

# UNIVERSITY OF SOUTH CAROLINA COLUMBIA CAMPUS

## NEW PROGRAM PROPOSAL

### Master of Engineering in Biomedical Engineering

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Date of Submission

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Harris Pastides, President

#### Program Contacts:

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**2. CLASSIFICATION**

<b>A. Program Title</b>	Master of Engineering in Biomedical Engineering
<b>B. Concentrations</b>	None
<b>C. Academic Unit in which Program Resides</b>	College of Engineering and Computing, University of South Carolina
<b>D. Designation of Degree</b>	Master of Engineering (M.E.)
<b>E. Proposed Date of Implementation</b>	Fall 2014
<b>F. Proposed CIP Code</b>	140501
<b>G. Site</b>	Columbia Campus
<b>H. Qualifies for supplemental Palmetto/LIFE Scholarship?</b>	No
<b>I. Delivery Mode</b>	Traditional face-to-face

### **3. INSTITUTIONAL APPROVAL**

Unit approval	February 21, 2013
Graduate Council approval	May 20, 2013
Provost approval	November 4, 2013
Board of Trustees approval	December 17, 2013

### **4. PURPOSE**

The multidisciplinary field of Biomedical Engineering incorporates life sciences, engineering sciences, design, manufacturing and operation of biomedical processes and devices. Biomedical engineering is one of the fastest growing engineering areas in terms of student enrollment, graduate employment and research funding. The objectives of the proposed Master of Engineering in Biomedical Engineering (M.E. in BME) are to:

1. Prepare graduates of the program to meet the growing demands for continued development of and entrepreneurship in the biomedical industry.
2. Respond to the rapidly growing national demand for new biomedical technologies and provide opportunities for economic development and entrepreneurial growth for the State of South Carolina.
3. Meet the goals of the University of South Carolina in its emphasis area of biomedical sciences.
4. Provide an alternate mechanism for students to increase their competitiveness in attaining admission for further graduate studies, including Ph.D. programs in biomedical engineering and medical school.

The proposed Master of Engineering degree program will offer intensive, focused training in the professional practice of biomedical engineering. The program will be beneficial to students who plan to pursue industrial careers, as a graduate degree will enhance their job application, yield a higher starting salary, and enable rapid promotion within many corporate structures. Moreover, the program will provide students who plan to pursue further graduate education a means to distinguish themselves from typical candidates for M.S./Ph.D./M.D. programs, i.e. those with a B.S. degree only, and insomuch facilitate admission to leading Biomedical Engineering graduate programs and medical schools nationwide.

### **5. JUSTIFICATION**

#### **(a) Need for program in the state**

Industry demand for post-baccalaureate training remains high, while reductions in federal research support have reduced the availability of assistantships for traditional M.S.-seeking students. Although absent in South Carolina, programs that are analogous to the proposed M.E. in BME have recently been introduced at top Universities both nationwide and at our peer institutions within the Southeast. In addition to meeting a local and national market demand, this degree program is designed to support economic development in the healthcare field, contributing to the advancement of a knowledge-based economy in South Carolina. We have recently observed strong growth in the

relocation or opening of new facilities by healthcare companies in the State, as well as the formation of new start-up businesses. According to the Bureau of Labor Statistics, employment of biomedical engineers is projected to grow by 62% from 2010 to 2020, much faster than the average for all occupations (14%) and the fastest among engineering disciplines (11%) – The Whitaker Foundation (<http://www.whitaker.org/glance/outlook2012.html>). Moreover, the latest report (period of May 2012) from the Bureau of Labor Statistics indicates that Biomedical Engineers (occupation code 172031) in the state have an annual mean wage of \$74,030, and those in the 90th percentile have an average annual earnings of \$104,640 (<http://data.bls.gov/oes/datatype.do>). The aging baby-boom generation is expected to increase demand for a variety of biomedical devices and procedures, as it seeks to maintain healthy and active lifestyles. The surge in biomedical engineering demand is thus due to the range of industries which seek this particular expertise. The Bureau of Labor Statistics reports the following industries are employing the largest number of biomedical engineers, with mean salaries indicated in brackets:

- Scientific research and development services [\$88,330]
- Pharmaceutical and medicine manufacturing [\$82,820]
- Medical equipment and supplies manufacturing [\$81,150]
- Colleges, universities, and professional schools [\$68,070]
- General medical and surgical hospitals [\$59,010]

Additionally, via intensive advertising campaigns from industrial leaders, the public has become aware of recent medical advances and procedures that are dependent on biomedical technologies. As a direct result, there are an increasing number of people who are inquiring and demanding new treatments from their physicians. Professional biomedical engineers will likely experience more demand for their services because of their central role in product development and evaluation coupled with the breadth of activities they are prepared to engage in. The high-value and in-demand attributes of biomedical engineers are made possible by the diverse nature of their training. Program administrators are working hard with biomedical engineering companies such as Rhythmlink, Selah Clinical, Stryker, and GE Health, locally and across the State, to enhance program diversity. Mechanisms such as our BME Advisory Board, Capstone Design Projects, collaboration with SC medical schools, and active participation in organizations like the SCBIO-SC Biomedical Engineering Companies Consortium, all contribute to enriching the opportunities that will be available to students in the program.

**(b) Centrality of the program to the Commission-approved mission of the institution**

As noted on the University website,

The primary mission of the University of South Carolina is the education of the state's diverse citizens through teaching, research, creative activity and service...

...With a flagship campus recognized by the Carnegie Foundation as a top research and service institution and nationally ranked in startup businesses and an eight-campus system that confers nearly 40 percent of all bachelor's and graduate degrees awarded at public institutions in South Carolina, the university has a profound relevance, reach and impact on the people of the state. The University of South Carolina provides all students with the highest-quality education, including the knowledge, skills and values necessary for success and responsible citizenship in a complex and changing world through engagement in nationally and internationally ranked research, scholarship, service and artistic creation. ([http://ipr.sc.edu/mission/system\\_ms.htm](http://ipr.sc.edu/mission/system_ms.htm))

The proposed M.E. in Biomedical Engineering degree program is directly related to the core USC mission, particularly the focus on education and the granting of terminal degrees, and is thus central to the continued evolution of our institution and in-line with the overarching goals delineated in the mission statement. The program will contribute in a substantial way to strengthening the economic and medical well-being of South Carolinians.

**(c) Relationship of the proposed program to related programs within the institution**

The University of South Carolina offers a Master of Science (M.S.) degree in Biomedical Engineering, but not a professional degree for the practice of biomedical engineering at the advanced level. The 30 credit hour M.E. in Biomedical Engineering degree program has been developed by the Biomedical Engineering Program at USC to meet the needs of students who desire to embrace a biomedical engineering industrial career in product and technology development or other related fields. Based on industrial career interest, students will be advised to select courses from an approved list of existing graduate level courses with the majority offered by the Biomedical Engineering Program at USC. Currently, the Biomedical Engineering Interdisciplinary program at USC offers a total of 36 graduate level courses in three colleges (Engineering and Computing, Arts and Sciences and the School of Medicine). Advising will be managed by the Biomedical Engineering Graduate Committee along with the assigned advisor of each student.

**(d) Similar programs in the state**

- Clemson University offers an M.S. degree in Bioengineering
- Clemson University is concurrently proposing an M.E. degree in Bioengineering

**(e) Comparison to similar programs in the state**

There is currently no similar program at a public or private university in South Carolina. Both Clemson University and the University of South Carolina offer Master of Science (M.S.) degrees in Bioengineering/Biomedical Engineering, but neither offers a professional degree for the practice of biomedical engineering at the advanced level. The M.S. degree is a research-focused advanced degree intended to prepare students for a career in biomedical research. The new M.E. program will integrate graduate-level course work with opportunities for internship experience to prepare students for

product and technology development. It is considered a professional terminal degree, but as stated above is expected to also be used by students to increase competitiveness for subsequent graduate/medical training. Both the University of South Carolina and Clemson University are currently developing the degree Master of Engineering in Biomedical Engineering. This new program was initiated and proposed based on mutual agreement between Dr. Abdel Bayoumi, Director of the BME at USC and Dr. Martine Laberge, Chair of the Bioengineering Department at Clemson University. The two programs at the two universities will coordinate and collaborate at all levels (teaching, research and service) in order to minimize cost and maximize the use of resources and the overall benefits. The employment projections and other needs described in the Justification section above provide substantial arguments to justify both schools offering this degree to meet biomedical economic development needs in South Carolina.

## **6. ADMISSION CRITERIA**

The same admission criteria as those currently required by the University of South Carolina for graduate engineering students will be followed for the proposed program. Applications will be reviewed bi-annually by the graduate committee, and acceptance to the program will be granted for program initiation in both the Fall and Spring semester of a given academic year.

## **7. ENROLLMENT**

We anticipate sustained growth in the M.E. degree in BME over the first five years it is offered. We anticipate that few to none of these students will enroll via transfer from another program at USC, but a large fraction will be drawn from recent SC graduates who have earned a B.S. in BME or a related discipline. Based on surveys with the current undergraduate population in BME at USC, we anticipate at least 10 students will enroll for the Fall semester immediately upon offering of this degree and another 3 will enroll in the Spring semester of that academic year. We expect a 30% annual increase in new student enrollment and will enforce a cap of 30 new students enrolled annually to ensure the highest quality students. We anticipate an annual graduation rate of 25%, and an attrition rate of 20%. The Biomedical Engineering Program is working closely with the South Carolina's Life Sciences Industry Organization (SCBIO) and its members to assure that the curriculum that will be delivered through this professional degree will meet the needs of the biomedical manufacturing community. The tabulated numbers below are based on the estimated rates of enrollment, attrition and graduation

**Table A – Projected Total Enrollment**

YEAR	FALL		SPRING	
	Head count	Credit Hours	Head count	Credit Hours
2014 – 15	10	150	13	195
2015 – 16	20	300	24	360
2016 – 17	30	450	35	525
2017 – 18	38	570	44	660
2018 – 19	52	780	57	855

**8. CURRICULUM**

The proposed curriculum is detailed below. Please note that no new courses will be added to the current institution’s course catalog, but rather the program curriculum will be constructed from currently available courses.

**The proposed curriculum consists of 30 total credit hours including:**

**Mandatory Courses (12 Credit Hours – all courses):**

- BMEN 710** Modeling and Simulation of Biomedical Systems. (3)
- BMEN 713** Human Cell and Molecular Biology for Biomedical Engineers. (3)
- BMEN 720** Transport Phenomena in Biomedical Systems. (3)
- BMEN 723** Anatomy and Physiology for Biomedical Engineers (3)

**Recommended Core Courses (6 Credit Hours – two courses):**

- BMEN 546** Delivery of Bioactive Agents (3)
- ECHE 572** Tissue Engineering (3)
- BMEN 589W** BioMEMS (Bio-Micro-Electro-Mechanical Systems) (3)
- BMEN 589W** Micro/Nanofluidics and Lab-on-a-Chip (3)

**Choice of BMEN Electives (12 Credit Hours – three to four courses):**

**College of Engineering and Computing:**

**BMEN 795** Biomedical Engineering Literature (1 credit)  
**BMEN 797** Biomedical Engineering Development (1 credit)  
**BMEN 798** Graduate Seminar in Biomedical Engineering (1 credit)  
**ECHE 710** Advanced Chemical Engineering Thermodynamics  
**ECHE 720** Advanced Fluid Flow  
Analysis  
**ECHE 721** Advanced Heat Flow Analysis  
**ECHE 722** Advanced Mass Transfer  
**ECHE 725** Rheology  
**ECHE 730** Chemical Reactor Design  
**ECHE 750** Process Dynamics and Control  
**ECHE 770** Electrochemical Engineering  
**ECHE 772** Principles of Polymer Systems

**EMCH 717** Advanced Finite Element Methods  
**EMCH 722** Plasticity  
**EMCH 741** Viscous and Turbulent Flow

**EMCH 751** Advanced Heat Transfer  
**EMCH 771** Design Properties of Plastics  
**EMCH 794** Thermodynamics  
**CSCE 555** Algorithms in Bioinformatics.  
**CSCE 561** Numerical Analysis.  
**CSCE 563** Systems Simulation.  
**CSCE 564** Computational Science.  
**CSCE 580** Artificial Intelligence.  
**CSCE 758** Probabilistic System Analysis  
**CSCE 763** Digital Image Processing.  
**CSCE 768** Pattern Recogn.and Classification.  
**CSCE 769** Computational Structural Biology  
**CSCE 784** Neural Information Processing  
**CSCE 822** Data Mining and Warehousing

**College of Arts and Sciences:**

**CHEM 751** Biosynthesis of Macromolecules  
**CHEM 752** Regulation and Integration of Metabolism  
**CHEM 753** Enzymology and Protein Chemistry  
**CHEM 754** Biomedical Biochemistry I  
**CHEM 755** Biomedical Biochemistry II  
**BIOL 714** Advanced Cell Biology



## **BIOL 736** Advanced Developmental Biology

### **School of Medicine:**

- ANAT 700** Principles of Electron Microscopy
- ANAT 701** Human Embryology and Gross Anatomy
- ANAT 720** Special Topics in Microscopic Anatomy
- BMSC 700** Biomedical Science Interdisciplinary Laboratory I
- BMSC 701** Biomedical Science Interdisciplinary Laboratory II
- BMSC 720** Signal Transduction
- BMSC 730** Cardiovascular Science
- CBNS 702** Human Microscopic Anatomy
- MBIM 710** Advanced Immunobiology
- MBIM 720** Comprehensive Microbiology
- MBIM 739** Medical Bacteriology
- MBIM 740** Virology
- MCBA740** Biological Microscopic Imaging
- MCBA741** Molecular Imag/Biomed Res
- PATH 710** Neoplasia
- PATH 741** Pathology I
- PATH 742** Pathology II
- PATH 760** Topics in Pathobiology
- PHPH 705** Biomedical Pharmacology
- PHPH 735** Cardiovascular Pharmacology
- PHPH 740** Neuroscience
- PHPH 745** Neurophysiology
- PHPH 750** Fundamental Neuroscience I
- PHPH 751** Fundamental Neuroscience II

## **9. ASSESSMENT**

The assessment plan for this new degree program will include reporting using WEAVE-online, a web-based tool that supports continuous improvement processes for academic programs within institutions of higher education. All students will also be required to submit an e-portfolio containing artifacts demonstrating competency in biomedical engineering design, oral/written communication, industrial practices, and mentoring/leadership. This e-portfolio will be evaluated by the assessment committee following a review by a sub-committee of the departmental industrial advisory board, whose members are practicing bioengineers in the biomedical industry. Because the M.E. Program in Biomedical Engineering is a professional degree program for students who are focused on a career in the healthcare, medical device, or bioinstrumentation industries, feedback from the industrial advisory board is central to meaningful assessment. The constructed curriculum ensures that students preparing for a career in the health care sector gain fundamental technology leadership skills important to biomedical engineers. Students in the M.E. degree program receive exposure to issues related to product development, project management, innovation, and

commercialization. Students are also required to focus their technical training by completing advanced biomedical engineering coursework.

**10. FACULTY**  
**(a) Faculty List**

Table B details the rank (not name) and academic qualifications of each faculty member who will be directly involved in the core courses which comprise the proposed program. In addition to the listed faculty, a number of other faculty will contribute to the success of the program by virtue of offering courses that will serve as electives in the proposed curriculum.

Table B– Faculty List

<b>List Staff by Rank (e.g. Professor #1, Professor #2, Associate Professor #1, etc.)</b>	<b>Highest Degree Earned</b>	<b>Field of Study</b>	<b>Teaching in Field (Yes/No)</b>
Program Director (#1)	Ph.D.	Mechanical Engineering	Yes
Professor (#1)	Ph.D.	Mechanical Engineering	Yes
Associate Professor (#1)	Ph.D.	Chemical Engineering	Yes
Associate Professor (#2)	Ph.D.	Cell Biology & Anatomy	Yes
Associate Professor (#3)	Ph.D.	Chemical Engineering	Yes
Associate Professor (#4)	Ph.D.	Computer Science & Engineering	Yes
Associate Professor (#5)	Ph.D.	Computer Science & Engineering	Yes
Associate Professor (#5)	Ph.D.	Computer Science & Engineering	Yes
Associate Professor (#6)	Ph.D.	Mechanical	Yes
Assistant Professor (#1)	Ph.D.	Chemical	Yes
Assistant Professor (#2)	Ph.D.	Chemical	Yes
Assistant Professor (#3)	Ph.D.	Mechanical	Yes

**(b) Enumeration and Necessary Qualifications of New Faculty**

Although no new faculty hires are anticipated in the realization of this program, the following qualifications would be sought for new hires at various stages in their academic careers:

- The new faculty member at the Professor level will have significant experience in both research and teaching in the biomedical engineering field and will be expected to lead the program.
- The new Associate Professors will have significant experience in both research and teaching in the biomedical engineering field.
- The new Assistant Professors will have the potential for development of research areas as well as the ability to teach in the biomedical engineering field.

**(c) Proposed Changes in Assignment for Current Faculty**

Current faculty members in the Departments of Mechanical and Chemical Engineering, and Cell and Developmental Biology and Anatomy will teach courses in this curriculum. All courses are currently taught by faculty in the M.S. and Ph. D. programs. This M.E. program will simply put more students in classes, improving educational efficiency.

**(d) Institutional Plan for Faculty Development**

The faculty already receive release time for research, consulting, and curriculum development. In addition to fulfilling the teaching requirements of the proposed program, the faculty devote a significant part of their time to research in biomedical engineering related activities. There will be a concerted effort to incorporate research activity into course curriculum, such that students will be exposed to current concepts and issues in the field.

The biomedical engineering field is rapidly evolving. To stay current, faculty members in the BME program attend conferences and symposia where the latest research and teaching trends are presented and discussed. In addition, several faculty members each year attend summer biomedical engineering workshops such as those sponsored by the United States National Institutes of Health and other health organizations.

**(e) Institutional Definition of the Full-Time Equivalents (FTE)**

One FTE is equivalent to a teaching load of 100 undergraduates, 48 masters-level, or 18 PhD-level graduate students in a 3-hour class.

**(f) Unit Administration, Faculty, and Staff Support**

Table C lists new and currently employed faculty, administrators, and staff for the proposed program. It should be noted that one FTE is equivalent to a teaching load of

100 undergraduate, 48 masters-level, or 18 PhD-level graduate students in a 3-hour class.

Table C – Unit Administration, Faculty & Staff Support

<b>UNIT ADMINISTRATION, FACULTY, AND STAFF SUPPORT</b>						
<b>YEAR</b>	<b>NEW</b>		<b>EXISTING</b>		<b>TOTAL</b>	
	<b>Headcount</b>	<b>FTE</b>	<b>Headcount</b>	<b>FTE</b>	<b>Headcount</b>	<b>FTE</b>
<b>Administration</b>						
<b>2014 – 15</b>			<b>1</b>	<b>0.25</b>	<b>1</b>	<b>0.25</b>
<b>2015 – 16</b>			<b>1</b>	<b>0.25</b>	<b>1</b>	<b>0.25</b>
<b>2016 – 17</b>			<b>1</b>	<b>0.25</b>	<b>1</b>	<b>0.25</b>
<b>2017 – 18</b>			<b>1</b>	<b>0.25</b>	<b>1</b>	<b>0.25</b>
<b>2018 – 19</b>			<b>1</b>	<b>0.25</b>	<b>1</b>	<b>0.25</b>
<b>Faculty</b>						
<b>2014 – 15</b>			<b>12</b>	<b>5</b>	<b>12</b>	<b>5</b>
<b>2015 – 16</b>			<b>12</b>	<b>5</b>	<b>5</b>	<b>5</b>
<b>2016 – 17</b>			<b>12</b>	<b>5</b>	<b>12</b>	<b>5</b>
<b>2017 – 18</b>			<b>12</b>	<b>5</b>	<b>12</b>	<b>5</b>
<b>2018 – 19</b>			<b>12</b>	<b>5</b>	<b>12</b>	<b>5</b>
<b>Staff</b>						
<b>2014 – 15</b>			<b>2</b>	<b>1</b>	<b>2</b>	<b>1</b>
<b>2015 – 16</b>			<b>2</b>	<b>1</b>	<b>2</b>	<b>1</b>
<b>2016 – 17</b>			<b>2</b>	<b>1</b>	<b>2</b>	<b>1</b>

<b>2017 – 18</b>			<b>2</b>	<b>1</b>	<b>2</b>	<b>1</b>
<b>2018 – 19</b>			<b>2</b>	<b>1</b>	<b>2</b>	<b>1</b>

Administration of the program will be overseen in tandem by the current Director of Biomedical Engineering and the Graduate Director in Biomedical Engineering at USC. The core faculty who will deliver the proposed curriculum will consist of 12 members with affiliation to the Biomedical Engineering Program. A USC staff member will coordinate all administrative issues associated with the proposed program. All administrators, faculty, and staff referenced above are currently employed by USC. Introducing this new degree program will not increase the faculty teaching load. Additionally will be no increase in the administration work load of the BME Director or the BME graduate director. Only 1/2 time of an administrative assistant will be added for this new degree program.

**11. PHYSICAL PLANT**

All resources required to deliver the proposed curriculum are already present at USC, and are available for the realization of this program. No additional physical plant requirements are foreseen specifically for the proposed program. However, some reallocation of existing space may be performed to allow for the development and operation of the class-associated laboratories as needed.

**12. EQUIPMENT**

No new equipment or resources are needed to support the proposed program.

**13. LIBRARY RESOURCES**

**(a) Assessment of current holdings**

University Libraries currently has 522 books and subscribes to 31 periodicals in biomedical engineering and the related fields. As a government Depository Library, University Libraries also has full access to NIH and other government publications. Holdings include the principal professional publications from the American Society of Mechanical Engineers (ASME), American Society of Chemical Engineers (ASCE), and Society of Manufacturing Engineers (SME), including publications relevant to biomedical engineering. Additionally, University Libraries currently subscribes to the principal publication of the Biomedical Engineering Society (BMES) and numerous, more specialized, basic science and clinical journals of relevance to aspects of biomedical engineers. These holdings are adequate for the proposed biomedical engineering degree program.

**(b) Estimate of Acquisitions Needed Annually**

The current BS, MS, and PhD degree programs in Mechanical Engineering and Chemical Engineering are supported by an allocation of about \$8,000 from the current library budget. An additional \$2,500, annually, will be requested to add books and periodicals explicitly devoted to biomedical engineering.

**14. ACCREDITATION, APPROVAL, LICENSURE, OR CERTIFICATION**

Not applicable

**15. ARTICULATION**

There are no formal articulation agreements associated with the proposed program. However, as mentioned above, the University of South Carolina and Clemson University have discussed the courses and curricula of both M.E. degrees. While we have not examined other possibilities of course sharing or other collaboration, we would certainly welcome collaboration with other schools.

**16. ESTIMATE OF COSTS**

The cost of implementation of the ME in BME is \$42,500 per semester. This includes \$15,000 for administrative oversight and advising students, and \$25,000 for supplies, consumables, marketing, publications, printing and other commercialization costs each semester. Student tuition will cover these implementation costs. The formula used to calculate the tuition in Table D is the number of credit hours listed in Table A multiplied by the in-state tuition per graduate credit hour. No new faculty, staff, or administrative costs are anticipated. All courses for the degree are already taught and managed as part of the Master of Science in Biomedical Engineering program.

Table D – Estimated Costs and Sources of Financing by Year

<b>ESTIMATED COSTS BY YEAR</b>						
<b>CATEGORY</b>	<b>1<sup>st</sup></b>	<b>2<sup>nd</sup></b>	<b>3<sup>rd</sup></b>	<b>4<sup>th</sup></b>	<b>5<sup>th</sup></b>	<b>TOTALS</b>
Program Administration						
Faculty Salaries						
Graduate Assistants						
Clerical/Support Personnel	\$30,000	\$30,000	\$30,000	\$30,000	\$30,000	\$150,000
Supplies and Materials	\$50,000	\$50,000	\$50,000	\$50,000	\$50,000	\$250,000
Library Resources	\$5,000	\$5,000	\$5,000	\$5,000	\$5,000	\$25,000
Equipment						
Facilities						
Other (Identify)						
<b>TOTALS</b>	<b>\$85,000</b>	<b>\$85,000</b>	<b>\$85,000</b>	<b>\$85,000</b>	<b>\$85,000</b>	<b>\$425,000</b>
<b>SOURCES OF FINANCING BY YEAR</b>						
Tuition Funding	\$167,325	\$320,100	\$472,875	\$596,550	\$792,975	\$2,349,825
Program-Specific Fees						
State Funding*						
Reallocation of Existing Funds**						
Federal Funding						
Other Funding (Specify)						
<b>TOTALS</b>	<b>\$167,325</b>	<b>\$320,100</b>	<b>\$472,875</b>	<b>\$596,550</b>	<b>\$792,975</b>	<b>\$2,349,825</b>