-ray spectroscopy, gas and liquid chromatography, and mass spectrometry.
**BES 555 Seminar** – A course designed to orient and acquaint a student with current issues and developments in the fields of biomedical sciences and technologies.
**BES 600 Computational Biology** – Principles of computational modeling of complex biological systems.
**BES 610 Information Flow in Biological Systems** – This course will convey the basic principles of modern genetics and the relationship between genetic information flow and tissue engineering. Specific components will include the historical development of genetics, gene regulation, and genetic control of development, molecular genetics and genomics.
**BES 620 Evolutionary Computation and Genetic Algorithms** – Course will address the study of evolutionary computation techniques including genetic algorithms, genetic programming, evolutionary strategies, and evolutionary programming. Topics include representation of individuals (genomes), fitness function, population and evolutionary operations. Different classes of genetic algorithms are covered. The basic tools for genetic programming are illustrated. The application of genetic algorithms within the sectors of machine learning, classifier systems, electrical engineering, and molecular biology are discussed.
**BES 630 Biomedical Basis for Engineered Replacements –** This course focuses on forms and functions of major human organs and systems, providing examples of engineering repair and replacement methods, presented in the light of pathologic or traumatic organ dysfunction.
**BES 640 Stem Cell Biology** – This course will introduce the study of human stem cells, their production and application. Specifically the course will cover topics such as cell cycle regulation, differentiation and activation, the blastocyst and inner mass cells. Different types of stem cells, stem cell therapies, and related ethical issues will also be discussed.

**BES 650 Methods in Bionanotechnology -** This course introduces concepts in nanomaterials and their use with biocomponents to synthesize and address larger systems. Technological impact of nanoscale systems, synthesis, and characterizations of nanoscale materials are discussed.
**BES 655 Capstone - Seminar** – A course designed to orient and acquaint a student with current issues and developments in the fields of biomedical sciences and technologies.
**BES 660 Tissue Engineering** (CU BIO E 801) – Structure and properties of the main classes of materials used in artificial organs and surgical implants; metals, ceramics, polymers, composites, and materials of biological origin; mechanical properties, corrosion, and design.
**BES 670 Bioengineering Field Experiences I –** In this course student will spend an eight week summer period as a research assistant in an established research laboratory conducting research designed in agreement with the research laboratory director or they will spend eight weeks in a cooperative internship position with a biotechnology or bioengineering industry.
**BES 671 Bioengineering Field Experiences II –** Limited to students pursuing the industry track only. Students will spend one semester in a cooperative position with a biotechnology or bioengineering industry. The student will be evaluated by the industry supervisor at the end of the semester. Graduation from the program will be contingent on a satisfactory evaluation.
**BES 672 MS Thesis** – Students write and orally defend a research-based thesis under the direction of an approved research mentor. The thesis and its defense serve as the MS comprehensive examination.

**Assessment**

The following student learning outcomes have been developed for the program:

1) Demonstrate effective communication skills. The students must be able to develop, evaluate, and review communication tools such as research proposals, scientific publications, and general methodologies on a specific topic.
2) Design, execute, and analyze the results of experiments on bioengineering problems.
3) Compose a report or presentation describing original research.
4) Write and defend a thesis (for thesis track students).
5) Demonstrate competency with bio-analytical instrumentation.
6) Evaluate and assess ethical issues in bioengineering sciences.

The assessment of the above student learning outcomes will be measured using multiple instruments including:

- Projects (individual and group), tests, exams, and/or reports. Details of each of these will be outlined in the course syllabi.
- For students in the thesis track, a thesis which includes the collection of data, observation of data, analysis of data, and conclusion from analysis.
- For students in the industry track, a satisfactory performance report from the industry supervisor of their internship

The program will be assessed through the following metrics:

- Graduation rate (it is expected that at least 50% of a cohort group will graduate annually after the second year).
- Rate of student publication and/or conference presentations (it is expected that there will be at least one publication or conference presentation for each student during the program).
- Employment data for graduates (it is expected that at least 50% of the graduates will obtain employment in industry or acceptance into professional or doctoral programs).
- Employer and alumni survey (a survey will be conducted annually to ascertain the perception among employers and graduates of the extent they believe the program has prepared students for their careers).

**Faculty**

Table B – Faculty List

| List Staff by Rank (e.g. Professor #1, Professor #2, Associate Professor #1, etc) | Highest Degree Earned | Field of Study | Teaching in Field (Yes/No) |
|---|---|---|---|
| Professor #1 | Ph. D. | Biology | Yes |
| Professor #2 | Ph. D. | Biology | Yes |
| Professor #3 | Ph. D. | Chemistry | Yes |
| Associate Professor #1 | Ph. D. | Chemistry | Yes |
| Associate Professor #2 | Ph. D. | Biology | Yes |
| Associate Professor #3 | Ph. D. | Computer Science | Yes |
| Assistant Professor #1 | Ph.D. | Biochemistry | Yes |
| Assistant Professor #2 | Ph.D. | Biology | Yes |
| Assistant Professor #3 | Ph.D. | Biology | Yes |

Any faculty added in support of the proposed program will be required to have a Ph.D. from an accredited program in biological, mathematical, chemical or bioengineering sciences as required by the position. In addition, they will be required to have postdoctoral experience and evidence of presentations at professional meetings and publications in refereed professional journals.

Faculty and administrators in the program will initially be drawn from existing faculty. Faculty in the proposed program will be released from one existing undergraduate course to teach one graduate course. The undergraduate course from which they will be released will be taught by existing adjunct faculty.

As is currently applicable to faculty in all existing programs at SC State University, the MBES faculty will be required to attend annual conferences, topical meetings, and participate in research, consulting, and in curriculum development. Release time is not provided by SC State University, but is paid from research grants. Travel funds for faculty attendance at conferences will be obtained from research grants. Academic program coordinators or department chairs have a 25%-50% release time respectively in their administrative capacities.

The institutional definition of the full-time equivalent (FTE) for a faculty member per semester in the undergraduate level is as follows:

4 – Course -load = 1 FTE  2 – Course -load = 0.50 FTE
3 – Course -load = 0.75 FTE  1 – Course -load = 0.25 FTE

For the graduate level, the full-time equivalent (FTE) is:

3 – Course-load = 1 FTE 2 - Course-load = 0.67 FTE

1 - Course-load = 0.33 FTE

Table C: Number and full-time equivalent of administrators, faculty and staff in the M.S. degree in Bioengineering Science program.

| UNIT ADMINISTRATORS, FACULTY AND STAFF SUPPORT | | | | | | |
|---|---|---|---|---|---|---|
| **YEAR** | **NEW** | | **EXISTING** | | **TOTAL** | |
| | Headcount | FTE | Headcount | FTE | Headcount | FTE |
| **ADMINISTRATION** | | | | | | |
| 2014-15 | 0 | 0 | 1 | 0.25 | 1 | 0.25 |
| 2015-16 | 0 | 0 | 1 | 0.25 | 1 | 0.25 |
| 2016-17 | 0 | 0 | 1 | 0.25 | 1 | 0.25 |
| 2017-18 | 0 | 0 | 1 | 0.25 | 1 | 0.25 |
| 2018-19 | 0 | 0 | 1 | 0.25 | 1 | 0.25 |
| **FACULTY** | | | | | | |
| 2014-15 | 0 | 0 | 6 | 2.0 | 6 | 2.0 |
| 2015-16 | 0 | 0 | 7 | 3.0 | 7 | 3.0 |
| 2016-17 | 0 | 0 | 7 | 3.0 | 7 | 3.0 |
| 2017-18 | 0 | 0 | 7 | 3.0 | 7 | 3.0 |
| 2018-19 | 0 | 0 | 7 | 3.0 | 7 | 3.0 |
| **STAFF** | | | | | | |
| 2014-15 | 0 | 0 | 1 | 0.25 | 1 | 0.25 |
| 2015-16 | 0 | 0 | 1 | 0.25 | 1 | 0.25 |
| 2016-17 | 0 | 0 | 1 | 0.25 | 1 | 0.25 |
| 2017-18 | 0 | 0 | 1 | 0.25 | 1 | 0.25 |
| 2018-19 | 0 | 0 | 1 | 0.25 | 1 | 0.25 |

During the first year, six faculty will teach one course at 0.33 FTE. During subsequent years, two faculty will teach two courses at .66 each and five faculty will continue to teach one course

## Physical Plant

No modifications are required to the existing buildings or facilities as a result of the new MBES program. The MBES program will be housed in the Department of Biological & Physical Sciences.

The Biological & Physical Sciences Department is located in Hodge Hall. This includes a new Hodge Hall Annex, the Leroy Davis Annex. The new annex facilities include offices, smart classrooms, an auditorium, teaching laboratories with prep rooms, and research laboratories and totals over 57,000 square feet. Computer science facilities, which will be used in the program, are located in a new 85,000 square foot engineering building.

## Equipment

No new equipment will be purchased for the program. Hodge Hall and Davis Hall contain sufficient equipment to support the program. There are four established research laboratories with biomedical, biochemistry, and molecular biology equipment available to the program. In addition, a recently established common user biomedical laboratory houses state-of-the-art items of equipment for molecular biology. The new equipment includes a real-time PCR machine, an autoclave / sterilizer, a -80°C freezer, a water purification system for ultra-pure water, a gel scanner and imager, 2 micro balances, a fluorescence microscope, an ice machine, a fluorospectrometer, a UV-VIS spectrophotometer, a sonic dismembrator and a dry ice maker. Equipment in the faculty research laboratories of Drs. David Scott, Waltena Simpson, Rahina Mahtab, Sakuntala Warshamana – Green and Dr. Mahtabbuddin Ahmed, will also be available for use in the program. The major equipment in these laboratories includes an additional real-time PCR machine, 2 -80°C freezers, two table top microcentrifuges, 2 centrifuges, a gel-doc gel photography system, an ultra-pure water filter, a fluorescence microscope, a universal microplate reader and $CO_2$ incubator for cell culture.

## Library Resources

The library provides subscriptions and bibliographic electronic databases for current and retrospective information in biology and bioengineering. These databases include millions of peer-reviewed journals and other reference sources for research and study. The databases include:

- Omni File, ACM Digital Library, Academic Search Premier, Dialog, Academic Library, Complete E-Book Collection, JSTOR, ProQuest, and ACM Digital Library.

The databases:

a) supplement the existing print materials for currency;
b) enhance the acquisition of new materials;
c) provide on-site and Internet access; and
d) improve the overall quality areas of the bioengineering collection.

The library uses the following resources and services to support access to quality biology and bioengineering collections:

- Statewide library borrowing available to students and faculty allows individual check-out privileges at more than 55 public, private, and technical college and university libraries in South Carolina.
- PASCAL Delivers allows users to request rapid book delivery using interlibrary loan services from any member library within the state of South Carolina by submitting an electronic request for delivery of a book to their home institution, and receive the books within a 48-hour period.

- Interlibrary loan services are available from more than 58,000 libraries of all types in 115 countries and more than 88 million bibliographic records when materials are not owned by the library. Many interlibrary loan requests for scientific articles can be filled in one day by electronic PDF.
- Community Higher Education Council (CHEC) agreement with Claflin University and Orangeburg-Calhoun Technical College provides interlibrary loan services among the three Orangeburg institutions.

**Accreditation, Approval, Licensure, or Certification**

The MBES is not subject to any specialized or professional accreditation or approved by any state agency other than the Commission on Higher Education (CHE). Also, the graduates of the program are not subject to licensure or certification by any public or private agency.

**Articulation**

Some of the courses included in the curriculum of this program are also taught in similar master's programs at USC and CU. The instructors for the courses from USC and CU will also teach the SC State University courses as distance courses. One course will be team-taught with MUSC faculty at MUSC. The distance courses will be taught as a part of an NSF-funded cooperative agreement between SC State, USC, and CU (see section 16, Estimate Costs, below), referenced in USC sub-award no. 13-2360, section E2. In addition to collaboration with USC, CU, SC State University has entered into agreements with two local biotech industries (Greenwood Genetics, Greenwood, SC, and ArborGen, Summerville, SC) to accept students in the program as interns to complete a nonthesis track. Letters of support have been obtained from each industry partner. Draft MOUs have been developed with USC and CU for mentoring graduate students and offering online courses. These will be executed upon approval of the program.

**Estimated Costs and Sources of Financing**

The program will be initially funded by an existing Cooperative Agreement with the National Science Foundation ("Research Infrastructure Improvement at SCSU" (NSF/EPSCOR Award EPS-0903795). The initial grant provides stipends for six students for the first year. These stipends will be granted to South Carolina residents. Once the grant expires, the program is expected to become self-sustaining through tuition and research grants. Initially, most students will in state. The tuition rate is $4,629 per semester ($9,258 per student for fall and spring. For the summer, six credit hours cost $3,084. Total cost for in-state students for the entire year (fall, spring and summer) is $12,392. Out-of-state tuition would generate more revenue. Tuition from the anticipated eventual enrollment of sixteen students will support all program costs beyond existing SC State professor salaries, which will be obtained through reallocation of existing funds. Every effort will be made to maintain affordability to students. Students in the program are likely to be eligible for federal student loans. Some students may be funded through federal grants, such as the National Science Foundation's Bridge to the Doctorate program, available to the state of South Carolina through SC State University as an SC Alliance for Minority Participation (SCAMP) institution. No "unique cost" or special state appropriations will be requested.

Table D - Costs to the Institution and Sources of Financing.

| ESTIMATED COSTS BY YEAR | | | | | | |
|---|---|---|---|---|---|---|
| **CATEGORY** | **1st** | **2nd** | **3rd** | **4th** | **5th** | **TOTALS** |

| | | | | | | |
|---|---|---|---|---|---|---|
| Program Administration | 18,000 | 18,000 | 18,000 | 18,000 | 18,000 | **90,000** |
| Faculty Salaries | 122,660 | 208,060 | 208,060 | 208,060 | 208,060 | **954,900** |
| Graduate Assistants | 0 | 0 | 0 | 0 | 0 | **0** |
| Clerical/Support Personnel | 8,000 | 8,000 | 8,000 | 8,000 | 8,000 | **40,000** |
| Supplies and Materials | 5,000 | 5,000 | 5,000 | 5,000 | 5,000 | **25,000** |
| Library Resources | 3,000 | 3,000 | 3,000 | 3,000 | 3,000 | **15,000** |
| Equipment | 0 | 0 | 0 | 0 | 0 | **0** |
| Facilities | 0 | 0 | 0 | 0 | 0 | **0** |
| Other (identify) | 0 | 0 | 0 | 0 | 0 | **0** |
| **TOTALS** | **156,660** | **242,060** | **242,060** | **242,060** | **242,060** | **1,124,900** |
| **SOURCES OF FINANCING BY YEAR** | | | | | | |
| Tuition Funding | 74,352 | 148,704 | 173,488 | 198,272 | 198,272 | **793,088** |
| Program-Specific Fees | 0 | 0 | 0 | 0 | 0 | **0** |
| State Funding | 0 | 0 | 0 | 0 | 0 | **0** |
| Federal Funding | 220,000 | 0 | 0 | 0 | 0 | **220,000** |
| Reallocation of Existing Funds | 110,160 | 172,160 | 172,160 | 172,160 | 172,160 | **798800** |
| Other Funding (Specify) | 0 | 0 | 0 | 0 | 0 | **0** |
| **TOTALS** | **404,512** | **320,864** | **345,648** | **370,432** | **370,432** | **1,811,888** |

The following calculations were made to estimate costs in the above table.

Faculty salaries are assumed to be the normal salaries for nine month positions in the Department of Biological and Physical Sciences: assistant professor $58,000, associate professor $62,000, full professor $72,000. An existing full professor will be assigned the job of Academic Program Coordinator (APC) for the program. The APC will be given 25% release time. If the APC earns about $72,000 in nine months, then 25% of $72,000 is $18,000. In the summer, faculty are paid 5% of their nine-month salary for a 3-credit course. Since the summer courses (six credit hours) will be taught by a full professor, his summer salary is calculated at $7,200.

In the first semester, 2 assistant professors will teach at 0.33 FTE each. The assistant professors earn $58,000 per year for a total cost of $38,280. The histology course will be taught at no cost to

SC State University as a part of the NSF cooperative agreement with USC described above. In the second semester one course each will be taught by 1 full professor (0.33 X $72,000 annual salary) and 2 associate professors (0.33 X $62,000 annual salary X 2), for a total of $64,680. In the first year adjuncts will be hired to teach the 5 courses taught by professors assigned to the graduate program at $2,500 per course or $12,500 total. The total faculty cost for the first year, including the summer will be $38,280 + $64,680 + $12,500 +7,200 = 122,660.

Clerical support, supplies and materials and new library resources (subscriptions to online refereed journals) will bring the total to $149,460.

In the second year, the equivalent of 3 associate professors teaching in Semester 3 at 0.33 FTE each will cost an additional $62,000 over year one. Elective courses from USC and CU (BES 600 -- Computational Structural Biology and BES 660 -- Tissue Engineering) will be offered as a part of the cooperative agreement. After the first year, the cost of these courses will be supported by tuition. Semester 4 is for research or industry internships and no courses will be taught. In year two there will be 3 additional adjunct positions for a total of 8, costing an additional $7,500. In the second year, after the cooperative agreement has expired, histology will be taught on a contract basis for $7,500. It is expected that two students will do research in laboratories at USC or CU and the research advisors at those schools will be compensated at 25% of their summer salary which is typically 2/9 of the 9 month salary. Assuming a salary of $75,000 the cost for this will be (0.25 X 0.222 X $75,000) = $4,200 each or 8,400 total. The total faculty costs for year two and subsequent years will be year 1 (115,460) + $62,000 + 7,500 + 7,500 + $8,400 +7,200 = $208,060.

Clerical support, supplies and library needs will remain the same.

Please provide a copy of the NSF Funded Cooperative Agreement for courses being offered through Clemson University and USC-Columbia as a part of the program.

ATTACHMENT A

FastLane PI/CO-PI Management - Award and Reporting Functions | HOME

Award Documents | MAIN

Principal Investigator's Name: Timothy Iittle
Department: SC EPSCoR Program
Organization: South Carolina Research Authority

Award 0903795 as of 2009-7-22 : Amendment 000 (current) Choose Version

Award Document | Last Notice Sent | Budget

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## COOPERATIVE AGREEMENT (CA)

| | | | |
|---|---|---|---|
| AWARD: EPS-0903795 | | EFFECTIVE DATE: | July 1, 2009 |
| | | EXPIRATION DATE: | June 30, 2014 |

| | |
|---|---|
| PROJECTED TOTAL AWARD FUNDING: | SOLICITATION: |
| (Subject to availability of funds) $20,000,000 | (Incorporated by reference, as amended) |
| CUMULATIVE AMOUNT: | NSF 08-587 |
| $8,000,000 * | EPSCoR Research Infrastructure Improvement Program: Track-1 |
| | CFDA NUMBER: 47.081 |
| | OTHER AWARDS UNDER THIS PROGRAM: |
| | Show List of Awards |

| | |
|---|---|
| AWARDEE: | South Carolina Research Authority |
| PROJECT TITLE: | 2009 Research Infrastructure Improvement Grant |
| PROJECT ABSTRACT: | https://www.fastlane.nsf.gov/servlet/showaward?award=0903795 |

ATTACHMENT A

| Principal Investigator (s) | Proposal No. | Institution (s) |
|---|---|---|
| Jerome D. Odom | EPS-0903795 | University of South Carolina |
| Roger R. Markwald | | Medical University of South Carolina |
| Timothy S. Little | | South Carolina Research Authority |

**NSF Contact Information:**

Financial/Administrative questions: e-mail your NSF Grants and Agreements Official, Ilonka Karasz, at ikarasz@nsf.gov or call the Division at 703-292-4831.

Programmatic questions: e-mail your NSF Program Officer, Maija M Kukla, at mkukla@nsf.gov or call the Program Division at 703-292-4940.

This CA is entered into between the United States of America, represented by the National Science Foundation (NSF), and the above named Awardee pursuant to the authority of the National Science Foundation Act of 1950, as amended (42 USC 1861-1875). This CA is provided electronically to the Awardee. The Awardee is responsible for full compliance with all Programmatic and Financial/Administrative Terms and Conditions as initially stated or as updated over the life of this CA. The Awardee's request to draw down funds under this CA will represent acceptance by the Awardee of all Terms and Conditions of the CA. The Authorized Organizational Representative (AOR) will be electronically notified of any changes to these Terms and Conditions and is encouraged to immediately review these changes and contact the Grants and Agreements Official or Program Officer within thirty days with any questions.

**Financial/Administrative Terms and Conditions (FATC):**

General FATC:
http://www.nsf.gov/publications/pub_summ.jsp?ods_key=NSF99999FATC003

Award Specific FATC:

Fiscal Year 2009 and 2010 budgets have been combined in this award for a total duration of 24 months. It is still the awardee's responsibility to submit an annual project report in accordance with Article 15 of the NSF Cooperative Agreement Financial and Administrative Terms (CAFATC), June 1, 2007.

In accordance with sections 1869a and 1869b of title 42 of the United States Code, the awardee will do the following:

1. Obtain from the school board or comparable authority responsible for the schools considering participation in the project, written approval prior to involvement of pre-college students in pre-college education research and development, pilot-testing, evaluation, and revision of experimental and innovative pre-college curriculum.

2. Include in every publication, testing, or distribution agreement involving instructional materials developed under this grant (including, but not limited to, teachers' manuals, textbooks, films, tapes, or other supplementary material) a requirement that such material be made available within the school district using it for inspection by parents or guardians of children engaged in educational programs or projects using such material of that school district.

As a condition of this award, the awardee agrees to provide cost sharing as specified in the referenced proposal, as amended, in the total amount of $4,000,000. No Federal funds may be used to meet the awardee's cost sharing obligation for this project. The amount of cost sharing must be documented on an annual and final basis, certified by the Authorized Organizational Representative, and reported to the cognizant NSF Program Officer via FastLane.

The Foundation authorizes the awardee to enter into the proposed contractual arrangements and to fund such arrangements with award funds up to the amount indicated in the approved budget. Such contractual arrangements should contain

appropriate provisions consistent with Articles 8.a.4 and 9 of the NSF Cooperative Agreement Financial and Administrative Terms (CAFATC), June 1, 2007.

Funds provided for participant support may not be diverted by the awardee to other categories of expense without the prior written approval of the cognizant NSF Program Officer. Since participant support cost is not a normal account classification, the awardee organization must be able to separately identify participant support costs. It is highly recommended that separate accounts, sub-accounts, sub-task, or sub-ledgers be established to accumulate these costs. The awardee should have written policies and procedures to segregate participant support costs.

NSF 08-587, EPSCoR Research Infrastructure Improvement Program: Track-1 (RII Track-1) has been amended to change the cost sharing requirement from 50% of the amount requested from NSF to 20%.

No human subjects may be involved in the project until the protocol has either been declared exempt or the protocol has been reviewed and approved by the organization's Institutional Review Board, and certification has been submitted to the cognizant NSF Program Officer.

The amount granted includes an indirect cost allowance at the rate of 6.77%, applicable to total direct costs, as specified in the approved budget. This is a maximum provisional rate which is subject to downward adjustment only.
Note that under the terms and conditions of this award, and in accordance with Federal Cost Principles, the awardee is responsible for submitting cost proposals to their cognizant Federal Agency annually to update their indirect cost rates. If another Federal Agency is your cognizant agency, the awardee is requested to submit a copy of the formally negotiated rate agreement to the NSF Division of Grants and Agreements as soon as it is available each year. A copy should be emailed to Robert Joyce, Branch Chief, at rjoyce@nsf.gov. A copy should also be emailed to bfacaarmpr@nsf.gov.

**Programmatic Terms and Conditions (PTC):**

General PTC:
http://www.nsf.gov/publications/pub_summ.jsp?ods_key=NSF08587TPTC000

Award Specific PTC:
Should the current research move towards using, exploring, and obtaining human stem cells in the course of the proposed work, all most current federal and other relevant regulations will be discussed between the SC RII leadership team and the EPSCoR office, the appropriate documentation will be arranged, and all rules and regulations will be followed.

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## A. STATUS AND OVERVIEW

The 2009 NSF EPSCoR Research Infrastructure Improvement (RII) Program presents an exciting opportunity for South Carolina to implement a statewide vision towards building a competitive edge in the emerging field of "organ printing" — operationally defined as computer-aided, layer-by-layer deposition of biologically relevant material with the purpose of engineering functional 3D tissues and organs. The long term goals are to build and enhance tissue biofabrication technologies that will: (1) develop into a statewide center of excellence at the interface of engineering, biomathematics and developmental biology; (2) create a transdisciplinary culture of innovation in tissue science and engineering research that links scientific discovery to innovation in advanced bioprinting (tissue biofabrication) technology; (3) produce a diverse group of graduates and trainees who will be creative innovators in an emerging, new biofabrication industry; (4) attract broad interest by faculty and students at colleges and universities across the state; and (5) serve to guide, focus and transform the enhancement of infrastructure into a large scale vision capable of stimulating competitive research proposals and sustainable partnerships among academe and the private sector. This broad-based vision, called "**The South Carolina Project,**" **will be an integrated program to engineer a vascular tree.** The Advanced Tissue Biofabrication Center (**Figure 1**) will be the hub for catalyzing infrastructure enhancements needed to pursue The South Carolina Project.

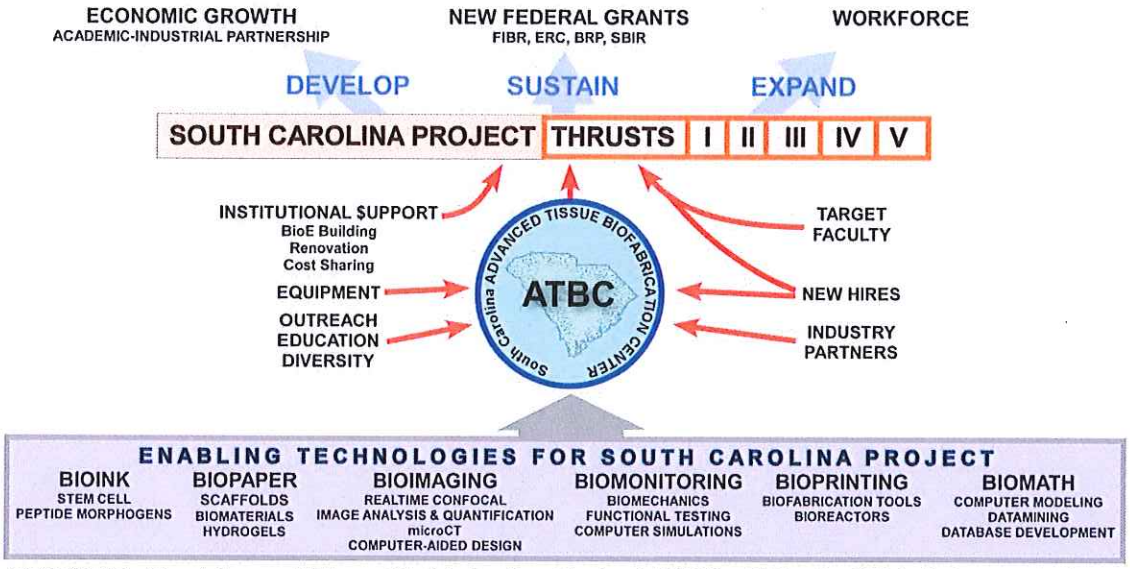


**FIGURE 1. The Advanced Tissue Biofabrication Center (ATBC) will be the RII hub for catalyzing sustainable infrastructure enhancements needed to become a leader in biofabrication.**

### A1. Selection of RII Theme

In February 2006, the State EPSCoR/IDeA Committee held a strategic planning retreat to consider state and national competitiveness initiatives. In Spring 2006, the national EPSCoR 2020 Workshop identified 8 strategic priorities to guide NSF and EPSCoR in meeting the future research needs of the nation. Based on recommendations from these two forums, SC's higher education leaders identified strategic focus areas representative of institutional strengths, research infrastructure needs, opportunities for development, and potential for technology commercialization. Each institution drew on external advisors, visiting committees and other consultants to help identify infrastructure improvement activities with high potential for increasing national competitiveness.

In October 2006, the State Committee issued a solicitation outlining NSF RII program criteria and the state strategic plan for EPSCoR/IDeA. The call for proposals generated 7 responses that

were reviewed by a panel of 5 external experts, including 2 National Science Board (NSB) members. They recommended: a) further developing 2 proposals in biofabrication and carbon research; b) maintaining the underlying SC EPSCoR strategy of targeting RII funds to recruit early-career faculty; c) accelerating the SC's research agenda by recruiting some mid-career "magnet researchers" at associate or full professor levels; and d) formalizing a statewide cyberinfrastructure plan.

Final selection of content for the RII proposal took place in July-August 2007. Expanded proposals in biofabrication and carbon sequestration were reviewed by select NSB members and additional experts. Their comments were sent to a panel convened by the State Committee on August 10, 2007, which found that the biofabrication initiative best fit the criteria set forth by SC EPSCoR/IDeA. The State Committee concurred with the panel's conclusions that: (1) the statewide initiative in tissue biofabrication builds on existing strengths and previous EPSCoR investments in engineering, mathematics and biosciences that will collectively yield substantial added value for building sustainable research capacity and exciting potential for economic development; (2) the RII theme is closely aligned with university, state and national research priorities in advancing tissue science and engineering and addressing research at the interface of the physical and life sciences; and (3) the state should proceed aggressively with its cyberinfrastructure plan.

The SC NSF EPSCoR RII proposal, aimed towards building a competitive edge in the field of biofabrication, was submitted in response to NSF 08-500 and reviewed in Feb/Mar 2008. Intellectual and scientific merit were uniformly rated as Excellent, but broader impacts of the proposed plan lacked meaningful involvement of SC's HBCUs and other predominately undergraduate institutions (PUIs). In May 2008 the SC EPSCoR/IDeA Office sent an invitation to higher administrators at 26 of SC's PUIs to participate in a workshop offering technical assistance for preparation of pre-proposals aligned with RII priorities and the biofabrication theme. Twenty-two (22) faculty from 13 institutions attended the workshop; pre-proposals were received in mid-June and reviewed by experts. Proposals from Claflin, Furman, SC State University, USC Beaufort, and Voorhees College were selected for further development and inclusion in the present 2009 SC NSF EPSCoR RII proposal.

### A2. Current Resource Base in Tissue Biofabrication

MUSC's Department of Cell Biology & Anatomy (CBA) has a reputation of excellence and leadership in developmental biology with emphasis on heart development and vessel assembly. Roger R. Markwald, PhD has served as chair since 1992. The department has 24 full-time, tenured/tenure-track faculty, 11 research faculty and 7 adjunct faculty with grants totaling >$11M/yr from sponsors such as NIH, DoD and NSF. The teaching division has pioneered computer-assisted instruction and distance learning techniques. Several NIH grants and an NSF FIBR (EF-0526854, with U. Missouri and U. Utah) support growing expertise in stem cell biology and organ printing. The department is a leader in building statewide research partnerships. Four Clemson bioengineering faculty members have joint MUSC appointments and full-time space in CBA. A 15-year collaboration with USC's Department of Cell and Developmental Biology has contributed to shared faculty, resources, and USC's new Biomedical Engineering Program. Postdoctoral fellows from MUSC and USC regularly guest lecture in bioinformatics and cell biology at Claflin, SC State and Furman.

RII investments at Clemson helped assemble a critical mass of faculty in Bioengineering and fostered the joint Clemson/MUSC Bioengineering Program. Launched in September 2003, the joint program lets faculty of both institutions move seamlessly between campuses. Clemson faculty and bioengineering graduate students interact daily with MUSC investigators and trainees. Teleconferencing facilities provide effective, efficient avenues for faculty and graduate students on both campuses to participate in didactic courses, seminars and departmental activities. Clemson is a leader in ink-jet printing approaches using single cell suspensions with a focus on building small tissue fragments that do not require vascularization. MUSC is a leader in developmental biology with approaches based on tissue spheroids leading to tissue self-assembly, fusion and maturation. Clemson engineers and MUSC scientists working together have made pioneering contributions to the field [1,2] with support from NSF and other agencies, including Emerging Frontiers in Research and Innovation (EFRI) and Frontiers in Integrative Biological Research (FIBR) awards.

SC's HBCUs and other PUIs offer a substantial research and education base. Claflin University has a new MS program in biotechnology with expanded faculty expertise in protein biochemistry and biostatistics, and an ACS certified chemistry department. South Carolina State University is establishing a specialized computer-aided design and rapid prototyping laboratory to train students in the biomedical applications of layer-by-layer manufacturing technologies. The laboratory will include several high-density 3D printers and imaging software for CT scan conversion. Furman University will soon complete a $62 million expansion and renovation of their science facilities to establish the 210,000 $ft^2$ Charles Townes Center for Science, the largest single academic building project in Furman's history.

USC's Industrial Mathematics Institute (IMI) was established as part of a highly successful NSF EPSCoR project funded from 1992-95. The goal was to leverage classical mathematical strengths to build new research capacity in numerical analysis, image processing, geophysical modeling and large-scale scientific computing. The 4 targeted hires remain as IMI faculty, each now a full professor with an established research profile and substantial federal and corporate funding. The IMI now has 21 faculty members with grants primarily from NSF, DoD, and corporate sponsors. In Spring 2007, the IMI completed a comprehensive self-study process with a major recommendation to extend collaborations across the state.

### A3. Alignment with University, State and National Research Priorities

***At the University Level.*** MUSC and Clemson have a well-established consortium that hosts Clemson bioengineers full-time at MUSC. A new Bioengineering Building planned for Charleston will be the state's first shared science facility accessible to all higher education institutions in SC. Funding for this building illustrates the commitment that the universities have made to NSF-style transformative and NIH-style translational research. The new building will make it possible to bring engineers, biomathematicians and biologists under one roof to pursue the shared vision of the South Carolina Project and develop a sustainable Advanced Tissue Biofabrication Center. A proposal to support Centers of Economic Excellence (COEE) Chairs in Tissue Biofabrication with an endowment of $10M was approved for funding in June 2008.

***At the State Level.*** The SC Dept of Commerce, SCRA and others have identified enhancement of research infrastructure in biotechnology and bioengineering as an essential strategy for attracting bio-technology companies and bio-manufacturing industries. For example, SCRA has created *SC Launch!*, an incentive program that awards matching grants up to $100,000 to SC-based businesses that obtain SBIR/STTR awards. In addition, 3D Systems Inc., a leader in rapid prototyping and biofabrication, relocated from California to SC to partner with York Technical College in building a unique "3D Systems University" for workforce training in rapid prototyping. The SC General Assembly provides $2-2.5M annually in a line item appropriation to the state's EPSCoR programs. These examples illustrate the alignment of state and private resources with the 2009 RII proposal's theme of tissue biofabrication, and provide clear indication of a strategic trend in South Carolina toward 21st century high tech manufacturing and knowledge-based industries.

***At National and International Levels.*** Two strategic planning documents that identify the technological needs to advance the field of tissue science and engineering have recently appeared [3,4]. The national Multi-Agency Tissue Engineering Science (MATES) group identified 3D biofabrication and "assembling and maintaining complex tissue" as a critical short term strategic priority for federal agencies. An editorial in *Tissue Engineering* [5] noted that understanding basic biology is a high priority, especially developmental biology. In reporting on an NSF-sponsored US-China workshop on new opportunities in bio-manufacturing, Sun et al. [6] identified advanced organ printing/biofabrication as a top priority. The highly respected "Wohler Report 2006" identified biomedical applications of rapid prototyping as a field with multibillion dollar growth potential. The European Union organized the 1st International Bioprinting Conference in 2006. Leading Asian countries are also developing research centers in biomedical application of rapid prototyping, robotic biofabrication and organ printing. A new international journal *Biofabrication* (IOP Publishing, UK) will print its first issue in March 2009. Thus, the theme of our NSF RII proposal is timely and well aligned with efforts essential to US technological leadership.

to address STEM needs, long-term goals, and mission. The Innovative Integration Board (IIB), modeled after the NSF $I^3$ program, will actively promote and coordinate the creative integration of the RII with NSF-funded and institutionally-driven diversity programs at SC's HBCUs. Mr. LaMont Toliver, Director of the Meyerhoff Program at U. Maryland-Baltimore County, will serve as Chair. Proposed members hold faculty and leadership appointments in SC's 4 largest HBCUs, and/or are Managing Directors for NSF/LS-AMP, NSF/HBCU-UP and NSF/ATE programs. The SC EPSCoR/IDeA Office will coordinate 2 Board meetings per year, rotating sites among the participating institutions. The IIB will identify and pursue ways and means to leverage resources that bridge SC's minority serving programs with the RII. The Board will increase communication among the programs' leadership thereby creating new multidisciplinary opportunities for a diverse group of future scientists.

**D3. Implement statewide programs to promote diversity in academe.** The SC EPSCoR/IDeA Office will develop a **Scientific Advocate Network** (akin to a resource library) of minority graduate students, postdoctoral fellows, faculty or STEM professional educators to present seminars in disciplines relevant to The South Carolina Project and other areas of S&T excellence. Invited speakers will be exposed to STEM career opportunities in South Carolina, thereby expanding candidate pools for future faculty and research staff positions. Speakers will serve as advocates for the state's S&T research enterprise by encouraging minorities to consider SC as a career destination. Speakers experienced in recruitment, mentoring and retention of historically underserved or underprivileged populations will share effective strategies to diversify the professoriate and STEM workforce. SC institutions may submit applications to the SC EPSCoR/IDeA Office for up to $3,000 in funding from the SAN program to support seminar-related expenses. EPSCoR/IDeA staff will assist departmental seminar programs at host institutions in publicizing invited speakers, and scheduling activities during their visit, e.g. tour of campus and research facilities, meetings with department/division chairs/deans, consultation with faculty involved in related research areas, etc. Other outcomes would include a sustained relationship with the SAN member as a potential new scientific collaborator or valued consultant.

The SC EPSCoR/IDeA Office will continue to support the statewide **Annual Ernest E. Just Symposium** hosted by MUSC during African-American History Month (February). The symposium celebrates the career and scientific achievements of an internationally recognized African-American developmental biologist born in Charleston in 1883. It is an outstanding forum to encourage minority students to pursue scientific research careers through discussions of Just's career and presentations by leading scientists and educators. It attracts accomplished African-American and other diverse scientists who serve as role models, speakers and future collaborators. Feedback from past symposia indicates that undergraduate participants highly value sessions with admissions personnel who offer specific advice on preparing for and applying to graduate programs in STEM fields. RII resources will support attendance by STEM students and faculty advisors from HBCUs across the Southeast. Students will have the opportunity to meet with admissions coordinators from SC colleges and universities with STEM graduate programs, including MUSC, USC, Clemson, Claflin, Furman and Winthrop University. Student progress to graduate school and research careers will be tracked as a primary outcome of the symposium.

## E. WORKFORCE DEVELOPMENT PLAN

The core philosophy guiding our Workforce Development Plan is the engagement of a diverse group of institutions that bring complementary approaches to the research, education, training and production of SC's future STEM workforce. This diverse group – comprising 3 research intensive institutions, 3 HBCUs (1 public and 2 private), and 2 other PUIs (1 private and 1 public), with outreach to 2 technical colleges and the K-12 community – form an alliance of institutions in support of The SC Project. Our overarching strategies include the following.

**E1. Build research and education capacity in the RII alliance institutions, aligned with their mission and needs.** A primary strategy of the SC EPSCoR/IDeA Program has been to develop intellectual resources by providing support for early career faculty who bring access to

critical technologies not yet represented in the state's targeted areas of S&T development. As described in Section C, twenty-two (22) new faculty will be hired into 6 institutions: Claflin (3); Furman (2); MUSC (5); USC Beaufort (2); USC Columbia (9); and Voorhees College (1). These faculty in turn can attract promising students to the emerging field of biofabrication through didactic training and research experiences.

Efforts directed towards strengthening STEM research and education in SC's undergraduate institutions and technical colleges, and interfacing with K-12/pre-college level programs, are critical for building SC's workforce and economy. Students trained in STEM areas can enhance the quality of the workforce, which in turn can attract biotechnology industries and enhance SC's economy. More students may choose to stay in SC given better employment opportunities. This logic defines the proposed RII activities of the HBCUs and other predominately undergraduate institutions.

*Claflin University* is an independent, predominately undergraduate HBCU located in Orangeburg, SC, consistently rated in the top tier of undergraduate institutions. Claflin proposes to use new RII funds to (1) recruit and mentor 3 new faculty with expertise in immunology, bioinformatics, and chemometrics as described in Table 1; (2) partner with Greenville Technical College to build the dual-degree, 2+2 program in biotechnology that was approved by the SC Commission on Higher Education in 2007; and (3) train Masters level and undergraduate students, and provide outreach to middle and high school teachers, guidance counselors and students for workforce building in bioscience research. The proposed RII activities will add 3 additional faculty who will comprise a 5-member research core contributing to the scientific needs of the SC Project. Other workforce outcomes will include research training in biotechnology-related methods for 40 high school science teachers, 20 high school students, 48 undergraduate students, and 8 master's level students and the increased awareness of 50 high school guidance counselors in the state with regard to career choices in the bioscience fields. It is anticipated that 90 percent of those trained will be from underrepresented populations or minority serving institutions and schools.

*Furman University* is a nationally recognized leader in undergraduate research. Their proposed NSF RII activities encompass a five-component plan: (1) development of a Biomaterials research initiative aimed at growing Furman's current faculty research capabilities, productivity and funding success through competitive summer research support; (2) addition of considerable new expertise in biomaterials research and biofabrication through three new faculty hires, two supported by NSF RII funding (in Surface Chemistry and Computer Science, see Table 1); (3) establishment of a faculty development program to be conducted in collaboration with SC's Comprehensive Research Universities (CRUs) that will provide mentoring and teaching experiences for SC postdoctoral fellows, while providing sabbatical opportunities for Furman faculty to engage in tissue biofabrication collaborations with CRU faculty; (4) development of a summer undergraduate research program designed to provide significant research opportunities on the Furman campus for minority students from Claflin University and other SC HBCUs; and (5) expansion of a K-12 ($6^{th}$-$12^{th}$ grades) STEM outreach program within the Greenville County School District designed to provide academic assistance and peer mentoring, while stimulating science/math engagement for African-American and other minority students in the local community.

*South Carolina State University* is the state's largest and public HBCU. Their proposed objective in the 2009 SC RII is to establish a masters degree program in Biorobotics and Biofabrication. The masters program is planned to contain a core curriculum and two distinct but complementary biotechnology "arms" in Biorobotics and Biofabrication. The total of 36 credits is distributed with 18 credits for core courses, 9 for electives, 3 for research seminar, and 6 for the masters thesis. To broaden the teaching portfolio at SCSU, faculty from MUSC, USC, Clemson, and York Technical College/3D Systems University, which currently offers courses in 3D printing, rapid prototyping and rapid manufacturing of non-human structures, will be appointed as adjunct SCSU faculty and be engaged in collaborative research and course teaching throughout the project. Competencies would instill ability to process morphological datasets of radiologic images from point of origin into devices that allow 3D printing, rapid prototyping or rapid manufacturing to create

needed tissues. Courses will include tools and techniques, a human gross anatomy course specifically designed to teach the anatomy needed to create specific tissues, and mentored hands-on training in prototyping laboratories. A long term goal will be to offer this MS degree to students at distant locations who could take coursework through live 2-way audio-videos, asynchronous webcasts and online modules. This approach would allow statewide access to training, provide a unique resource for industrial recruitment and economic development, and generate new jobs for South Carolinians in a high tech, high growth field. Furthermore, this new workforce would be relatively difficult to outsource overseas due to FDA regulations.

The *University of South Carolina Beaufort (USCB)* is SC's newest four-year university located in the Lowcountry area of the state. Although this area is well known for the wealthy residents of Hilton Head Island, this wealth has not made its way into the surrounding areas. The current economy of this Lowcountry region is based predominately on agriculture and the hospitality/tourism industry, both of which rely heavily on low paying jobs. An Economic Diversification Plan for the region identified the need for employees skilled in the use of computers and computational technology for security and logistical analyses for the planned expansion of the Port of Savannah into neighboring Jasper County; for CAD design processes used in architecture and manufacturing; and for medical database mining and analyses. USCB's proposed objectives for the 2009 SC RII are to (1) hire two new tenure track faculty in the area of computational science (see Table 1), at least one of whom will be an expert in computational biology; (2) enhance the research equipment infrastructure of USCB by establishing a Computational Core Facility containing workstations, storage server, desktop and laptop computers, along with ancillary small equipment, software and licenses; (3) implement a degree program in computational science that will have at least 48 students enrolled by 2013; and (4) provide research experience for undergraduate students to learn techniques in computing as well as basic methods of research design.

*Voorhees College* is a non-research intensive, private, rural HBCU located in Denmark, SC. The College's STEM departments seek more interdisciplinary collaborations among Biology, Computer Science, and Mathematics. The processing of biologically-derived information broadens career options for graduates in STEM disciplines. Voorhees College proposes three RII activities: (1) hire a tenure-track faculty member to chair the Computer Science Department (see Table 1) and develop a Computer Science curriculum that integrates computer science with applied mathematics and biology; (2) leverage SC AMP, NSF RII and institutional funds to "shore up" the College's educational capacity in molecular biology/biotechnology; and (3) use NSF RII funds to support a Bridge Program to target the needs of students transferring from Denmark Technical College, one of SC's eight HBCUs located adjacent to the Voorhees campus. This six-week residential bridge program will provide academic enrichment and undergraduate research experience in Computer Science, Mathematics, and Biology. Voorhees College's long term goal is to offer a BS degree via a 2+2 program with Denmark Tech, which has an enrollment of 1,408 students with 93% African American representation.

**E2. Implement innovative and transformative approaches for a new workforce in biofabrication.** Much effort has been devoted to prioritizing the technological needs to advance the field of tissue science and engineering. Given sufficient resources, in the foreseeable future we will be able to manufacture human tissues in a bio-laboratory environment. Interestingly, there is currently no known educational program to train the individuals who will work in this emerging field. The proposed RII initiative to build a Masters degree program in Biorobotics and Biofabrication — led by South Carolina State University in conjunction with MUSC, USC, and Clemson — is a step in this direction. Existing faculty within the participating institutions, in addition to the 22 new hires (see Table 1), provide a substantial base of expertise to build towards an innovative, competitive workforce to address the educational and technological needs of a new 21$^{st}$ century biofabrication industry. Additional short term activities include the following:

**E-Textbooks.** Electronic textbooks on *Biomedical Applications of Rapid Prototyping* and *Introduction to Organ Printing* will be developed and evaluated for age-appropriate audiences. The