

UCF Ph.D. in Biomedical Engineering

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**Board of Governors, State University System of Florida
REQUEST TO OFFER A NEW DEGREE PROGRAM**

In Accordance with BOG Regulation 8.011

(Please do not revise this proposal format without prior approval from Board staff)

University of Central Florida
Institution Submitting Proposal

College of Engineering and Computer Science
Name of College(s) or School(s)

Biomedical Engineering
Academic Specialty or Field

14.0501
Proposed CIP Code (2020 CIP)

Fall 2022
Proposed Implementation Term

Mechanical and Aerospace Engineering
Name of Department(s)/Division(s)

PhD in Biomedical Engineering
Complete Name of Degree

The submission of this proposal constitutes a commitment by the university that, if the proposal is approved, the necessary financial resources and the criteria for establishing new programs have been met prior to the initiation of the program.

November 18, 2021

Digitally signed by Alexander Cartwright
Date: 2021.11.05 14:36:27 -04'00'

Date Approved by the University Board of Trustees
Alex Martins 11.18.21
Alex Martins, Chair, UCF Board of Trustees
Board of Trustees Chair's Signature **Date**

President's Signature **Date**
Michael Johnson Digitally signed by Michael Johnson
Date: 2021.10.20 14:19:02 -04'00' 2021-10-20
Provost's Signature **Date**

PROJECTED ENROLLMENTS AND PROGRAM COSTS

Provide headcount (HC) and full-time equivalent (FTE) student estimates of majors for Years 1 through 5. HC and FTE estimates should be identical to those in Table 1 in Appendix A. Indicate the program costs for the first and the fifth years of implementation as shown in the appropriate columns in Table 3 in Appendix A. Calculate an Educational and General (E&G) cost per FTE for Years 1 and 5 (Total E&G divided by FTE).

Implementation Timeframe	HC	FTE	E&G Cost per FTE	E&G Funds	Contract & Grants Funds	Auxiliary/Philanthropy Funds	Total Cost
Year 1	11	8.25	\$15,759	\$130,013	\$200,000	\$0	\$330,013
Year 2	16	12.00					
Year 3	18	13.50					
Year 4	22	16.50					
Year 5	27	20.25	\$7,618	\$154,262	\$472,727	\$0	\$626,989

Note: This outline and the questions pertaining to each section **must be reproduced** within the body of the proposal to ensure that all sections have been satisfactorily addressed. Tables 1 through 4 are to be included as Appendix A and not reproduced within the body of the proposals because this often causes errors in the automatic calculations.

Introduction

I. Program Description and Relationship to System-Level Goals

- A. Briefly describe within a few paragraphs the degree program under consideration, including (a) level; (b) emphases, including majors, concentrations, tracks, or specializations; (c) total number of credit hours; and (d) overall purpose, including examples of employment or education opportunities that may be available to program graduates.**

The UCF College of Engineering and Computer Science (CECS) is proposing to implement a formal PhD academic program in Biomedical Engineering (BME) (CIP code: 14.0501). It is a strategic goal of the CECS to establish a BME program aimed at significantly enhancing its growth, reputation and ranking, to meet strong demand from motivated students, that typically includes a significant proportion of women, minority and students with disabilities, and to promote productive research collaborations with the UCF College of Medicine (UCF-COM) at the Lake Nona campus and, more generally, with biomedical researchers throughout UCF and Central Florida. The CECS has established a successful Bioengineering Minor that complements BS degrees in Engineering and Computer Science. The CECS has collaborated with the Burnett School of Biomedical Sciences at UCF to establish a companion Bioengineering Minor that was launched in 2019 and the Medicine-Engineering Double Degree (MEDD) program established in 2016 for pre-med students. The MSBME program was launched in Fall 2016 and is housed in the Mechanical and Aerospace Engineering (MAE) Department. The MAE department has an extensive history of biomedical engineering funding and research and production of theses and dissertations. UCF and the MAE Department have invested substantial resources in preparation of the PhD in BME program in terms of recruitment of a strong core of twelve (12) BME faculty that will support this proposed program.

We have followed the successful path that led to the creation of the PhD in Aerospace Engineering that was developed organically from a MS in Aerospace Engineering to a PhD in Aerospace Engineering in response to student and industry demand. The PhD in Aerospace Engineering was launched in the MAE Department in Fall 2019. The groundwork for the proposed PhD in BME program started with the creation of the minors in bioengineering in CECS (2011) and BSBS (2019), with the creation of our MSBME program launched in Fall 2016, with the investments made by the university in the hiring of the Bionic Materials, Implants & Interfaces (Bionx) and Disability, Aging and Technology (DAT) cluster faculty based in MAE and in the investment in their laboratories (Q. Fu, Hwan Choi, Joon Park), as well as with the hiring of five BME faculty members in MAE (H. Huang, R. Steward, S. Song, L. Perotti, and W. Shen) over the course of 2015-2020. The MAE department has invested in the required infrastructure and research space. The proposed PhD program does not place an additional burden on instructional delivery as the BME curriculum and BME supporting courses have been developed and are currently being delivered under the MSBME program and the PhD in Mechanical Engineering program as part of electives within those programs.

The proposed PhD in BME program aligns with the UCF strategic mission to be a leading research university and with the SUS BOG Strategic Planning Goals that specifically identifies biomedical engineering as a key enabling industry that: (1) provides jobs with high average annual salaries, and (2) fits within the overarching strategy of building a stable Florida economy based on knowledge and innovation.

The proposed PhD in BME will be offered through and housed in the Department of Mechanical and Aerospace Engineering. The aim is to formally establish a strong research-based graduate program that is focused on biomedical engineering applications. Biomedical engineering is distinct from biomedical science. The latter typically addresses medical issues on the scale of cells, biomolecules, atoms and nanoparticles, for example for application to drug discovery. Such a program already exists and is well-established at UCF at the Burnett School of Biomedical Sciences (<https://med.ucf.edu/biomed/>) at the Lake Nona Campus of the UCF College of Medicine.

The proposed biomedical engineering PhD program addresses medical issues at the level of tissues, organs, and the body as a system, with the application of engineering methodologies in surgical and cancer treatment planning, device development for improved and novel diagnosis, and for development of assistive and rehabilitative technology.

The MAE department currently has twelve (12) faculty members (Alain Kassab, Olusegun Ilegbusi, Sam Song, Hansen Mansy, Robert Steward, Helen Huang, Qiushi Fu, Hwan Choi, Luigi Perotti, Joon Park, Wen Shen, and Sudeshna Pal) who are actively engaged in research and teaching in BME and who shaped the current proposed program. These current MAE faculty members, referred to as *the BME faculty* from this point forward in the proposal, are engaged in wide range of BME research that includes research in computational fluid mechanics for cardiovascular and lung cancer treatment-planning, bioacoustics device development for patient monitoring and bedside diagnosis, and mechanical force-induced biochemical responses, image guided surgery and soft robotics, biomechanics of rehabilitation and neural control of movement, biomechanics of falls, mobility and mitigation of fall risks and development of gait assistive device, and lab on chip biomedical research. This research portfolio benefits from partnership with the UCF COM, local hospitals and medical industry programs, and it is supported by local and national funding agencies.

The PhD in BME will require completion of 72 hours at the graduate level beyond the BS (a combination of 5000, 6000, and 7000 level classes) and the successful defense of a PhD dissertation. The proposed program is in concordance with the UCF Graduate School policies and requirements of PhD program (<http://catalog.ucf.edu/content.php?catoid=4&navoid=255>). The PhD in BME program requires:

- (1) 57 hours coursework beyond the BS (comprised of a minimum of 27 hours of formal coursework exclusive of Independent Study (BME 6908), dissertation, and doctoral research hours, and 15 hours Doctoral Dissertation. At least one-half of the credit hours used to meet program requirements must be in 6000-level or 7000-level courses, including the allowed number of research and dissertation hours
- (2) Successful completion of the BME PhD Qualifying Examination (inaugurated in the MAE Department in Fall 2019 and currently administered Fall/Spring as an option for students pursuing the PhD in Mechanical Engineering who are engaged in BME research).
- (3) Successful completion of the Candidacy examination.
- (4) Successful defense of the doctoral dissertation.
- (5) Completion of four (4) zero credit hour MAE Seminars.

Because biomedical engineering is highly interdisciplinary and covers many areas of science and engineering, the specialized training of PhD in BME is best suited by a curriculum that has a strong foundation of required courses complemented by a rich number of Representative Electives which enables tailored education that best suits the research specialization of the PhD student. The curriculum consists of a core set of 7 required courses (21 hours) that have been approved by the BME faculty and an additional 12 elective courses (36 hours). The additional 12 elective courses could include independent study and directed research but must include a minimum of 6 hours of formal coursework chosen from a selection of graduate elective courses. The details of the curriculum are provided in the curriculum section of this proposal and the list of required courses is provided below:

- BME 5216C: Mechanics of Biostructures I (3 hours)
- BME 5217C: Mechanics of Biostructures II (3 hours)
- BME 6500C: Bio-instrumentation (3 hours)
- BME 6935: Topics in BME (3 hours)
- BME 6231: Continuum Biomechanics (3 hours)
- BME 5742C: Modeling Techniques and Methodologies in Bioengineering (3 hours)
- ESI 5219: Engineering Statistics (3 hours) or STA 5206: Statistical Analysis (3 hours)

It should be noted that a substantial portion of the proposed PhD in BME required courses are shared with the current MSBME program delivered in MAE and that all additional courses required for the PhD program, for example, BME 6231 - Continuum Biomechanics (3 hours), have been formally approved at the State level, provided BME designation, and are currently delivered as part of the BME course offering at the MAE Department. We have fashioned and prepared the required curriculum as we hired our BME faculty in preparation of this proposal. Furthermore, the procedures and policies for the PhD Qualifying Examination BME option (to be described in detail later in the proposal) have been crafted and approved by the BME faculty and by the MAE faculty at large. The BME PhD Qualifying Examination has been administered as an option to our Mechanical Engineering PhD students who are engaged in BME research and who consequently may select

this topic for the PhD Qualifying Examination since Fall 2019. To date five students have passed this examination and two more are scheduled to take it in Fall 2021.

The proposed PhD in BME degree offers the following gateways into the program:

- (1) a PhD in BME for students with formal training in engineering or biomedical engineering who have earned an MS degree and are seeking higher level graduate education and research training.
- (2) a PhD in BME with a MSBME along-the-way to engineering students who are admitted into the PhD program with a BS in biomedical engineering, mechanical engineering, aerospace engineering or a closely related discipline.

The proposed PhD in BME degree will further strengthen academic and medical industry partnerships at UCF by training graduates with professional skills enabling them to gain employment in the biomedical engineering industry or to successfully seek competitive positions in the biomedical industry or post-doc and faculty positions at SUS institutions or research and teaching universities across the country. We provide ample evidence of this in the needs and demand section of this program proposal.

B. Please provide the date when the pre-proposal was presented to CAVP (Council of Academic Vice Presidents) Academic Program Coordination review group. Identify any concerns that the CAVP review group raised with the pre-proposed program and provide a brief narrative explaining how each of these concerns has been or is being addressed.

Thursday, October 5, 2017, the Dean of the College of Engineering and Computer Science, Dr. Michael Georgiopoulos, received an email notice from Dr. Paige Borden, Associate Provost at UCF, informing us that the Pre-Proposal for a PhD in Biomedical Engineering was discussed and approved for development by the statewide Council of Academic Vice Presidents' Academic Coordinating Committee with no concerns.

Four universities did make comments that were provided back to our Dean and the BME PhD pre-proposal committee as we were advised to continue the proposal process. In quotes below are the comments reproduced from Dr. Borden's email who shared these comments in particular:

"FIU and the FSU/FAMU engineering deans had no concerns, and all agreed that additional, doctoral-trained Biomedical Engineers would be a positive."

"UF – Also no concerns. UF has an excess of applicants and is only able to accept a fraction of their volume. There will definitely be applicant demand for any new program."

C. If this is a doctoral level program please include the external consultant's report at the end of the proposal as Appendix D. Please provide a few highlights from the report and describe ways in which the report affected the approval process at the university.

The consultant's report, provided in Appendix D, was prepared by Dr. Ted Conway who is currently a Professor of Biomedical Engineering at Florida Tech. Dr. Conway is a Fellow of the American Association for the Advancement of Science (FAAAS) and an Elected Member of the College of Fellows in the American Institute for Medical and Biological Engineering (FAIMBE). He was the Inaugural Head of the Biomedical and Chemical Engineering and Sciences Department (2017 – 2020) and the Inaugural Head of the Biomedical Engineering Department (2014 – 2017) at Florida Tech. Prior to returning to Florida he had a permanent appointment with the National Science Foundation (NSF) as the Program Director (2008 – 2014) for the: 1) General & Age Related Disabilities Engineering Program (GARDE); 2) CBET-National Robotics Initiative (NRI); 3) CBET-Broadening Participation Research Initiation Grant in Engineering Program (BRIGE); and 4) Science and Technology Center (STC): Emergent Behaviors of Integrated Cellular Systems (EBICS) in the Chemical, Bioengineering, Environmental and Transport Systems Engineering (CBET) Division of the Engineering Directorate.

Quoted below is the summary provided by Professor Conway upon review of the PhD in BME program proposal:

"Overall, this is a well thought out graduate degree program. The UCF PhD Program in

Biomedical Engineering will build on current resources in both the College of Engineering and Computer Science and the College of Medicine. This program is needed to fulfill the current and emerging research and teaching requirement for Universities and local, national and international industries. The proposed academic program is strong and will provide a strong research, educational and mentoring environment for students interested in pursuing an advanced degree in Biomedical Engineering.”

Furthermore, Dr. Conway stated in his report that

“The BME PhD program that is being proposed at UCF will complement the other BME PhD programs within the State of Florida and is aligned with many of the top Universities in other states that offer similar programs. The variety of teaching and student mentoring modes (in-class presentation, virtual presentations, face-to-face and virtual student meetings, etc.) take advantage of 21st Century communication tools.

It is well established that BME programs across the United States are the most diverse with respect to students’ gender, ethnicity, disability status, etc. The proposed UCF BME PhD Program will leverage and build upon this diversity of students to create an inclusive environment that maximizes the opportunity to generate solutions to problems that currently exist in the Biomedical Engineering research community.”

The report was reviewed the Dean of CECS, Dr. Michael Georgiopoulos, and the CECS Associate Dean of Academic Affairs, Dr. Ali Gordon, and was reviewed by Dr. John Weishampel who is the Senior Associate Dean of the College of Graduate Studies. The report by the external consultant reinforced the commitment at UCF for the creation of a much-needed PhD in BME program.

D. Describe how the proposed program is consistent with the current State University System (SUS) Strategic Planning Goals. Identify which specific goals the program will directly support and which goals the program will indirectly support (see link to the SUS Strategic Plan on [the resource page for new program proposal](#)).

The proposed PhD in BME program aligns with UCF strategic mission to be a leading research and partnership university and with the SUS BOG Strategic Planning Goals that specifically identifies biomedical engineering as a key enabling industry that: (a) provides jobs with high average annual salaries, and (b) fits within the overarching strategy of building a stable Florida economy based on knowledge and innovation.

The PhD in BME program aligns itself with the Board of Governors three SUS Strategic Planning Goals [2025 System Strategic Plan 2019.pdf \(flbog.edu\)](#)

Goal 1: Excellence. The PhD in BME program will directly support the SUS strategic planning goals of increasing the number of degrees in STEM fields, increase research and commercialization activities by strengthening the pipeline of researchers pursuing graduate degrees in biomedical engineering, and achieving excellence in quality and reputation of scholarship, research, and innovation in BME research at UCF in the targeted areas of biofluids and biomechanics. The proposed PhD in BME is complementary to our existing BME minors and the MSBME program housed in MAE as well as the well-established BME research programs in MAE that, in close partnership with the UCF-COM faculty and professional medical partners at Orlando’s healthcare delivery systems, focuses on problems at the interface of engineering and medicine aimed at improvements in health monitoring and treatment planning. Current research is funded by the NIH, American Heart Association, the NSF, Orlando Health, and non-profit charitable foundations dedicated to addressing health related problems will benefit and grow in scope with formal BME training of graduate students with a rapidly increasing research enterprise to support expected program growth. The proposed PhD in BME program directly responds to the SUS Board of Governors continued expectation that state universities provide academic programs of the highest quality, to produce world class, consequential research, and to reach out and engage Florida’s communities and businesses in a meaningful and measurable way.

Goal 2: Productivity. The proposed PhD in BME program will directly support the SUS strategic planning goals of increasing the number of degrees in STEM fields, increase research and commercialization activities by strengthening the pipeline of researchers pursuing graduate degrees in biomedical engineering, and achieving excellence in quality and reputation of scholarship, research, and innovation. This program supports the SUS BOG goal of enabling Florida to become more competitive in the national and global economy as the proposed PhD in BME degree will increase the educational attainment levels that can be obtained by the large pool of Central Florida residents seeking education and subsequent employment in BME. Therefore, UCF is responding directly to the BOG directive that “*state universities must respond by awarding more degrees in specific high demand programs, particularly the STEM disciplines.*”

Goal 3: Strategic Priorities for a Knowledge Economy. The proposed PhD in BME (CIP: 14.0501) is identified in the Florida SUS Board of Governors Programs of Strategic Emphasis (http://flbog.org/pressroom/strategic_emphasis/ and is listed in the CIP code program list <https://www.flbog.edu/wp-content/uploads/Current-PSE-list-approved-by-the-BOG-at-its-September-2020-meeting-PDF.pdf>). The proposed PhD in BME program will directly support the SUS strategic planning goals of increasing the number of degrees in STEM fields, increase research and commercialization activities by strengthening the pipeline of researchers pursuing graduate degrees in biomedical engineering, and achieving excellence in quality and reputation of scholarship, research, and innovation. According to the US Bureau of Labor Statistics, Florida remains among the states with the highest BME employment, therefore students who complete our program will 1) increase the percentage of graduates who continue their education in Florida and 2) increase the percentage of students employed in Florida. In addition, the following SUS goals will be indirectly supported: increase community and business workforce and increase levels of community and business engagement.

The proposed PhD in BME program also aligns itself with strategic goals of UCF to become a top 50 major metropolitan research university ([Office of the President | Dr. Alexander N. Cartwright \(ucf.edu\)](http://www.ucf.edu/office-of-the-president) and <https://www.ucf.edu/strategic-plan/implementation/>). In particular, our proposed PhD in BME program aligns with the following UCF aims:

Achieving international prominence in key programs of graduate study and research.

The MAE department aims at national and international prominence in its research and educational programs. MAE faculty are highly research productive, carry out well-funded and impactful research programs, publish in high quality scientific journals, and are visible at the national and international levels in participating and organizing professional conferences and symposia. MAE graduate students have an established track record of securing positions in academia and industry upon graduation. The addition of a PhD in BME program will expand the department’s reputation of distinction and excellence by formalizing its activities in the area of biomedical engineering research and education, preparing highly trained graduates to meet the demands of this growing industry in Florida and nationwide.

Building an inclusive environment with a culture of compassion at its core. Biomedical Engineering programs nationwide attract talented and highly motivated female and minority students. Moreover, UCF’s College of Engineering and Computer Science, which has nearly 13,500 students, is the fourth college of choice in the US for Hispanics. The MAE department has a Fall 2020 enrollment of nearly 4,500 students (3,980 UG and 401 G), and MAE faculty engaged in BME research have successfully recruited from this pool Hispanic and female students in their research programs. Many students have been awarded prestigious national fellowships, for example Andres Ceballos won UCF’s first NIH Graduate Fellowship in 2014 and Kelly Cox won an NSF Graduate Fellowship in 2013. Over half of our current MSBME program is comprised of female graduate students. The PhD in BME program will allow us to further attract and recruit many more talented students who are under-represented in STEM. Recently, the MAE Department and the MAE BME Director led the proposal for the establishment of the Biionix Cluster in partnership with the UCF COM and played a leading role in the three-year recruiting effort of seven faculty members for the cluster including two junior female faculty members and the senior cluster lead who is a female of African descent (<https://med.ucf.edu/biionix-cluster/>).

Becoming America's leading partnership university by partnering internally and externally to serve and positively impact our community. The MAE Department's well-established collaborations and partnerships with local industry such as Siemens, Lockheed Martin, and the Center for Advanced Turbine Education and Research (CATER) and the Siemens Energy Center are examples of the successful outcome and impact of such partnerships. The MAE faculty has established biomedical engineering research collaborations and partnerships with the UCF College of Medicine and local industry partners such as Orlando Health, Advent Health, and Nemours. The proposed PhD in BME will promote the expansion of these partnerships and the establishment of new partnerships with medical professionals in the five large health delivery systems, and with the BME industry in the Central Florida region and beyond to support the educational and research experiences of our students.

E. If the program is to be included in a category within the Programs of Strategic Emphasis as described in the SUS Strategic Plan, please indicate the category and the justification for inclusion. The Programs of Strategic Emphasis Categories are:

- **Critical Workforce:**

- Education
- Health
- Gap Analysis

- **Economic Development:**

- Global Competitiveness
- Science, Technology, Engineering, and Math (STEM)

Please see the Programs of Strategic Emphasis (PSE) methodology for additional explanations on program inclusion criteria at [the resource page for new program proposal](#).

The field of biomedical engineering combines fundamental principles and skillsets of engineering to the biomedical field with the goal to improve and advance human health. Therefore, the interdisciplinary PhD in BME program (CIP: **14.0501**) at UCF falls under SUS Programs of Strategic emphasis categories and is identified specifically on line 480 of the downloadable spreadsheet to be found at the SUS BOG site ([Current PSE list, approved by the BOG at its September 2020 meeting \(XLSX\)](#)).

Science, Technology, Engineering, and Math (STEM): The proposed PhD in BME program curriculum covers subjects that span: (1) *Science*: anatomy, physiology, biology and chemistry, (2) *Technologies*: instrumentation, medical imaging and segmentation software, and 3D printing, (3) *Engineering*: fluid and solid mechanics, acoustics, controls, robotics, and 4) *Math*: ordinary and partial differential equations, computational fluid dynamics, computational solid mechanics, and continuum biomechanics.

F. Identify any established or planned educational sites at which the program is expected to be offered and indicate whether it will be offered only at sites other than the main campus.

The proposed PhD in BME program will be located on UCF's main campus and will be housed and administered within the Department of Mechanical and Aerospace Engineering (MAE). The MAE Department Chair, Prof. Yoav Peles, appointed Dr. Alain Kassab as BME program director in Fall 2015. The BME Program Director is responsible for the development and administration of the BME program, the scheduling of courses, and the delivery of the PhD in BME Qualifying Examination option for the Mechanical Engineering PhD Qualifying Examination. The courses for the proposed PhD in BME will be delivered on the main UCF campus except for the two lab sections of Biostructures I and II that are currently delivered at the anatomy lab at the UCF College of Medicine Lake Nona Campus.

Graduate courses for the PhD in BME program that have no lab content will be taught on the main campus via video-streaming modality using Panopto and will be available at remote sites via SUS Feeds. There are BME graduate courses (BME 5742C, BME 6286C and BME 6500C) that have lab content and require presence of students on the UCF Main campus, and there two courses (BME 5216C and BME 5217C) have a lab component that requires presence of the students at the UCF-COM Lake Nona Campus, specifically to access the UCF-COM anatomy lab. These courses which have associated lab sections are described below:

1. ***BME 5216C: Mechanics of Biostructures I (3 hours)*** has a lab component and is currently offered in close collaboration with the UCF-COM in Fall for our MSBME program and requires presence at the UCF-COM anatomy lab at the Lake Nona Campus.
2. ***BME 5217C: Mechanics of Biostructures II (3 hours)*** has a lab component and is currently offered in close collaboration with the UCF-COM for in Spring for our MSBME program and requires presence at the COM anatomy lab at the Lake Nona Campus.
3. ***BME 6500C: Bioinstrumentation***– has a lab component, is offered every Fall for our MSBME program and will require the presence of students at the lab which is located in the Engineering I building of the UCF Main Campus.
4. ***BME 5742C Modeling Techniques and Methodologies in Bioengineering (3 hours)*** has a lab component, is offered every Fall for our MSBME program and will require the presence of students at the lab which is located in the Engineering I building of the UCF Main Campus.
5. ***BME 6286C Applied and Computational Biofluids (3 hours)*** has a lab component, is offered every Spring for our MSBME program and will require the presence of students at the lab which is located in the Engineering I building of the UCF Main Campus.

Institutional and State Level Accountability

II. Need and Demand

- A. Need: Describe national, state, and/or local data that support the need for more people to be prepared in this program at this level. Reference national, state, and/or local plans or reports that support the need for this program and requests for the proposed program which have emanated from a perceived need by agencies or industries in your service area. Cite any specific need for research and service that the program would fulfill.**

Nationwide, the Bureau of Labor Statistics reports that employment of bioengineers and biomedical engineers grew 27 percent from 2012 to 2019 and is projected to grow 5 percent from 2019 to 2029, faster than the average for all occupations (<http://www.bls.gov/ooh/architecture-and-engineering/biomedical-engineers.htm/>).

Increasing numbers of technologies and applications to medical equipment and devices, along with the medical needs of a growing and aging population, will require the services of these workers, much faster than the average for all occupations. Demand will be strong because an aging population is likely to need more advanced medical care and because of increased public awareness of biomedical engineering advances and their benefits. Such positions require an advanced degree such as a MS or a PhD. (<http://www.bls.gov/ooh/architecture-and-engineering/biomedical-engineers.htm/>). Examples of such positions include engineering design and development (biofluids, bioinstrumentation, biomaterials, biosensors, sensors and controls) of left ventricular assist devices (heart pumps) at Heartware (<http://www.heartware.com/>) in Ft. Lauderdale, engineering innovative solutions (biomechanics and biomaterials) for knee, hip, shoulder and spine surgery at Exatech (<https://www.exac.com/>) in Gainesville, and device development (biofluids, biomechanics, bio-instrumentation) at Covidian and Medtronic surgical in Jacksonville Florida.

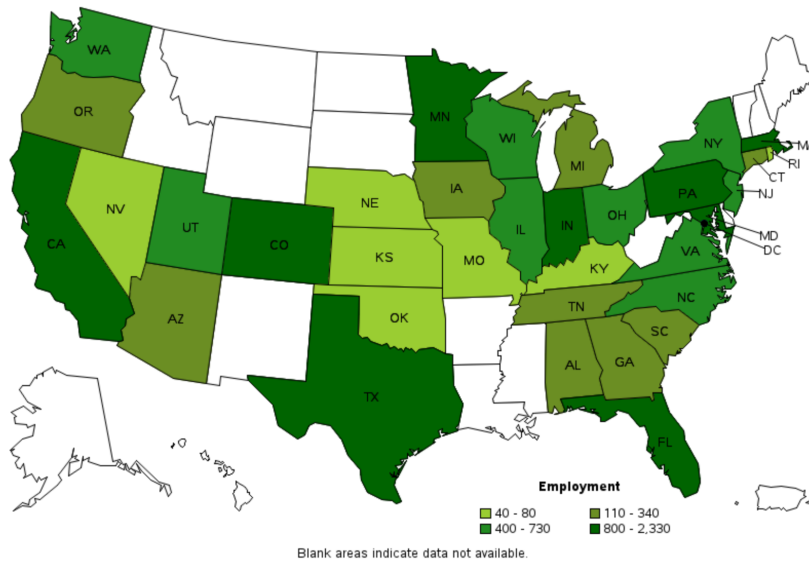
There is a strong demand for individuals with a PhD in BME and there are numerous positions available for well-trained individuals with such advanced training in Academia and industry nationwide. A search on LinkedIn from 7/21/2021 shows 200 current openings for biomedical engineers in Florida alone with the first such posting seeking a PhD in BME. Searches on other

popular job posting sites such as Indeed likewise reveal strong current demand. Examples of such industry job postings seeking PhD in BME applicants that were downloaded from the web on 7/13/2021 include (images of postings taken from the internet are provided in Appendix C):

- The Metropolitan Orlando area: JS Held and Advent Health.
- St. Petersburg: John Hopkins Institute for Fundamental Biomedical Research and Hackley-Roberts.
- Panama City: US DOD
- National level: Proctor and Gamble.

As of May 2020, there were 18,660 Bioengineers and Biomedical Engineers who were employed nation-wide with a mean salary of \$98,340 (\$47.28 hourly). Florida is one of the states with the highest published employment and wages with an estimated 1,130 employed at average salary of \$91.5K/year (<http://www.bls.gov/oes/current/oes172031.htm/>). The growth of Biomedical engineering positions in the State of Florida from 2019-2020 was nearly 4% (<http://www.floridajobs.org/workforce-statistics/data-center/statistical-programs/employment-projections>). Specifically, Florida ranks in the top five states with the highest employment of bioengineers and biomedical engineers. Production of a well-trained workforce with PhD level training in research and development to enable the State of Florida to maintain its leadership role and foster the growth of this important industry. Provided below are data provided by the BLS which demonstrate the need and opportunity in the State of Florida and the greater Orlando metropolitan area for the biomedical engineering discipline.

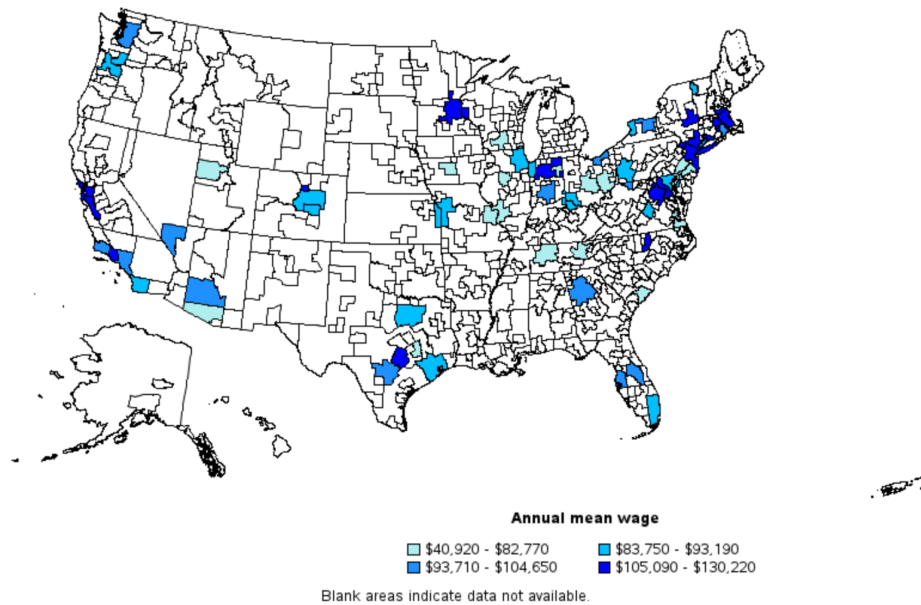
Employment of bioengineers and biomedical engineers, by state, May 2020



States with the highest employment level in Bioengineers and Biomedical Engineers:

State	Employment (1)	Employment per thousand jobs	Location quotient (9)	Hourly mean wage	Annual mean wage (2)
California	2,330	0.14	1.06	\$ 51.30	\$ 106,700
Massachusetts	1,350	0.40	3.00	\$ 59.69	\$ 124,160
Texas	1,200	0.10	0.74	\$ 41.78	\$ 86,900
Pennsylvania	1,130	0.21	1.53	\$ 37.38	\$ 77,750
Florida	1,130	0.13	0.99	\$ 43.81	\$ 91,130

Annual mean wage of bioengineers and biomedical engineers, by area, May 2020



Bureau of Labor Statistics, U.S. Department of Labor, Occupational Outlook Handbook, Bioengineers and Biomedical Engineers, at <https://www.bls.gov/ooh/architecture-and-engineering/biomedical-engineers.htm/> (visited May 11, 2021).

In addition to the UCF College of Medicine and the five large health delivery programs serving the Orlando metropolitan region, Florida is rapidly becoming a major presence in the fast-growing field of biomedical engineering and biotechnology. On March 1, 2021, the UCF College of Medicine launched a full-service acute care hospital (<https://www.ucf.edu/news/ucf-lake-nona-medical-center-opens-full-service-acute-care-hospital/>) at its Lake Nona campus. This new teaching hospital provides 24/7 emergency care and comprehensive in-patient, and outpatient hospital services will also afford clinical access to our PhD students engaged in BME translational research.

Offering a PhD in BME program naturally serves the needs of this local constituent industry. According to the *BioFlorida BioDatabase November 2019 Industry Report* (https://cdn.ymaws.com/www.bioflorida.com/resource/resmgr/industry_data/BioDatabase_Industry_Report.pdf/), the number of companies in Florida's biotechnology industry grew 8.5% from 2018 through the first half of 2019 bringing the total number of biotechnology companies to 372 with the addition of 50 new companies. Florida's growth for 2018 is slightly greater than the nation's biotechnology sector which showed a growth rate of 7% over the same period according to *Nature Biotechnology*. Around 75% of Florida's biotech companies are involved in therapeutics, medical devices or diagnostics with 38% located in Southeast Florida, 22% in greater Tampa Bay, 20% in Gainesville, and 13% in Orlando—all remaining stable. Over the last decade, Florida's biotech companies have increased by 174% whereas US biotech company growth over the past decade has been approximately 65%. It worth noting that biotechnology companies tracked by the Florida BioDatabase are characterized by having a true research and development core that helps fuel the innovation of new products for Florida's growing life sciences industry and does not include numerous biomedical companies that are involved only in manufacturing and/or distribution of products. Examples of such R&D and product development companies include *Exatech* in Gainesville, *Lensar* in Orlando, and *Mako Plasty*, a Florida orthopedic company that was acquired by Stryker for \$1.65 billion and is based in Fort Lauderdale. A relatively recent example of the expansion of the biotech industry into Florida is the \$14 million expansion of Codivian and Medtronic surgical technology division in Jacksonville which the *Jacksonville Business Journal* reports will create 175 full-time jobs.

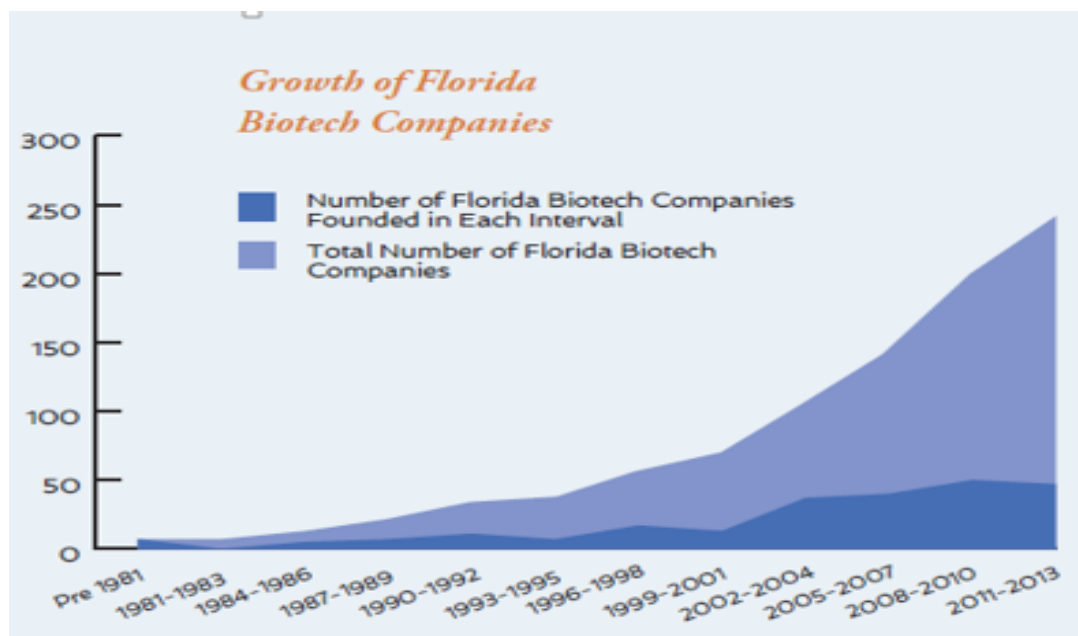
A representative, and by no means exhaustive, list of biomedical companies involved in research and development in Florida that employ biomedical engineers is provided below:

1. Baycare Health System, Inc - Clearwater, FL 33755: <http://www.baycare.org/>
 2. Stryker, Fort Lauderdale, FL.: <http://www.stryker.com/en-us/index.htm>
 3. SHL Pharma, Deerfield Beach, FL., 33442 <http://www.shl-group.net/>
 4. Tenet Healthcare Corporation Delray Beach, FL: <https://www.tenethealth.com/>
 5. Faro Industries (Biomedical Equipment), Lake Mary, FL: <http://www.faro.com/en-us>
 6. Mark Two Engineering, Miami Lakes, FL: <http://www.marktwo.com/>
 7. Rti surgical, Alachua, FL: <http://www.rtix.com/>
 8. Riverside Research, Melbourne, FL: <http://www.riversideresearch.org/labs/biomedlab>
 9. Exactech, Gainesville, FL: <http://www.exac.com/>
 10. Heartware Miami, FL: <http://www.heartware.com/>
 11. Dot decimal Sanford, FL: <http://www.dotdecimal.com/>
 12. Medi Future, Tampa, FL: <http://medifuture.com/index.html>
 13. Johnson and Johnson, Jacksonville, FL: <http://www.jnj.com/>
 14. Medtronic and Covidian, Jacksonville, FL: <http://www.medtronic.com>
 15. Noble Rx, Orlando, FL. (South Orange ave). <http://gonoble.com/>
 16. LensAR , Orlando, FL. <http://www.lensar.com/>
 17. Medicomp, Melbourne, FL <https://medicompinc.com/>
 18. Engage Surgical, Orlando, FL <https://engagesurgical.com/>
- ...

A complete listing of the 328 companies in the database may be found at <https://www.biofloridabiодatabase.com/>. A distribution map of these bioengineering companies compiled by the database is reproduced below:



The chart below from the *UF Sid Martin Florida Biodatabase* provides a graphical representation of the growth of BME companies in Florida for the 1981-2013 period including the number of companies founded in Florida over that period.



Joshua Bedwell, Director of Marketing at UCF carried out a Marketing Study for the purposes of this proposal, and the data gathered show that the number of PhD degrees in Biomedical Engineering conferred in the 5 programs in Florida grew by 14% from 2013-2019. Nationwide in 2019, there were 1,128 PhD in BME granted by 114 programs and the number of degrees granted grew by 24% nationwide over the 2013-2019 period. The proposed PhD in BME is very competitive in terms of cost, given that the annual cost for tuition at UCF is a little under 1/3 of the \$31,440 average cost nationwide (source EMSI and UCF student accounts). The internet search volume for PhD in BME is high nationwide and in Florida so that we expect good search traffic to our corresponding program webpage/s. The UCF Marketing report is consistent with the US BLS and confirms that the job growth rate for biomedical engineering in Florida was above the average job growth rate for other disciplines in 2019.

Joshua Bedwell, Director of Marketing, UCF Market Study Report 5/23/2021

B. Demand: Describe data that support the assumption that students will enroll in the proposed program. Include descriptions of surveys or other communications with prospective students.

A source of PhD students are applicants to the State of Florida SUS which cannot accept the volume of applicants. Reproducing a quote from the SUS CAVP review of our pre-proposal "UF – Also no concerns. UF has an excess of applicants and is only able to accept a fraction of their volume. There will definitely be applicant demand for any new program."

Another source of PhD in BME students is the pool of potential applicants from our own institution. The CECS has 13,500 students and MAE has nearly 4,500 students enrolled respectively. Specifically, a potential source of applicants are those students who are enrolled in our MSBME, CECS Bioengineering minor, BSBS Bioengineering Minor, and those UG and G students engaged in BME research. Another source of students is the CECS/COM Medical Engineering Dual Degree (MEDD) degree program.

According to a summer 2017 student survey carried out for the purpose of the pre-proposal (219 MAE undergraduate respondents), 48.9% would consider applying for the PhD in BME, and 95.9% overwhelmingly support the PhD in BME at UCF to meet students' growing interest. Also, 27.4% considered leaving UCF to pursue this degree if it wasn't offered at UCF. Below are reproduced selected quotes from the respondents:

"I think that it would greatly benefit the university to have such a cutting-edge program."

"Please start a BME PhD Program. I am starting my PhD program this fall at UCF (ECE) but I would prefer the BME if available."

"I think the biomedical field is one of the most important fields we can continue to substantially improve on. It truly impacts our well-being and our politics. I want there to be further advancement of this cause so that people will not be so sick and suffer under high costs of health burdens"

"Help me pay for it and I'll be one of your first students. I have a 3.6 GPA so that's that"

"Having a PhD program would make this school even better than it already is and would attract more bright students to the up-and-coming engineering program here at UCF."

"UCF is the only major university in the region without a BME program. This was a long-due initiative."

A more recent survey carried out in spring 2019 of 110 senior/junior undergraduate students in MAE reported that 18% were interested in obtaining a Doctoral degree in biomedical engineering, 49% were interested in R&D positions in the biomedical industry, and 61% were interested in participating funded research activities in biomedical engineering.

A recent spring 2021 survey of current and prospective UCF BME MS students and ME PhD students revealed that 67% of 27 respondents probably or definitely consider having a career in Biomedical Engineering and 58% of 31 respondents were probably or definitely interested in pursuing a PhD in BME.

Several students commented that it would be great for UCF to offer a BME PhD. One student commented that "I would like UCF to introduce BME PhD program as soon as possible so that I can have my PhD in BME" and another student commented that "It's high time we have biomedical engineering PhD program."

Consistently over the past 4 years and over the three surveys of 2017, 2019 and 2021, students have indicated a strong interest and demand in the proposed PhD in BME program. By all indications the program will be well-subscribed by our students at UCF. Data from these surveys are provided in Appendix-C

Moreover, the local industry is a source of such students. For example, Prof. Kinzel has a graduate student who is currently enrolled in the MAE PhD program and who is engaged in a federally funded COVID19 research project. This student is a female US citizen and Florida resident, is a full-time employee at Disney and is scheduled to stand for the BME PhD qualifying examination option in Fall 2021.

A source of PhD students is also our own MSBME program which has grown from an initial enrollment of 11 in 2016 to 28 in 2021. Currently three such graduates of our MSBME program are enrolled in our PhD in ME program pursuing research in BME, two are being mentored by Dr. Helen Huang and one by Dr. Hwan Choi. These students indicate that they wish to transfer to the PhD in BME program should that become an option in the future. Anecdotally, on Friday September 10, 2021, the BME program director in MAE (Alain Kassab) recently advised an undergraduate student engaged in Dr. Joon Park's research group as a research assistant who is applying to the MSBME program and who indicated he will pursue the PhD in BME at UCF should that become an option in the near future.

Currently, there are 12 BME faculty in the MAE Department supporting PhD students, several of whom have indicated that they will petition the UCF Graduate School to transfer into the PhD in BME program as should it be launched upon BOG approval with a target start date of Fall 2022. Moreover, we expect that these BME faculty members will support at least 27 PhD students annually through their research grants by the fifth year of the PhD in BME program. This corresponds to 2.45 PhD students/faculty member. This number may be substantially larger as our research portfolio grows.

- C. If substantially similar programs (generally at the four-digit CIP Code or 60 percent similar in core courses), either private or public exist in the state, identify the institution(s) and geographic location(s). Summarize the outcome(s) of communication with such programs with regard to the potential impact on their enrollment and opportunities for possible collaboration (instruction and research). In Appendix C, provide data that support the need for an additional program.**

There are four (4) PhD in BME programs in the State of Florida SUS that serve their region. These are listed in the table below along with their research emphasis.

SUS institutions with a PhD in BME program	Research Focus Areas
FIU (Department of Biomedical Engineering)	Engineered Tissue Model Systems, Diagnostic Bio-imaging and Sensor Systems, Therapeutic and Reparative Neurotechnology. (https://bme.fiu.edu/)
FSU/FAMU (Department of Chemical and Biomedical engineering)	Cellular and tissue engineering. (https://www.eng.famu.fsu.edu/node/404) (https://www.eng.famu.fsu.edu/cbe/about-cbe)
UF (J. Crayton Pruitt Family Department of Biomedical Engineering)	Neural Engineering, Imaging & Medical Physics, Biomaterials & Regenerative, Medicine, Biomedical Informatics & Modeling. (https://www.bme.ufl.edu/)
USF (Department of Biomedical Engineering in collaboration with the Morsani College of Medicine)	Cell and Tissue Engineering, Neuroscience and Neuro-engineering , Auditory Neuroscience, Neural Bases of Age-Related Hearing Loss, Brain Plasticity Following Injury. Molecular Medicine & Drug Delivery. Biomedical Imaging & Bioelectronics. (Department of Medical Engineering Home University of South Florida (usf.edu))

Two BME programs are standalone and in a Department of Biomedical Engineering (UF and FIU) while two are in the Chemical Engineering Departments (FSU/FAMU and USF). Consequently, the curriculum and research emphasis of each program is particularly tailored to the focus that each program has identified and there is little if no overlap with the PhD in BME program proposed at UCF. We have sought letters/emails of support for our program from all SUS institutions and these are provided in the Appendix C.

There are two (2) PhD in BME programs in the State of Florida that are offered by private non-SUS institutions that serve their region. These are listed in the table below along with their research emphasis.

Non-SUS private institutions with a PhD in BME program	Research Focus Areas
FIT Biomedical and Chemical Engineering and Sciences program	Drug delivery, biomaterials and tissue engineering, and computational methods and machine Learning. Biomedical Engineering > Biomedical Engineering Florida Tech (fit.edu) Biomedical Engineering, Ph.D. Florida Tech (fit.edu)
University of Miami Department of Biomedical Engineering	Imaging Optics Lasers, Biomechanics, Microfluidics, Biomaterials and Tissue, and Neural Engineering, Signals, & Instrumentation. Home Biomedical Engineering University of Miami

There is some overlap at FIT in the cardiovascular area (one faculty member) and there is another faculty member involved in modeling of neurological diseases such as stroke affect movement and traumatic injury to the brain and eye. FIT has a small program with 6 faculty members, and Dr. Ted Conway, who just stepped down as Chair of the BME program at FIT noted that our proposed program was complementary to that at FIT. There is little overlap in areas (1) and (2) as Imaging is carried out in CS and Optics and Lasers at CREOL at UCF and area (2) is mainly at the tissue level and there is no overlap with our program. There is some overlap with area (3) in the areas of brain computer interface and neural interface and neuroprosthetic devices. However, our faculty members are well-established in this area and the university has invested in a Bionix cluster with 2 BME faculty (Choi and Fu) hired under this university initiative. Our current BME faculty have several NIH grants as well as 2 recent NSF CAREER awards. This is a complementary activity which may open the door for collaborative research between our respective faculties.

The PhD in BME program at UCF is unique since it will be housed in the Mechanical and Aerospace Engineering Department and in its research and teaching focus in biofluids and biomechanics. It is likewise structurally unique in: (1) offering a PhD in BME as a follow-up to the minor in Biomedical Engineering in CECS and BSBS capitalizing on the BS-MS track, (2) offering an MSBME along-the-way to students enrolled in the PhD in BME program who are carrying out BME-topic research for their dissertations under guidance of PhD in BME program faculty or other qualified MAE faculty advisors, and (3) a PhD in BME that admits qualified students from the level of the BS degree in biomedical engineering, mechanical engineering or a closely related discipline. It is noted that at UCF, cell and tissue engineering and neuroscience research and education are carried out at the UCF College of Medicine's Burnett School of Biomedical Sciences (BSBS) which our BME faculty collaborate. The only cell-level research carried out by our BME program is undertaken by Dr. Robert Steward who is supported by NIH and the NSF and whose wet lab is located at the BSBS. His work is at the interface of engineering and the cell as his focus is on the manifestation of hemodynamic induced shear stress on endothelial cell function with applications to cardiovascular disease. While Medical Imaging research is carried out at the CECS Computer Sciences Department Center for Computer Vision Center headed by Prof. Mubarak Shah (<https://www.crcv.ucf.edu/>) who has provided a letter of support for our program (see Appendix C). As such, the proposed PhD in BME program is predominantly an engineering-based biomedical engineering degree.

Moreover, the program features close collaboration with the UCF COM and Orlando regional hospitals and medical professionals. The BME curriculum is taught with the support of the UCF-COM which offers the laboratory section of the course Mechanics of Biostructures I (Fall) and Mechanics of Biostructures II (Spring). This course uniquely features lab sessions at the UCF-COM anatomy lab, and these are delivered by a UCF-COM faculty member, Dr. Emily Bradshaw. Finally, the program offers a biofluids and a biomechanics emphasis that draws upon training in MAE and typical undergraduate BME and engineering programs nationwide.

The research program in the PhD in BME will capitalize on existing research collaborations between BME faculty and UCF-COM faculty as well as Orlando Medical Professionals in the areas of: engineering assisted cardiovascular, pulmonary, cancer and orthopedic treatment-planning as well as bio-acoustic diagnostic device development. With the additions of Dr. Helen Huang (joining Spring 2016), Dr. Sam Song (joined Spring 2015), Dr. Luigi Perotti (joined 2017), Dr. Hwan Choi (joined Fall 2018), Dr. Qiushi Fu (joined Fall 2017), Dr. Joon Park (joined Fall 2019), and Dr. Wen Shen (joined Fall 2020), to the faculty, the proposed PhD BME program will also feature medical robotics, image guided surgical planning (image-guided robotic needle biopsies and prostate surgery) as well as gait and rehabilitative research, wearable robotic assistive devices and curriculum experiences (BME 6215 - Advanced Biomechanics). The research program is focused on translational research in partnership with medical professionals and UCF-COM Colleagues and the UCF Bionix and Disabilities and Aging Technologies Faculty Clusters. Recently, in Fall 2020, the BME Faculty and Advent Health University held a joint research seminar and followed up establishing the foundations of research partnerships and education collaborations facilitated by Dr. Mohtashem Samsam Director of Research at Advent Health in Orlando.

Proposed PhD in BME Program at UCF	Research Focus Areas
UCF (in the Mechanical and Aerospace Engineering Department)	<p>Biofluids: translational research in multiscale computational fluid dynamics for cardiovascular treatment planning, lung cancer treatment planning, upper airways fluid mechanics, bioacoustics for patient monitoring and bedside diagnosis. Lab on a chip and nano-fluidics sensors.</p> <p>Biomechanics: developmental dysplasia of the hip, cellular mechanics and force-induced biochemical responses, image guided surgery, surgical robotics navigation and tracking, soft robotics, and biomechanics of movement rehabilitation and neural movement control for upper and lower body. Wearable and assistive robotics.</p>

- D. Use Table 1 - Appendix A (1-A for undergraduate and 1-B for graduate) to categorize projected student headcount (HC) and Full Time Equivalents (FTE) according to primary sources. Generally undergraduate FTE will be calculated as 30 credit hours per year and graduate FTE will be calculated as 24 credit hours per year. Describe the rationale underlying enrollment projections. If students within the institution are expected to change majors to enroll in the proposed program at its inception, describe the shifts from disciplines that will likely occur.

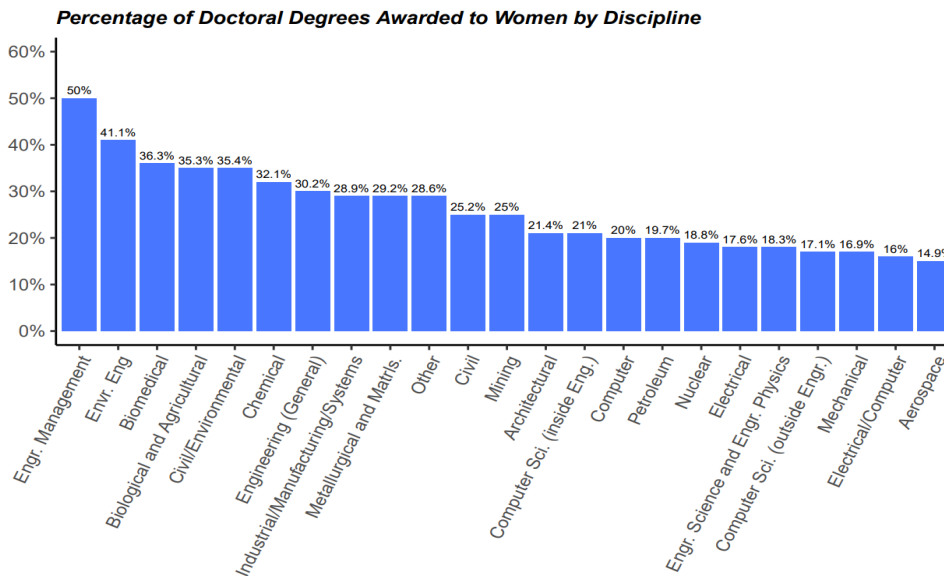
Referring to Table 1B in Appendix A, the projected student headcount (HC) for Year 1 is 11 generating 8.25 Full Time Equivalents (FTE) calculated as 24 credit hours per year for graduate students. We estimate the average FTE per graduate student to be 0.75 as these students will be in various stages of their PhD studies and will be taking dissertation hours after passing candidacy. It is expected that up to five students will successfully petition to transfer from the current PhD in Mechanical Engineering in which they are currently enrolled. We are coordinating with the College of Graduate Studies to enable this transfer over the course of the first year of the program in accordance with the College of Graduate Studies policies and procedures. Moreover, we expect that we will recruit at least 6 new PhD students by the start the program, expected in Fall of 2022. The headcount and corresponding FTEs are projected to increase over the course of four years to 27 students and 20.25 FTE in year five.

E. Indicate what steps will be taken to achieve a diverse student body in this program. If the proposed program substantially duplicates a program at FAMU or FIU, provide, (in consultation with the affected university), an analysis of how the program might have an impact upon that university's ability to attract students of races different from that which is predominant on their campus in the subject program. The university's Equal Opportunity Officer shall review this section of the proposal and then sign and date Appendix B to indicate that the analysis required by this subsection has been completed.

The proposed PhD in BME program does not substantially duplicate the programs at FIU or FSU/FAMU. Our program is focused on biofluids and biomechanics while the program at FIU focuses on engineered tissue model systems, diagnostic bio-imaging, and therapeutic and reparative neurotechnology and the FSU/FAMU program is focused solely on cellular and tissue engineering. Our program course offerings are also different with less than 10% course overlap. As such, our program will not impact the ability of these two programs and their associated universities' ability to attract students of races different from that which is predominant on their campus in their subject programs.

The University of Central Florida has a tradition of fostering diversity in its student body, and it is a Minority Serving Institution (MSI). UCF was formally designated in 2019 as a Hispanic Serving Institution (<https://diversity.ucf.edu/hsi-homepage/>). The CECS is the 4th college of choice for Hispanic students nationwide. In Fall 2020, UCF had a Hispanic/Latino undergraduate enrollment of 17,891 or 29.1%; a Black undergraduate enrollment of 6,290 or 10.24% and a female undergraduate enrollment of 33,847 or 55% of its total student body. UCF is 5th nationwide in awarding degrees to Hispanic/Latino and Black undergraduate students. Diversity and inclusion are an institutional mission at UCF which has a dedicated office for Diversity and Inclusion (<https://diversity.ucf.edu/>) and Institutional Equity (<https://oie.ucf.edu/>). National ranking source can be found in "Diverse: Issues In Higher Education" that has produced the Top 100 Degree Producers rankings of the institutions that confer the most degrees to minority students. <https://diverseeducation.com/top100/pages/index.php>

Moreover, by its very nature, the BME program is highly successful in attracting females in STEM. According to the American Society for Engineering Education (ASEE), biomedical engineering ranked in the top 3-choices among the PhD degrees awarded to women in 2021 at 36.9%. (<https://ira.asee.org/wp-content/uploads/2021/02/Engineering-by-the-Numbers-FINAL-2021.pdf>)



Moreover, of all the engineering disciplines, biomedical engineering is the discipline which nationwide has granted the highest percentage of PhD degrees in 2021 to under-represented minorities in STEM according to ASEE (<https://ira.asee.org/wp-content/uploads/2021/02/Engineering-by-the-Numbers-FINAL-2021.pdf>). As such, the PhD in BME will to a certain extent organically attract a diverse student population.

Table 56: Doctoral Degrees Awarded to Underrepresented Minorities by Engineering Discipline: 568

Discipline Name	Degrees Awarded
Biomedical	91
Other	76
Chemical	68
Mechanical	61
Civil	38
Computer Sci. (inside Eng.)	37
Electrical/Computer	37
Metallurgical and Matrls.	31
Industrial/Manufacturing/Systems	30
Electrical	26
Aerospace	18
Envr. Eng	13
Civil/Environmental	11
Nuclear	9
Biological and Agricultural	6
Computer	5
Computer Sci. (outside Engr.)	5
Engineering (General)	4
Petroleum	4
Engr. Science and Engr. Physics	3
Architectural	0
Engr. Management	0
Mining	0

* Total does not include computer science (outside engineering).

We are committed to attracting a diverse student body. We have hired highly successful BME faculty members who are under-represented in STEM. Specifically, of the 12 BME faculty members in MAE supporting our PhD in BME program, five (5) are under-represented in STEM faculty (42% of the BME faculty). In particular, three are female (Helen Huang, Wen Shen, and Sudeshna Pal), and two are African American (Olusegun Ilegbusi and Robert Steward). These faculty members serve as role models and attract students from varied backgrounds. Dr. Huang and Dr. Pal currently have NIH funding. Dr. Helen Huang has a current RO1 grant and an NSF CAREER Award and has recently won the Reach for the Stars Award in 2021 at UCF. Dr. Steward has been awarded the NSF CAREER Award and has been awarded a multi-year NIH mentoring grant in which he collaborated with the Associate Dean for Research at the UCF College of Medicine. Dr. Ilegbusi has a history of sustained and substantial NSF funding in BME. Dr. Wen Shen recently joined MAE in Fall 2020, and she is establishing her lab at the NanoScience and Technology Center and is recruiting PhD students. Dr. Sudeshna Pal has a multi-year NIH R25 education grant aimed at expanding our undergraduate and graduate rehabilitation engineering curriculum and to provide immersive experience in rehabilitation engineering for graduate and undergraduate students at local hospitals, clinics, and research and development companies. This enables our outstanding BME faculty to recruit diverse graduate students and serve as role models and mentors to our graduate students. Moreover, these colleagues have a track record of outreach and success in recruiting talented students who come from under-represented groups in STEM. The BME faculty, in general, have a track record of engaging under-represented in STEM students. Currently, our BME graduate students count a substantial number of female, Latino/Hispanic and African Americans. For example, our MSBME program has a nearly 50/50 mix of male to female students. In Fall 2017 the student makeup of the MSBME program was 41% White 30% Hispanic, 12% African American, 12% Asian and 5% international.

With a pool of nearly 13,500 students in the CECS and 3,980 undergraduate students in MAE, the PhD in BME offers a unique opportunity to achieve a diverse body of graduate students by active recruitment of women and taking advantage of UCF's large underrepresented in STEM student population.

We will capitalize on regional and national funding opportunities to recruit under-represented groups in STEM. Examples include promoting minority PhD students taking the MSBME along-the-way in the McKnight Fellowship program and obtaining grant support for PhD in BME minority and under-represented in STEM students from the NIH Research Education Program (R25) whose aim is to support educational activities that enhance the diversity of the biomedical, behavioral, and clinical research workforce. Another example is the NSF Research Traineeship (NRT) program that is part of a general initiative at NSF to broaden participation in interdisciplinary graduate STEM research and education (<https://www.nsf.gov/pubs/2021/nsf21536/nsf21536.htm>).

At the institutional level, UCF is a member of the Florida-Georgia Louis Stokes Alliance for Minority participation, and UCF also has an active Multicultural Academic and Support Services which advises all minority engineering students. We will utilize these resources to reach out to qualified and talented minority students.

The university's Equal Opportunity Officer has reviewed this section of the proposal and signed and dated the appropriate section of Appendix B, indicating that the analysis required by this subsection has been completed.

III. Budget

- A. Use Table 3 - Appendix A to display projected costs and associated funding sources for Year 1 and Year 5 of program operation. Use Table 4 - Appendix A to show how existing Education & General funds will be shifted to support the new program in Year 1. In narrative form, summarize the contents of both tables, identifying the source of both current and new resources to be devoted to the proposed program. (Data for Year 1 and Year 5 reflect snapshots in time rather than cumulative costs.)**

Referring to Table 3 in Appendix A, the projected costs for Year 1 are \$330,013 and for Year 5 are \$626,989.

Year 1: The costs incurred in Year 1 are for: (1) \$130,013 in E&G funds reflecting salaries for 1.13 person-year for program course delivery, (2) \$200,000 for support of graduate PhD students who are GRAs supported on contracts and grants and this amounts to stipend of close to \$20K on average. There are no Library costs associated with the proposed PhD in BME program as reported in Appendix B. The MAE department will re-allocate E&G funds to support the course delivery. As shown in Table 4 of Appendix A, the existing E&G funds for the MAE Department are \$8,086,988 in FY 2021, and \$130,013 in E&G funds will reallocated for the program leaving a balance of \$7,956,975 in E&G funds in Year 1.

Year 5: The costs incurred in Year 5 are for: (1) \$154,262 in E&G funds reflecting salaries for 1.16 person-year for program course delivery, (2) \$472,727 for support of graduate PhD students who are on GRA contacts, and this number is escalated from year 1 in proportion to the expected increase in PhD students. This is an average of 2.45 PhD student/faculty in year 5 of the program which is achievable without the need to hire additional faculty. There are no Library costs associated with the proposed PhD in BME program as reported in Appendix B. The MAE department will re-allocate E&G funds to support the course delivery.

- B. Please explain whether the university intends to operate the program through continuing education, seek approval for market tuition rate, or establish a differentiated graduate-level tuition. Provide a rationale for doing so and a timeline for seeking Board of Governors' approval, if appropriate. Please include the expected rate of tuition that the university plans to charge for this program and use this amount when calculating cost entries in Table 3.**

Tuition for this program will be regular graduate tuition rate as reported by UCF student accounts (<https://studentaccounts.ucf.edu/tf-graduate/>). At the time of submission, the rate was \$369.65 per credit hour for In-State students and \$1,194.05 for Out-of-State students.

- C. If other programs will be impacted by a reallocation of resources for the proposed program, identify the impacted programs and provide a justification for reallocating resources. Specifically address the potential negative impacts that implementation of the proposed program will have on related undergraduate programs (i.e., shift in faculty effort, reallocation of instructional resources, reduced enrollment rates, greater use of adjunct faculty and teaching assistants). Explain what steps will be taken to mitigate any such impacts. Also, discuss the potential positive impacts that the proposed program might have on related undergraduate programs (i.e., increased undergraduate research opportunities, improved quality of instruction associated with cutting-edge research, improved labs and library resources).**

The proposed PhD in BME program will initially benefit from transfer of PhD students from the MAE PhD program into the PhD in BME program following UCF Graduate Studies policies and procedures. We have identified such students who wish to transfer once the program is approved (expected transfer in Fall 2022). Dr. Ali Gordon, Associate Dean of Academic Affairs at the CECS, is coordinating this procedure with Associate Dean, Dr. Barbara Fritzsche, at the College of Graduate Studies to enable the potential transfer of these students over the course of year 1 of the program. We have provided the CGS with a list of these students, their status in terms of coursework taken, having passed the qualifying examination or when planning to take the qualifying examination, as well as expected date to take the candidacy examination. We are preparing to have petitions ready for review and potential approval soon after the degree is approved by the Florida BOG. This follows the same path that our recently approved PhD in Aerospace Engineering where 23 PhD students transferred from the ME PhD program to the AE PhD program upon the launch of the PhD in AE in Fall 2019.

Beyond the first year, the program will only grow organically by recruiting new graduate students supported by our grants and contracts for BME research. As such, the transfer is within intra-departmental programs and will not significantly affect our ME and AE PhD programs in MAE that currently have a Student Head Count (SHC) of 147 in Fall 2020. Moreover, the PhD in BME program will not negatively impact undergraduate programs but rather will benefit the minors in BME both in the CECS and BSBS colleges at UCF by providing a path to a terminal degree in BME at UCF for our undergraduate students. This should help recruit high quality undergraduates who are often, as previously stated, women and from an under-represented in STEM population.

- D. Describe other potential impacts on related programs or departments (e.g., increased need for general education or common prerequisite courses, or increased need for required or elective courses outside of the proposed major).**

Considering the fact that the proposed PhD in BME program will be located in Mechanical and Aerospace Engineering (MAE) but focused in the interdisciplinary field of biomedical engineering, students within the PhD in BME program will take electives outside of the department and college that are related to BME. Consequently, PhD in BME students will take additional approved electives from the following departments: Mechanical and Aerospace Engineering, Materials Science and Engineering, Electrical Engineering and Computer Science, the College of Science, Burnett School of Biomedical Sciences, and College of Medicine. Thus, the PhD in BME program does not compete with, but rather enhances, other UCF graduate programs by providing students who will take elective graduate courses offered by the previously mentioned departments. Many elective graduate courses at UCF are seldom populated beyond 10-15 students, therefore, there would certainly be room to accommodate additional students from the PhD in BME program providing an additional benefit of increased FTE production to the departments offering these courses. Moreover, the BME courses offered in the MAE department enrich the department curriculum and offer additional courses for our PhD students to consider in their graduate education. As noted in the curriculum section, all elective courses are currently being delivered at UCF and the departments in CECS have committed to offering these courses (see the letters from CS and ECE for example).

E. Describe what steps have been taken to obtain information regarding resources (financial and in-kind) available outside the institution (businesses, industrial organizations, governmental entities, etc.). Describe the external resources that appear to be available to support the proposed program.

In developing the plan for the PhD BME in BME program proposal, we have investigated both government and corporate sources of funding, beyond research grants which our BME Faculty have a track record of successfully earning from the NIH, NSF, AHA, DARPA and the medical industry and other such competitive funding sources. For government funding, training grants are potential opportunities. Many of these require the terminal degree to be the doctoral degree (typical NIH T32, T35, and "F" programs) and are available to fund PhD in BME graduate students as well as MSBME along-the-way students who will be enrolled in the PhD in BME program. An example of such a grant is the R25, or "bridge-to-the-doctorate" program administered by the National Institute of General Medical Sciences (NIGMS) which is directed toward minority students and requires the institution with the terminal master's program to partner with an institution offering the doctoral degree (which could be UF or FIT, for example). Thus, this program seeks to provide a "bridge" for a qualified master's student to go on to the doctorate at the other institution. The funding is directed to (1) establishing a mentoring program between the two institutions, (2) enhancing the curriculum of the master's institution, (3) providing academic counseling for the master's students, and (4) strengthening the research capability of the master's institutions, through funded collaboration between the two institutions. The award is made to the two-institution partnership. The master's students must have the intention of ultimately obtaining the doctoral degree. The NIH Research Education Program (R25) also has the specific goal to support educational activities that enhance the diversity of the biomedical, behavioral and clinical research workforce. To this end, this funding opportunity announcement encourages the development of creative educational activities with a primary focus on Research Experiences and Courses for Skills Development. NIH encourages applications from research-intensive institutions that propose to develop recent baccalaureate science graduates from diverse backgrounds underrepresented in biomedical and behavioral sciences so that they have the necessary knowledge and skills to pursue PhD or MD-PhD degrees in these fields. As such, this program is ideally suited to recruit PhD students taking the MSBME along-the-way as well as traditional students who have the career goal to pursue a PhD.

The American Heart Association offers Pre-doctoral Fellowships related to cardiovascular function and disease and stroke, or to related biomedical engineering/biotechnology problems. The Biomedical Engineering Society offers both undergraduate and graduate student awards (see www.bmes.org). Graduate PhD students can apply for these awards, which could provide some summer session funding.

Given that UCF is designated as a minority serving institution, we will capitalize on opportunities from federal agencies aimed at enhancing minorities and under-represented students in STEM programs in recruiting graduate students for the proposed PhD in BME program. For example, in Florida, the McNair Fellowship offers a tuition waiver and a \$25,000 annual stipend for 4 years and aims to promote diversity in our graduate student programs. Another such program is the Graduate FAMU Feeder Fellowships. UCF offers Graduate FAMU Feeder Fellowships to provide financial support to the most outstanding FAMU Feeder Scholars who are admitted to UCF graduate programs. In addition to tuition and health insurance coverage, this fellowship pays a yearly stipend \$12,000 for four years for doctoral students. Award recipients are selected in spring by the UCF Diversity Fellowship Committee for awards beginning the following fall term.

UCF is member of the GEM consortium (<https://gemfellowship.org/gem-fellowship-program/>) whose mission to enhance the value of the nation's human capital by increasing the participation of underrepresented groups (African Americans, American Indians, and Hispanic Americans) at the master's and doctoral levels in engineering and science. GEM Fellowship applications are open annually and due November 15.

The UCF College of Graduate Studies hosts a site with available competitive fellowships for incoming graduate students (<https://graduate.ucf.edu/fellowships/>). Moreover, the UCF Office of Prestigious Awards (<https://opa.ucf.edu/>) provides mentoring for students applying annually to the National Science Foundation's Graduate Research Fellowships Program (<https://www.nsfgrfp.org/>). The GRFP welcomes applications from individuals who are pursuing full-time research-based master's and doctoral degrees in science, technology, engineering, and

mathematics (STEM) or in STEM Education and offers an annual stipend of \$34,000 and a cost of education allowance of \$12,000 to the institution. Our students have been successful in such applications, for example, in 2021 three of our graduate students, Brendan Cavainolo, Jake Carter, and Robert Greene earned NSF GRFP, and in 2020 four of our graduate students, Debraliz Isaac-Aragones, Leslie Simms, Victor Rodriguez and Alex Ruiz, earned the NSF GRFP.

We have performed a web-based search for companies emphasizing or with needs in the areas of our initial foci, which are biomechanics and biofluids. The companies with biomechanical interests include Bertec, Amti, OptiTrack, Novel, Qualisys, MotionAnalysis, Vicon, Motekforce Link, TekScan, Noraxon, C-Motion, Delsys, Simi, SimVitro, Kistler, Xsens, Polhemus, BTS Engineering, and Metria Innovation. The companies with biofluids interest include Goretex, Bard, Boston Scientific, Microfluidics, Medtronic, St. Jude, Abbott Labs, Johnson & Johnson, Biotronik, Xona Microfluidics, Heartware, and Thoratek. Many of these have divisions or offices in Florida. We are also compiling a list of software and imaging companies that have interests in computational fluid dynamics. We have specifically spoken to Medtronic about possible support. Medtronic issued over 100 grants in 2020, some of which were in Florida and to organizations in Jacksonville, where Medtronic has facilities. Medtronic's business activities have increased dramatically in central Florida due to the growing Orlando healthcare systems. It is possible that a partnership with our BME program, perhaps in the form of educational grants for the proposed PhD program, could be fashioned.

Finally, central Florida's major healthcare systems are potential sources of financial, facilities and human resources support for the proposed PhD program in BME. The healthcare systems (OrlandoHealth, Advent Health, and HCA) will be key in providing clinical facilities for the PhD research. Physicians and other healthcare professionals will be solicited to serve as mentors for many of our students. Many of these physicians already hold faculty positions in the COM, and some have already served as mentors to medical students pursuing BME-related FIRE (Focused Inquiry & Research Experience) projects as part of the COM curriculum. Most willingly serve on a volunteer basis. This synergy in the support of our PhD program from Orlando Health for example, is clearly stated in both the letter from the CEO as well as Dr. DeCampli's support letter, along with other industry support letters (Appendix I).

IV. Projected Benefit of the Program to the University, Local Community, and State

Use information from Tables 1 and 3 - Appendix A, and the supporting narrative for “Need and Demand” to prepare a concise statement that describes the projected benefit to the university, local community, and the state if the program is implemented. The projected benefits can be both quantitative and qualitative in nature, but there needs to be a clear distinction made between the two in the narrative.

BME is an interdisciplinary field that involves the development of new technologies in health care. Developing a PhD in BME at UCF offers a multitude of benefits across UCF, Orlando, and Florida.

Nationwide, the Bureau of Labor Statistics (BLS) (<http://www.bls.gov/ooh/architecture-and-engineering/biomedical-engineers.htm>) reports that employment of bioengineers and biomedical engineers grew 27 percent from 2012 to 2019 and is projected to grow 5 percent from 2019 to 2029 at a faster rate than the average rate of growth for all occupations. Increasing numbers of technologies and applications to medical equipment and devices, along with the medical needs of a growing and aging population, will require the services of these workers and many of whom are expected to

linkedin.com/jobs/search/?currentJobId=2510797164&keywords=biomedical%20

biomedical engineering Florida, United States

Jobs | Date Posted | Experience Level | Company

Biomedical engineering in Florida, United ... Job Alert Off

200 results

R&D Project Engineer
Halkey-Roberts Corporation
St Petersburg, FL

UF FLORIDA 2 alumni work here

Promoted • Easy Apply

have advanced degrees PhD in BME (and MSBME). A LinkedIn search on 7/21/2021 shows 200 postings. The first such posting for example with Halkey-Roberts Corp. in St. Petersburg seeks preferably a PhD in BME applicants.

Biotech companies in Florida have increased by 174% over the past decade (FloridaBioDatabase.com). PhD in BME will provide highly trained graduates to support the fast-growing biomedical industry in the state. A distribution map of bioengineering companies compiled by the Florida Bioengineering database shows that UCF is well located to answer the needs of the growing bioengineering industry. Central Florida is home to three large hospital networks (Florida Hospital, Orlando Health, and HCA), as well as VA and Nemours in the Medical city. The PhD in BME will help UCF to align with the local biomedical infrastructure, and support the medical delivery, research and education enterprise of these large and important community institutions. The PhD in BME program will also support the growing medical city at Lake Nona, see for example the GuideWell Innovation Center (<https://guidewellinnovation.com/>) incubator at Lake Nona which seeks to develop Health Technology Start-ups.

The PhD in BME will strengthen existing multidisciplinary collaboration within UCF between CECS and COM, as well as multiple research cluster initiatives (Bionic Material and Interface, Disability and Aging, Bioinformatics), therefore enhancing UCF's extramural research funding portfolio.

The PhD in BME program will offer more opportunities for the participation of undergraduate research and entice UCF CECS undergraduates to pursue a BME PhD degree at UCF instead of going to other universities, thus organically growing the PhD population.

V. Access and Articulation – Bachelor's Degrees Only

- A. **If the total number of credit hours to earn a degree exceeds 120, provide a justification for an exception to the policy of a 120 maximum and submit a separate request to the Board of Governors for an exception along with notification of the program's approval. (See criteria in Board of Governors Regulation 6C-8.014)**

Not applicable – graduate program.

- B. **List program prerequisites and provide assurance that they are the same as the approved common prerequisites for other such degree programs within the SUS (see link to the Common Prerequisite Manual on [the resource page for new program proposal](#)). The courses in the Common Prerequisite Counseling Manual are intended to be those that are required of both native and transfer students prior to entrance to the major program, not simply lower-level courses that are required prior to graduation. The common prerequisites and substitute courses are mandatory for all institution programs listed, and must be approved by the Articulation Coordinating Committee (ACC). This requirement includes those programs designated as "limited access.**

If the proposed prerequisites are not listed in the Manual, provide a rationale for a request for exception to the policy of common prerequisites. **NOTE: Typically, all lower-division courses required for admission into the major will be considered prerequisites. The curriculum can require lower-division courses that are not prerequisites for admission into the major, as long as those courses are built into the curriculum for the upper-level 60 credit hours. If there are already common prerequisites for other degree programs with the same proposed CIP, every effort must be made to utilize the previously approved prerequisites instead of recommending an additional "track" of prerequisites for that CIP. Additional tracks may not be approved by the ACC, thereby holding up the full approval of the degree program. Programs will not be entered into the State University System Inventory until any exceptions to the approved common prerequisites are approved by the ACC.**

Not applicable – graduate program.

- C. **If the university intends to seek formal Limited Access status for the proposed program, provide a rationale that includes an analysis of diversity issues with respect to such a designation. Explain how the university will ensure that Florida College System transfer students are not disadvantaged by the Limited Access status. NOTE: The policy and criteria**

for Limited Access are identified in Board of Governors Regulation 6C-8.013. Submit the Limited Access Program Request form along with this document.

Not applicable – graduate program.

- D. If the proposed program is an AS-to-BS capstone, ensure that it adheres to the guidelines approved by the Articulation Coordinating Committee for such programs, as set forth in Rule 6A-10.024 (see link to the Statewide Articulation Manual on [the resource page for new program proposal](#)). List the prerequisites, if any, including the specific AS degrees which may transfer into the program.

Not applicable – graduate program.

Institutional Readiness

VI. Related Institutional Mission and Strength

- A. Describe how the goals of the proposed program relate to the institutional mission statement as contained in the SUS Strategic Plan and the University Strategic Plan (see link to the SUS Strategic Plan on [the resource page for new program proposal](#)).

As articulated in Section I-D and I-E, the PhD in BME program aligns itself with the strategic goal of UCF to become a top 50 metropolitan research university by becoming America's leading partnership university by partnering internally and externally to serve and positively impact our community, building an inclusive environment with a culture of compassion at its core, and achieving international prominence in key programs of graduate study and research. The PhD in BME aligns itself with the SUS BOG mission and its strategic plan that specifically identifies biomedical engineering as a key enabling industry that: (1) provides jobs with high average annual salaries, and (2) fits within the overarching strategy of building a stable Florida economy based on knowledge and innovation. The PhD in BME program mission statement is articulate below:

PhD in BME Mission Statement

The Department of Mechanical and Aerospace Engineering (MAE) in keeping with the Mission and Goals of the University of Central Florida and the SUS BOG will be home to a PhD in Biomedical Engineering program exploiting the combined intellectual and physical resources at the University of Central Florida to, (a) serve engineering students pursuing a career in biomedical engineering or a related field, and (b) create new knowledge through cross-college collaborative research between engineering, the biological sciences and the local medical community.

The proposed program is designed to support UCF's special mission as a Metropolitan Research University. It will:

- enhance and enrich our high-quality engineering graduate program offerings,
- enhance a key thrust in research and graduate education,
- provide a multiplicity of opportunities for research and educational partnerships with Central Florida medical, industrial, and governmental institutions.

As such, the PhD in BME program is also aimed at fulfilling the stated mission of the SUS BOG that directs the State University System of Florida to provide undergraduate, graduate, and professional education, research, and public service of the highest quality through a coordinated system of institutions of higher learning, each with its own mission and collectively dedicated to serving the needs of a diverse state and global society.

- B. Describe how the proposed program specifically relates to existing institutional strengths, such as programs of emphasis, other academic programs, and/or institutes and centers.

Significant research in biomedical engineering has been achieved at UCF with BME research carried out by faculty in several Departments of CECS. Moreover, the now-famous student-developed prosthetic limb (arm) is a product of BME work carried out by MAE students (<http://limbitless-solutions.org/index.php/en/>). UCF is strong in robotics and simulation, both products as well as tools of biomedical engineering. A number of National Institutes (NIH), American Heart Association (AHA) and NSF supported studies have been carried out in both the CECS, COM and CREOL. All of these are fundamentally under the moniker of BME.

The MAE department has developed a strong BME research portfolio. BME faculty whom we recruited in preparation of our PhD in BME program have been highly productive. For example, Helen Huang established the highly successful BRAIN lab (<https://mae.ucf.edu/BRAIN/>) has an ongoing \$5M NIH RO1 grant and has recently won a 500K 5-year NSF CAREER award in the general area of biomechanics and rehabilitation and interdisciplinary neuroscience. Robert Steward was awarded a 700K 5-year NIH mentoring grant and has won a 500K 5-year NSF CAREER award in the area of the interaction of shear stress on endothelial cell migration and proliferation with applications to cardiac disease. Alain Kassab has been awarded a 3-year transformative grant from the American Heart Association in a collaborative effort with Dr. William DeCampi at the UCF COM and Orlando Health for their work on improving Left Ventricular Assist Device implantation to reduce stroke and a recent two-year grant from Additional Ventures for work on the development of injection jet concept for the Fontan palliative treatment. Moreover, Dr. DeCampi and Dr. Kassab have been continuously funded over the past 10 years by American Heart Association in a collaborative effort in computational hemodynamic studies for congenital heart disease treatment planning. Dr. Sudeshna Pal has a NIH R25 multi-year grant entitled "A Biodesign Program in Rehabilitation Engineering" structured to train undergraduate and graduate students in the design, innovation and commercialization process of assistive and rehabilitative medical devices for persons with disabilities. This collaborative project with the UCF COM the College of Nursing. The proposed Biodesign program is designed as a sequence of two courses with an intermediate clinical immersion junior and senior undergraduates and graduate engineering students. Dr. Qiushi Fu has an active 3- year NIH R15 (research enhancement award) to 'strengthen the biomedical research environment of the institution' and 'increase undergraduate research involvement' with funded undergrad RA positions. The research focus of the grant is to understand how to improve the efficacy of hand rehabilitation.

Another example is a CREOL/COM/Orlando Health collaborative project, supported by an NIH R21 grant, is looking at continuous measurement of blood viscoelasticity as a measure of coagulation status during open-heart surgery. This project is currently part of a CREOL doctoral student's thesis work, but projects like this could be available to PhD BME students.

There are other ongoing multi-year collaborations between Orlando Health/COM/MAE that have been supported by grants from the AHA in the general area of multi-scale computational fluid dynamics for treatment planning of congenital heart disease that has led to several Honors in Major (HIM), MS and PhD Dissertations and numerous journal publications both in the medical and engineering literature. They have also engaged international collaborations with the University of Toronto and Sick Kids Hospital in Canada. These projects have also engaged several undergraduate engineering and UCF-COM FIRE students over the course of several years. An example of the visibility of our collaboration is the 5th International Symposium on Engineering Frontiers in Congenital Heart Disease organized and hosted by Dr. DeCampi and Dr. Kassab June 9 and 10, 2016 at the UCF-COM.

Another such collaborative project between Orlando Health/COM/MAE and supported by Orlando Health and the NSF in the area of treatment planning for orthosis utilized to treat developmental dysplasia of the hip has led to MS and PhD theses as well as several publications. This project is now funded by the International Hip Dysplasia Institute. Other examples include NIH funded collaborations between Nemours/MAE in the area of bioacoustic medical sensors led by Prof. Hansen Mansy. MAE faculty engaged in BME research have attracted over \$15M in external grants over the past 10 years.

There are several examples of successful 2-year COM FIRE projects with MD students that were guided collaboratively by COM/MAE faculty and that have produced publications and led to work beyond the 2-year FIRE project. Medical students with BME background pursuing a FIRE project could have led to a thesis and participation in the MSBME/MD should the program, as proposed, have been in place. Specific examples include Virgil Secanasu (external counter-pulsation of a

systemic-to-pulmonary artery shunt designed to increase coronary blood flow), Christopher Cooper (benchtop studies of Left Ventricular Assist Device), and Benjamin Elsaphazir (pulsatile benchtop studies of LVAD cannula implantation to reduce stroke risk). All three MD students have graduated from the UCF COM and have begun their professional careers. Dr. Kassab and Dr. DeCampli have recruited a number of female UCF-COM students with a BME background for FIRE projects in the cardiovascular field.

Although not exhaustive, these are additional examples of vibrant and productive going collaborations that will offer research projects for dissertations. It is fully expected that these collaborations will expand in scope and fully support the research portfolio of the BME program.

The UCF Lake Nona Medical Center opened March 1, 2021, bringing full-service, acute care to the growing Lake Nona community in a hospital that will also train the next generation of healthcare providers and support innovative medical research. Located next to the UCF College of Medicine in Orlando's Medical City, UCF Lake Nona Medical Center provides 24/7 emergency care, comprehensive inpatient and outpatient hospital services, and is expected to serve more than 17,000 patients in its first year. The hospital is also the centerpiece of UCF's new Academic Health Sciences Center, that one day will bring many of the university's clinical training programs to Lake Nona and create more interprofessional medical education and research. As an academic hospital, UCF Lake Nona Medical Center will have three missions – patient care, medical education and research as such provides a unique opportunity for collaboration with our BME program and access to clinical data for our PhD students.

The Veteran's Administration Hospital in the Medical City is a major clinical, equipment and facility resource for graduate students pursuing research in biomechanics and medical robotics. Other potential collaborators include the Nicholson Center for Research and Simulation, Nemours Children's Hospital, and Advent Health. In 2020, the director of research at Advent Health University, Prof. Mohtashem Samsam and Prof. Alain Kassab organized a research symposium connecting BEM faculty in MAE with medical professionals at Advent Health with the aim of building research partnerships. Our own COM houses a state-of-the-art anatomic pathology teaching laboratory that will serve the program, in particular, MSBME students taking the course Mechanics of Biostructures I and II will have access to the pathology lab to participate in selected pro-section experiences that will be taught by Prof. Emily Bradshaw, who is the COM faculty member currently teaching the Form and Function MD curriculum.

C. Provide a narrative of the planning process leading up to submission of this proposal. Include a chronology in table format of the activities, listing both university personnel directly involved and external individuals who participated in planning. Provide a timetable of events necessary for the implementation of the proposed program.

The College of Engineering and Computer Science has prepared and planned for the PhD in BME for nearly 10 years beginning the BME minor instituted in 2011, and the appointment by the MAE Department chair of Prof. Alain Kassab Director of BME in Spring 2015. The MAE department began recruiting BME faculty over the period 2015-2020 (Huang, Steward, Song, and Perotti). The MAE department launched the MSBME program in Fall 2016. In Spring 2017, a PhD in BME pre-proposal committee was formed with Alain Kassab (MAE) as Chair, and committee members Robert Steward (MAE), Brian Kim (ECE), Juan Cendan (UCF COM), William DeCampli (UCF COM). A survey of undergraduate students was carried out to provide data supporting the student interest in the proposed PhD in BME program. The committee drafted the pre-proposal which was approved by the SUS CAVP in Fall 2017 without concerns.

The MAE Department spearheaded the Prosthetics Interfaces Cluster initiative in 2016 which led to the recruitment of 7 faculty members including the cluster head Dr. Melanie Coathup who is a minority faculty (<https://med.ucf.edu/person/melanie-coathup-bsc-phd/>). Cluster faculty members (Fu and Choi) joined the MAE Department in 2017-2018. The MAE Department participated in the Disabilities and Aging Technologies Faculty Cluster initiative and added an additional BME faculty 2019 (Park). Dr. Wen Shen was recruited in 2020. The MAE Department and CECS as well as the faculty cluster initiatives provided the necessary resources and laboratory space for recruited BME faculty.

The BME faculty met regularly over the course of 2018-2019 to shape the BME curriculum, determine the core required courses, and fashion the BME PhD Qualifying Examination option for the ME PhD Qualifying Examination procedures and policies. The curriculum was discussed and as it was developed with industry input from Dr. DeCampi Chief of the Division of Cardiothoracic Surgery and Co-Director of the Heart Center at Orlando Health and Dr. Mohtashem Samsam Director of Research at Advent Health. Dr. Samsam also materially contributed to the development of the Biostructures I and II courses as well as the specific sequence of pre-section anatomy laboratory experiences provided to our biomedical engineering students.

Course Action Requests forms for the new BME courses were submitted and approved at the State level, and the new BME courses were incorporated into the MAE graduate course offering. A five-year BME course offering plan was put into effect in coordination with the MAE Graduate Coordinator and MAE Advising Office. The BME PhD Qualifying Examination was presented to the MAE Graduate Committee, approved by the MAE faculty at its Fall 2019 meeting, and implemented as an option for PhD students in the MAE program pursuing BME research. To date 5 such students passed the BME PhD Qualifying Examination and two more are scheduled for Fall 2020.

Over the course of Summer 2019 and Fall 2019, Alain Kassab contacted the library and worked with Terrie Sypolt and Buenaventura Basco, Research and Information Services Librarians, who carried out an extensive library assessment and needs and report provided in Appendix B. The original report was completed in Fall 2019. The Library report was updated in July 2021 at the completion of the PhD in BME program proposal and reviewed by the Head Librarian who signed the report on July 23, 2021.

In Fall 2020, the College of Engineering and Computer Science Associate Dean for Graduate Affairs, Dr. Ali Gordon, the MAE Chair, Yoav Peles, and Alain Kassab, met with Dr. Winston Schoenfeld Interim Associate Dean of Graduate Studies to chart and coordinate the timing of the milestones to be met for successful the submission for the proposal with the aim to have a program approved by the SUS BOG for the identified start date of Fall 2022.

A PhD in BME in proposal drafting committee was assembled in Spring 2021 to prepare the program proposal. The PhD in BME drafting committee consisted of Alain Kassab, Ali Gordon, Helen Huang, Robert Steward and Qiushi Fu. The external reviewer, Dr, Ted Conway, was identified, formally contacted, and agreed to carry-out PhD in BME program proposal review.

Letters of support were sought and obtained internally at UCF within the college of engineering and computer science as well as from the college of medicine and the college of nursing. Letters were sought and obtained from industry. Finally, the College of Engineering and Computer Science Associate Dean for Graduate Affairs, Dr. Ali Gordon, contacted SUS institutions that have PhD in BME programs to expose our proposed program and obtain letters of support.

The PhD in BME program proposal draft was completed and provided to Dr. Ted Conway who provided the external review. The program proposal and appendices A-E were reviewed by UCF Graduate studies and the UCF Vice Provost Tim Letzring in August 2021. In Fall 2021, the proposal was submitted for approval by the MAE Graduate Committee, the CECS Graduate Committee, the UCF Graduate Council Curriculum Committee (GPCC), the UCF Graduate Council Program Review and Awards Committee (GPRC), and finally submitted the UCF Administration for approval to submit to the UCF BOT for review at its Fall 2022 meeting.

Planning Process

Date	Participants	Planning Activity
Spring 2017	PhD in BME pre-proposal committee was formed with Alain Kassab (MAE) as Chair, and committee members Robert Steward (MAE), Brian Kim (ECE), Juan Cendan (UCF COM), William DeCampi (UCF COM).	Pre-proposal is prepared and submitted to the Provost and forwarded to the CAVP for review and comments.
Spring 2017	SUS CAVP and UCF Administration.	Reviews pre-proposal and returns with no concerns. UCF administration gives instructions to proceed with proposal.
Fall 2018-Fall 2019	MAE BME faculty: Kassab, Ilegbusi, Mansy, Huang, Fu, Steward, Song, Pal, Park, Hwang Industry participation: Dr. DeCampi at Orlando Health and Dr. Mohtashem Samsam at Advent Health.	Prepare and shape PhD in BME curriculum, set required courses, and submit course action requests for new courses. New BME courses approved and scheduled in 5-year course offering plan.
Spring 2019	MAE BME faculty: Kassab, Ilegbusi, Mansy, Huang, Fu, Steward, Song, Pal, Park, Hwang	Draft PhD in BME Qualifying examination procedure. proposal and present to the MAE Graduate Committee and MAER faculty for approval.
Summer 2019-Fall 2019	Kassab (MAE) and Terrie Sypolt (Library).	Prepare and coordinate library report.
Fall 2019	MAE BME faculty and Jihua Gou (MAE Graduate Program Coordinator)	PhD in BME Qualifying examination is inaugurated.
Fall 2020	Ali Gordon (Associate Dean for CECS Graduate Affairs and MAE), Yoav Peles(MAE Chair) and Alain Kassab (MAE), Winston Schoenfeld (Interim Associate Dean of Graduate Studies)	Chart and coordinate the timing of the steps for the proposal preparation and submission.
Spring 2021	Alain Kassab (MAE), Ali Gordon (CECS Associate Dean & MAE), Helen Huang (MAE), Robert Steward (MAE) and Qiushi Fu (MAE)	PhD in BME program proposal drafting committee meets and maps proposal section assignments and developments. Proposal draft begins.
Summer 2021	Alain Kassab (MAE) and Ted Conway (External Reviewer)	External Reviewer provides comments and on the PhD in BME proposal
Summer 2021	Alain Kassab (MAE), Ali Gordon (CECS Associate Dean & MAE), Helen Huang (MAE), Robert Steward (MAE), Qiushi Fu (MAE) and John Weishampel (Associate Dean of Graduate Studies)	Complete PhD in BME program proposal draft and revisions with College of Graduate Studies.
Summer 2021	Gordon (CECS Associate Dean & MAE), Peles (MAE) and Georgiopoulos (CECS Dean)	Meet and finalize Appendix A issues relating to budget, library needs, and faculty time allocations.
Summer 2021	Alain Kassab (MAE), Ali Gordon (CECS Associate Dean & MAE), Helen Huang (MAE), Robert Steward (MAE), Qiushi Fu (MAE) and John Weishampel (Associate Dean of Graduate Studies)	Final draft of PhD in BME program proposal is completed.
Fall 2021	MAE Graduate Committee Jan Gou (Chair), Yuanli Bai, Subith Vasu, Kareem Ahmed, Tarek Elgohary, Felipe Viana, Robert Steward, and Sam Song	Early in Fall 2021, MAE Graduate Committee reviews and approves the PhD in BME proposal at the MAE department level.

Events Leading to Implementation

Date	Implementation Activity
Fall 2021	PhD in BME proposal submitted to CECS Graduate Committee reviews and to forward to the UCF Graduate Council.
Fall 2021	PhD in BME proposal submitted to UCF Graduate Council for review and to forwards to the UCF administration for review and signatures and to forward to the UCF BOT.
Spring 2022	PhD in BME forwarded to the UCF BOT for review and program approval.
Spring 2022	PhD in BME forwarded to the SUS BOG for review and program approval.
Spring 2022	Catalog program description and content is prepared
Summer 2022	Upon BOG approval, PhD in BME is included in UCF Graduate Catalog (published online).
Summer 2022	Recruitment brochures are prepared and mailed out locally at the UCF-CECS, state-wide, and nationwide.
Summer 2022	Program website is prepared and goes live on MAE webpage.
Summer 2022	Approval of program is announced. Eligible students are recruited for admission into the Fall 2022 class.
Summer 20122	Process transfer of PhD graduate students to PhD in BME program
Summer 2022	Prepare Institutional Effectiveness materials for rollout with begin date of the program in Fall 2022.
Fall 2022	Official Begin date of program.

VII. Program Quality Indicators - Reviews and Accreditation

Identify program reviews, accreditation visits, or internal reviews for any university degree programs related to the proposed program, especially any within the same academic unit. List all recommendations and summarize the institution's progress in implementing the recommendations. Please include evidence that teacher preparation programs meet the requirements outlined in Section. 1004.04, Florida Statutes, if applicable.

The PhD BME program is aligned directly with the strategic initiatives articulated in the 2017-2022 College of Engineering and Computer Science (CECS) Strategic Plan. The CECS is committed to growing the size and quality of its graduate program, strengthening partnerships with industry, and serving the state of Florida and beyond. The college identified several interdisciplinary research areas that align with the PhD in BME program such as smart materials and sensors to represent its highest priorities in its desire to accomplish its mission and realize its vision as well as support its desire to strengthen the departmental structure of our college and its research enterprise.

The PhD BME program also serves to achieve the CECS strategic goal to grow the size and quality of its graduate program. As a result, two Faculty Cluster Initiatives related to Biomedical Engineering have been established: Bionic Materials, Implants & Interfaces (Bioniix), as well as Disability, Aging and Technologies (DAT).

The MAE Department that will be home to the PhD in BME program offers two accredited undergraduate degrees: (1) BS in Mechanical Engineering and (2) BS in Aerospace engineering. A Draft Statement presenting the findings of the recent evaluation by the Engineering Accreditation Commission (EAC) of the Accreditation Board for Engineering & Technology (ABET) based on their virtual visit in Spring 2021 was given and we responded. The department has subsequently received notification that both BSME and BSAE programs have received a full 7-year accreditation that is valid until September 2027 (next regular ABET accreditation review cycle)

The Biomedical Engineering MS program in MAE Department has completed an Academic Program Review in 2018-19 with external consultants. The recommendations were (1) continue to target a high-quality diverse pool for graduate student recruitment, (2) enrich curriculum content in biomedical engineering and assure course offering availability, (3) improve student career preparation, (4) increase student financial support.

The MAE department has made progress in addressing the MSBME program review recommendations:

- The department has since hired two additional faculty members with training and with research programs in biomedical engineering, who also teach undergraduate and graduate courses in traditional mechanical engineering discipline. These faculty members are: (1) Dr. Joon-Hyuk Park teaches classes in robotics and dynamics, (2) Dr. Wen Shen (Female), who teaches in biomaterials.
- The BME program successfully recruits under-represented in STEM students. Nearly half of our graduate students are female, and they have the opportunity to be mentored by a diverse faculty that includes three (3) females (H. Huang, W. Shen, and S. Pal) and two African Americans (O. Ilegbusi and R. Steward).
- Three new Biomedical Engineering graduate courses were developed and taught on a regular basis: BME 6231 Continuum Biomechanics (Dr. Perotti), BME 5742C Modeling and Simulation of Physiological Systems (Dr. Fu), and BME 6525 Methods in Neural-Machine Interfaces (Dr. Fu).
- The BME courses as described in the curriculum are offered once a year as part of the overall MAE Graduate Program 5-year plan of course offerings. This not only enables satisfaction of the MSBME required courses but also lays the groundwork for the delivery of the 7 required courses for the proposed PhD in BME program.
- These new courses emphasize the application aspects through course projects, therefore enhance student career preparation in both academia and industry. Three recent graduates of the MSBME program are currently PhD students pursuing BME research projects for their dissertations as well as sitting for the BME PhD Qualifying exam option (2 with Dr. Helen Huang and one with Dr. Hwan Choi).
- Multiple external funding awards (see faculty CVs) have enhanced the MAE research portfolio thereby increasing student financial support (for example, Dr. Huang and Dr. Stewart: NIH RO1, NIHK25 and both with NSF CAREER awards, Dr. Fu: NIH R15). We will also seek additional funding opportunities (NIH R25 and T32, NSF NRT, McNight Fellowships, etc..) as indicated in the needs section and in other sections of this proposal.

The formal PhD BME program proposal was prepared by the BME faculty in MAE (Kassab, Huang, Fu, and Steward) over the course of several meetings in the Spring and Summer of 2021. The concept of the program, as well as key elements (e.g., courses, qualifying examinations) have been evolving prior to the introduction of the MSBME degree in Fall 2016. All the necessary courses are in place and the curriculum has been presented and approved by the MAE Graduate Committee and MAE Faculty. The proposed PhD BME program proposal was reviewed and approved by the MAE Graduate Program Committee chaired by Prof. Jan Gou. Moreover, the BME Program Advisory Committee (BME-PAC) will serve to review, assess, improve, and revise the curriculum to ensure its effectiveness in achieving the identified program objectives, outcomes, and competencies with regards to career preparation, skills, and professionalism.

VIII. Curriculum

- A. Describe the specific expected student learning outcomes associated with the proposed program. If a bachelor's degree program, include a web link to the Academic Learning Compact or include the document itself as an appendix.

There are three objectives and outcomes set out for the proposed PhD in BME program.

Objective I: Career Preparation

- The objective is to prepare graduates for successful employment as biomedical engineers, for further graduate study in engineering or science, and for medical school. Career opportunities include research, design, analysis, and testing and product development in the biomedical and rehabilitation industries, in clinical engineering, and in biomedical engineering. Also included is clinical practice as a physician.
- Student Learning Outcomes:
 - Ph.D. in BME graduates will have a command of the application of engineering principles to biological and health systems.
 - Students will be able to conduct research in one or more of the following areas: Robotics/surgical intervention/biomedical devices, Biofluids, Biomechanics, Biomaterials, Rehabilitation/prosthetics/orthotics, bioacoustics, biosensing, medical imaging, instrumentation, bioelectronics, and electrophysiology.

Objective II: Skills

- The objective is to engender in Ph.D. in BME graduates requisite skills enabling them to be immediately productive in the biomedical engineering profession.
 - Student Learning Outcome: Ph.D. in BME graduates will have
 - a command of modern biomedical engineering tools,
 - an understanding of relevant physiology and biology,
 - knowledge of contemporary topics in medical technology,
 - the ability to engage in advanced biomedical engineering industry and research enterprises including elements of research, analysis, design, and experimentation.

Objective III. Professionalism

- The objective is to produce graduates who understand and are committed to fulfilling professional and public responsibilities.
 - Student Learning Outcome: Ph.D. in BME graduates will:
 - have a strong commitment to ethical conduct.
 - understand how the rapid progress in medical technology imposes an obligation to engage in lifelong learning.
 - communicate effectively orally and in writing at an advanced engineering level with elements of research, analysis, design, and experimentation.
 - have an appreciation of their special responsibility as biomedical engineers to promote safe, reliable, and effective medical technology.

These student learning outcomes are measured in basically three ways. As a PhD program, the primary method is through the completion of a research dissertation that clearly demonstrates Objectives 1 and 2. In addition, the PhD in BME program will utilize the assessment tools that have been developed for the other two PhD programs in our department (PhD in Mechanical Engineering and PhD in Aerospace Engineering). The assessment tools have been specifically tailored to the assess the PhD in BEM Objectives and Student Learning Outcomes. These tools have been utilized for the purpose of satisfying the SACSCOC assessment of our graduate programs at the MS and PhD levels. There are two main tools employed for such purposes include:

- (1) The Graduate Committee Questionnaire for the SACSCOC program assessment (GCQ).
- (2) The Graduate Student Questionnaire for the SACSCOC program assessment (GSQ).

These tools are deployed at two discrete times points in the course of the PhD program:

- (1) At the PhD candidacy examination as formative assessment tools that provide both the faculty committee assessment and student self-assessment of the student learning outcomes.
- (2) At the PhD dissertation defense as summative assessment tools that provide both the faculty committee assessment and student self-assessment of the student learning outcomes.

These assessment tools (GCQ and GSQ) are collected by the MAE Graduate Office and data are compiled annually for the purposes of responding to annual UCF institutional effectiveness review and the SACSCOC accreditation review.

B. Describe the admission standards and graduation requirements for the program.

The PhD in BME degree will offer the following gateways into the program:

- A. A PhD in BME for students with formal training in engineering or biomedical engineering who have earned a BS degree and seek post-baccalaureate training and research experience in biomedical engineering with the option of earning a MSBME along-the-way.
- B. A PhD in BME for students with formal training in engineering or biomedical engineering who have earned a MS degree and further graduate training and research experience in biomedical engineering.

Admissions Requirements

The PhD in BME applicants must complete an online application (<https://applynow.graduate.ucf.edu/apply/#/>) and must meet the minimum UCF standards for admission to the graduate programs at UCF as set out in the graduate catalog (<https://catalog.ucf.edu/content.php?catoid=4&navoid=201#university-admission-standards>). The applicants must have earned a bachelor's degree or equivalent from a regionally accredited U.S. institution or its equivalent from a foreign institution AND earned a 3.0 GPA (or equivalent) or better in all work attempted while registered as an undergraduate student working for a baccalaureate degree OR earned a 3.0/4.0 GPA (or equivalent) or better in all work attempted while registered as an upper-division student working for a baccalaureate degree. Consideration will be given to applicants with undergraduate degrees in one of the following areas: BS in Biomedical Engineering (BSBME), BS in Aerospace Engineering (BSAE), BS in Mechanical Engineering (BSME), Materials Science and Engineering or a closely related discipline. Applicants with MS degrees in Biomedical Engineering (MSBME), MS in Aerospace Engineering (MSAE), MS in Mechanical Engineering (MSME), Materials Science and Engineering or a closely related discipline may also apply.

Each applicant to a doctoral degree program shall present competitive scores on the Graduate Record Examination (GRE) in the verbal, quantitative, and writing portions. Since the program is competitive and each applicant is assessed holistically with GRE scores serving as one of many factors used in the process, a minimum score is not set. However, based on the other Ph.D. programs in the College of Engineering and Computer Science, the average GRE score for admission is 310. Applicants must submit three letters of recommendation, a resume or a curriculum vitae, and a written essay. The submitted materials will be evaluated in the context of a holistic credential review by the BME Program Director (Alain Kassab) and the MAE Graduate Program Coordinator (Jan Gou) who will make admissions decisions for the PhD in BME program and match applicants with potential PhD advisors/mentors.

Admission to the PhD in BME will be granted following current standards and practices for admission to the PhD programs in the CECS and in MAE. Generally, an acceptance decision will be based on the assessment of the applicant's GPA from previous college/university, past

work experience, recommendation letters and the statement of interest and objectives. Additionally, the admission decision considers evaluation of other academic indicators such as having completed a senior thesis, a master's thesis, authorship on publications, internship, involvement in scientific research projects, and/or presentations at major scientific meetings and non-academic indicators such as evidence of leadership, extracurricular activities, work or military experience, and/or volunteer activities. The quality of past research experience and training experiences as indicated in recommendation letters will also bear upon the admission decision.

For international students, a course-by-course evaluation of the student's official transcript must be submitted to a credential evaluation service recommended by UCF and an official GPA must be provided by the evaluating agency. Currently there are two agencies approved by the UCF Graduate College, and these are: World Educational Services (www.wes.org) and Joseph Silny (www.jsilny.com). International students can visit the Country Requirements page (<https://ww2.graduate.ucf.edu/countryrequirements/>) to review and submit the correct required documents for admission and evaluation purposes and can find further guidance at the College of Graduate Studies at (<https://graduate.ucf.edu/international-applicants/>).

Application and supporting document

- One official transcript (in a sealed envelope) from each college/university attended.
- Three letters of recommendation.
- A written statement of experience and research, areas of current and future potential research interests, and future career goals.
- Resume/CV.
- A score of 80 or above (computer-based test or paper-based equivalent) on the Test of English as a Foreign Language (TOEFL) is required for applicants from countries where English is not the official language or applications with degrees from a non-US accredited institution.
- Competitive GRE test score.

Pre-Requisites

For students who apply without a Mechanical Engineering BS or Biomedical Engineering BS, the following is list of a minimum requirement of undergraduate coursework that must be successfully completed prior to consideration for admission to the program:

Students must have completed the mathematics foundations which includes the Calculus sequence through Differential Equations, Physics with Calculus foundations, and a programming course:

- Calculus I, II, III
- Differential equations
- Physics with Calculus I and II
- Programming language (Matlab, C, C++, Python, etc.)

And students must have completed courses from at least three of the following areas:

- Statics or Dynamics
- Thermodynamics, heat transfer, or fluid mechanics
- Engineering materials, solid mechanics, or biomechanics
- Engineering mathematics or statistics
- Electrical circuits, electronics, or signal processing

Students that do not meet the above criteria should specify their plans to complete these requirements prior to admission or outline how other non-didactic experiences could substitute for these requirements. Students who do not meet admission requirements may be conditionally admitted, whereby they would be required to articulate this required coursework during their first year of study. Courses taken to meet these requirements would not count towards their graduate degree.

Graduation requirements

Graduation requirements for the PhD in BME program follow the standards of the College of Engineering and Computer Science and the UCF College of Graduate Studies graduation requirements. Students must maintain a minimum 3.0 graduate program GPA to be eligible to graduate, and only graduate-level credit with a grade of "C-" or higher may be used to satisfy degree requirements.

Furthermore, to complete all PhD in BME requirements and to be eligible to graduate, students must:

1. Complete 57 hours of coursework beyond the BS degree.
2. Successfully complete the PhD Qualifying examination.
3. Successfully complete the PhD Candidacy Examination and Dissertation Proposal Defense.
4. Complete 15 hours of Doctoral Dissertation
5. Successfully defend the PhD Dissertation.
6. Submit a completed PhD Dissertation.

As the PhD in BME is a research-based degree, there is an expectation of presentation of research work at professional conferences and publication of research in scholarly journals. These expectations shall be met by the date of the defense of the dissertation and evaluated by the PhD dissertation committee. Typically, the expectation is that there will be at least one peer-reviewed conference paper and presentation and a peer-reviewed journal manuscript published, under review, or accepted by the time of graduation.

The MAE department requires all graduate students to participate in the Department Seminar series in Fall and Spring. PhD in BME students are required to register in four (4) semesters of the MAE zero credit seminar (EML 5090) and make two seminar presentations prior to graduation: one prior to the candidacy and one prior to the Dissertation Defense.

C. Describe the curricular framework for the proposed program, including number of credit hours and composition of required core courses, restricted electives, unrestricted electives, thesis requirements, and dissertation requirements. Identify the total numbers of semester credit hours for the degree.

The PhD in BME will strictly adhere to the general requirements of a PhD program as set out in the University of Central Florida Graduate College Catalog Doctoral Program Policies (<https://catalog.ucf.edu/content.php?catoid=4&navoid=255>).

Specifically, the PhD in BME will require completion of a total of 72 hours at the graduate level post-bachelor's degree. These course requirements must satisfy the following:

- 57 hours comprised of a combination of 5000- and 6000-level classes (with a minimum of 27 hours of formal coursework exclusive of Independent Study, Doctoral Research, and Doctoral Dissertation), and 15 hours of Doctoral Dissertation.
- at least one-half of the credit hours used to meet program requirements must be in 6000-level or 7000-level courses, including the allowed number of research and dissertation hours.
- the doctoral dissertation hour requirements (15 hours) may only be satisfied by enrollment in dissertation hours, and these are only available after the student has passed the Candidacy Examination.

- only courses completed with a grade of “C-“ or better qualify to satisfy degree course requirements.

The PhD in BEM curriculum includes a core requirement of seven (7) classes, and it is provided below:

PhD in BME required core courses – 7 courses (21 hours)

BME 5216C: Mechanics of Biostructures I (3 hours)
 BME 5217C: Mechanics of Biostructures II (3 hours)
 BME 6500C: Bioinstrumentation (3 hours)
 BME 6935: Topics in BME (3 hours)
 BME 6231: Continuum Biomechanics (3 hours)
 BME 5742C: Modeling Techniques and Methodologies in Bioengineering (3 hours)
 ESI 5219: Engineering Statistics (3 hours) or STA 5206: Statistical Analysis (3 hours)

Representative Electives (36 hours) *minimum of 2 additional formal courses*

BME 5267 Biofluids (3 hours)
 BME 6268C Applied and Computation Biofluids (3 hours)
 BME 6215 Advanced biomechanics (3 hours)
 BME 5572 Biomedical Nanotechnology (3 hours)
 BME 6525 Methods in Neural-Machine Interfaces (3 hours)
 EML 5060 Mathematical Methods in MAE (3hours)
 EML 5237 Intermediate Mechanics of Materials (3 hours)
 EML 6067 Finite Elements I (3 hours)
 EML 6068 Finite Elements II (3 hours)
 EML 6725 Computational Fluid Dynamics I (3 hours)
 EML 6726 Computational Fluid Dynamics II(3 hours)
 EML 6712 Viscous Flow (3 hours)
 EAS 6185 Turbulent flow (3 hours)
 EML 5291 MEMS Materials (3 hours)
 EML 6299 Advanced Topics on Miniaturization (3 hours)
 EMA 5584 Biomaterials (3 hours)
 EMA 5588 Biocompatibility of Materials (3 hours)
 EMA 5060. Polymer Science and Engineering (3 hours)
 EEL 5272 Biomedical Sensors (3 hours)
 EEE 5265 Biomedical Effects and Applications of Electromagnetic Energy (3 hours)
 CAP 5510 –Bioinformatics (3 hours)
 CAP 5516 –Medical Image Computing (3 hours)
 OSE 6118 Optical Propagation in Inhomogeneous Media (3 hours)
 IDS 5127 Foundation of Bio-Imaging Science (3 hours)
 IDS 6253 Bioanalytical Technology (3 hours)
 ESI 5219 Engineering Statistics (3 hours)
 ESI 6247 Experimental Design and Taguchi Methods (3 hours)
 ESI 6609 Industrial Engineering Analytics for Healthcare (3 hours)
 BSC 5418 Tissue Engineering (3 hours)
 STA 5206: Statistical Analysis (3 hours)
 STA 5176: Introduction to Biostatistics (3 hours)
 GMS 6860: Statistics for Biomedical Scientists (3 hours)
 BME 6908 Independent Study (variable hours)
 BME 7919 Doctoral Research (variable hours)

Doctoral Dissertation (15 hours)

BME 7980 Doctoral Dissertation (variable hours)

Total required coursework for the PhD in BME: 72 hours

In addition to completing coursework with a 3.0/4.0 of better GPA, the PhD in BME program requires:

- (1) successful completion of the **PhD in BME Qualifying Examination**
- (2) successful completion of the **PhD Candidacy Examination and Dissertation Proposal Defense.**
- (3) successful defense of a **PhD dissertation.**
- (4) completion of four (4) zero-credit hour MAE Seminars.

The PhD in BME Qualifying examination is a proposal-based examination and the procedures have been determined by the BME faculty, approved by the MAE Graduate Program Committee, and by the MAE Faculty. The PhD in BME Qualifying examination was instituted in Fall 2019 and is administered each Fall and Spring semester as an option for ME PhD students engaged in BME research and who were seeking BME training under our current curriculum and structure.

The Biomedical Engineering (BME) PhD Qualifying Examination (QE) is structured as a proposal-based examination. This option was selected due to the wide variety of research areas within BME program that places severe challenges to traditional curriculum-based qualifying exams. This format requires students to demonstrate their research skills, particularly surveying the literature and planning experiments with different techniques or modeling. The format offers as well to the faculty on the QE exam committee the opportunity to interrogate the student in his/her understanding of fundamental subject matter required for the successful completion of the student's PhD program. Proposal-based QEs provide students with exposure to grant writing and practice preparing such documents that are useful skills to have later in their careers.

Purpose of the BME PhD Qualifying Examination: the intent of BME qualifying examination is to evaluate the topical and technical skills of the student required to conduct the proposed research. There is no requirement of preliminary results and the intent of the draft proposal submitted by the student is at the level of a seed proposal to obtain data whether experimental or numerical or both. This proposal is to be a reflection of the student's work and understanding. This is not a pre-candidacy exam, and this exam replaces the question-based traditional PhD qualifying examination and has the same aims. The qualifying examination topic should be distinct enough that it would not be included in the future candidacy exam about the actual PhD research to be undertaken by the student.

The BME qualifying exam is as rigorous as the traditional written question-based exams. The student applying to the BME PhD Qualifying Examination should devote the same amount of time and effort to study and prepare properly.

Format: The BME Qualifying Exam consists of a proposal prepared and defended by the student. The student will submit a written document on an approved subject and will give an oral presentation of the proposal followed by a question-and-answer session. The proposal will be evaluated by at least 3 faculty members (which does not include the PhD advisor), who will deliberate and vote on a pass or fail recommendation for the student. Each student will have an independent QE committee and two chances to pass the QE.

The proposal prepared by the student will focus on a topic that is topically broadly related to their research area but not their PhD research. The student will submit their topic as an abstract (1 page in length) to the committee of three members responsible for their Qualify Exam to confirm the suitability of the topic. The committee may provide feedback at this point to guide the student and may require modification of the abstract and/or topic.

This examination is taken within the first two years into the PhD in BME program and must be successfully completed prior to the Candidacy Examination and Dissertation Proposal Defense.

PhD in BME Candidacy Examination and Dissertation Proposal Defense are exams taken place prior to admission to Candidacy Status. It is normally taken near the end of completion of coursework and must be passed before being allowed to enroll in doctoral dissertation (XXX 7980) hours. The student shall identify a dissertation committee consisting of the dissertation advisor, two additional members of the MAE faculty, and an external member all of whom must be on the UCF graduate faculty (<https://graduate.ucf.edu/graduate-guide/graduate-faculty-and-graduate-faculty-scholars>). The student shall provide a written document of the dissertation proposal which will constitute the written portion of the examination and will be permanently filed in the student's permanent records. The student shall make an oral presentation to the dissertation committee and successfully defend the proposed dissertation topic. All committee members will evaluate and vote as to whether the student has successfully completed the examinations and will formally inform the Graduate Program Coordinator who will update the student's status upon successful completion of the exams. All materials including the approved proposal and other agreements will be kept in the student's file in the program. Students must have passed candidacy and have the candidacy and dissertation advisory committee documentation received and processed by the College of

Graduate Studies prior to the first day of classes for the term in order to enroll in dissertation hours for that term.

Dissertation Defense is an oral defense of the dissertation presented to the dissertation committee. This defense is made after consultation with the dissertation advisor and reports the outcomes of the doctoral research undertaken by the candidate as outlined in the dissertation proposal. The dissertation draft is to be provided to the committee at least two weeks in advance of the defense and the announcement of the defense (abstract, location, date and time) is to be posted at the CECS website two weeks prior to the defense. The student shall file an intent to graduate form and comply with the Graduate College regulations regarding the formatting and final submission of the dissertation for archival purposes (<https://graduate.ucf.edu/thesis-and-dissertation/>).

D. Provide a sequenced course of study for all majors, concentrations, or areas of emphasis within the proposed program.

The following is a 4-year sample Program of Study (POS) for completion of the PhD in BME for a full-time student admitted with a BS degree. Called out are only the 7 required core courses. The MAE Seminar (EML 5090) is a zero-credit hour course required to be taken by all MAE graduate students. PhD students are required to take four such MAE Seminar courses.

Year 1			Year 2			Year 3			Year 4		
FA	SP	SU	FA	SP	SU	FA	SP	SU	FA	SP	SU
BME 5216C	BME 5217C	Doc Rsch BME 7919	BME 6935	BME 6231	Doc Rsch BME 7919	Elective	Diss Hours BME 7980	Diss Hours BME 7980	Diss Hours BME 7980	Diss Hours BME 7980	
BME 5742C	ESI 5219	Doc Rsch BME 7919	Elective	Elective	Doc Rsch BME 7919	Elective	Diss Hours BME 7980				
BME 6500	Elective		Elective	Elective		Elective					
				PhD Qual Exam		PhD Candidacy				PhD Defense	
	MAE Seminar EML5090			MAE Seminar EML5090			MAE Seminar EML5090			MAE Seminar EML5090	

E. Provide a one- or two-sentence description of each required or elective course.

PhD in BME Core Courses

BME 5216C: Mechanics of Biostructures I 3(3,1) PR: Graduate standing or C.I. Part I of a two semester course. Mechanical analysis of hard and soft tissues and prosection lab on human anatomy and physiology.

BME 5217C: Mechanics of Biostructures II 3(3,1) PR: 5216C or C.I. Part II of a two-semester course. Cell physiology and engineering principles applied to analysis of cellular processes and prosection anatomy lab on human anatomy and physiology. Spring

BME 6500C: Bioinstrumentation 3(3,1) PR: BME 5587C or C.I An introduction to the fundamental theory and experimental techniques needed for performing bioengineering measurements, designing related experiments, and analyzing experimental results. Fall

BME 6935: Topics in BME 3(3,0) PR: EML 3701 and EGM 3601 and graduate standing or C.I. In this course students will explore research topics in biomedical engineering (BME) guided by BME faculty. This team-taught course will involve seminars and presentations of research and case studies by faculty engaged in BME research as well as regional medical professionals. Fall

BME 6231: Continuum Biomechanics 3(3,0) PR: EGM 3601. Material laws for biological tissues, with / without microstructure and/or an incompressibility constraint. Models of damage, growth, remodeling, and electro-mechanical coupling. Introduction to multiscale modeling. Odd Spring, Even Spring

BME 5742C: Modeling Techniques and Methodologies in Bioengineering 3(3,0) PR: EGN 3034, PHY 2048C, or C.I. Model identification and simulation implementation for physiological systems (e.g., cardiovascular, respiratory, neural, and muscular systems). Odd Fall, Even Fall

ESI 5219. Engineering Statistics 3(3,0). PR: C.I. Discrete and continuous probability distributions, hypothesis testing, regression, nonparametric stats and ANOVA.

OR

STA 5206: Statistical Analysis 3(3,0) PR: STA 2023; not open to students who have completed STA 4164. Graduate status or senior standing or C.I. Data analysis; statistical models; estimation; tests or hypotheses; analysis of variance, covariance, and multiple comparisons; regression and nonparametric methods. Fall

Representative Elective Courses

BME 5267 Biofluids 3(3,0) PR: EML 3701 and EGM 3601 or C.I. This course will cover the physical and mathematical principals of fluid mechanics and its application and relevance to human physiology and pathology. Fall

BME 6268C Applied and Computational Biofluids 3(3,1) PR: EML 3701, EGM 3601, BME 5267, or C.I. Principles and foundations of applied fluid mechanics and computational methods to the human circulation. Spring

BME 6215 Advanced Biomechanics 3(3,0) PR: BME 5216C or C.I. The objectives of this course are to understand the basic concepts and biomedical applications of medical robotics, human motion mechanics and neuro-mechanics. Spring

BME 5572 Biomedical Nanotechnology 3(3,0) PR: EEL 3123C or C.I. Human Physiology, Bioelectric Phenomena and Neurons, Nanoelectronics for fabrication of biochips for human biomedical applications, self-assembly, bioelectronics, moral and ethical issues. Occasional

BME 6525 Methods in Neural-Machine Interfaces 3(3,0) PR: PHY 2048C and EML 4225, or C.I. Signal processing techniques for interpreting human intention from electromyography (EMG) and Electroencephalography (EEG) signals and human-safe control algorithms will be discussed and practiced. Odd Spring

BSC 5418 Tissue Engineering 3(3,0) PR: Graduate standing. Introduction to Tissue Engineering with a special emphasis on the current status of the field, on novel methods and on cell biomaterial interactions. Occasional

EML 5060. Mathematical Methods in Mechanical and Aerospace Engineering 3(3,0). PR: MAP 2302. Vector field theory, generalized coordinates, complex variables, contour integration and Laplace and Fourier transforms and inversions, variable coefficient ODEs and solution of PDEs for governing equations of heat transfer, ideal fluid flow, and mechanics. Fall and Spring

EML 6067. Finite Elements in Mechanical, Materials, and Aerospace Engineering I 3(3,0). PR: EML 5237 or EML 5713, or C.I. Finite element analysis of thermomechanical response of aerospace and mechanical components and structures. Plates and shells. Vibrations. Composite materials. Minimum weight design. CAD interface. Introduction to codes. Spring

EML 6068. Finite Elements in Mechanical, Materials, and Aerospace Engineering II 3(3,0). PR: EML 6067 or C.I. Advanced finite element applications to aerospace and mechanical components and structures. Rotating systems. Fracture mechanics. Aeroelasticity. Buckling. Impact. Use of codes. Occasional

EML 6725 - Computational Fluid Dynamics and Heat Transfer I –3(3,0) PR: EML 5152 or C.I.

Finite Difference methods; error and stability analysis; applications to model equations and further developments; matrix methods. Spring

EML 6726 - Computational Fluid Dynamics and Heat Transfer II –3(3,0) PR: EML 6725. Development of governing equations; turbulence modeling; numerical solution of Euler and potential equations, Navier-Stokes equations, and boundary layer equations; grid generation. Occasional

EML 6712 Viscous Flow 3(3,0) PR: EML 5060, EML 5713. Principal concepts and methods for viscous fluid motion. Incompressible and compressible boundary layer analysis for laminar and turbulent flows. Odd Fall

EAS 6185 Turbulent flow 3(3,0) PR: EML 5060 and EML 5713. Phenomena and methods of characterizing turbulence; spatial and temporal velocity correlation; energy spectra; transition prediction; turbulent boundary layer equations; hot wire and LDV measurement techniques. Even Fall

EML 5237. Intermediate Mechanics of Materials 3(3,0). PR: EML 3500 or EAS 4200. Elements of elasticity. Failure theories. Bending and torsion. Thin plates. Energy principles. Thick-walled cylinders. Applications to design.

EML 5291. MEMS Materials 3(3,0). PR: EML 5060, EML 6211, or C.I. Introduction of materials that are frequently used for MEMS applications such as silicon, metal, ceramics and polymers. The course will focus on fundamental principles involved in structures and properties of the materials, and their applications in MEMS.

EMA 5060. Polymer Science and Engineering 3(3,0). PR: EGN 3365. Structure and properties of polymers, preparation and processing of polymers, mechanical properties, use in manufacturing and high tech applications.

EMA 5584. Biomaterials 3(3,0). PR: EGN 3365. Properties of natural biological materials and their relation to microstructure, biocompatibility, specific applications in orthopedic, cardiovascular, visual, neural, and reconstruction implants.

EMA 5588. Biocompatibility of Materials 3(3,0). PR: EGN 3365 or C.I. Biocompatibility and bioactivity; cell-biomaterials interactions; engineering bone and cartilage; soft-tissue replacements; total hip replacements; nanostructured biomaterials, imaging techniques, preservation techniques for biomaterials, MSDS and FDA compatibility data.

EEL 5690. Introduction to Medical Robotics and Tele-Operation 3(3,0). PR: EEL 3657 or Medical students in their second year or later. Medical robots for minimally invasive surgery, kinematics, constrained workspace and dexterity, haptics, tele-operation and network based control, basics of laparoscopic surgery.

EEL 5272. Biomedical Sensors 3(3,0). PR: EEL 4750 or EEL 4832 or C.I. Study of engineering concepts behind the various biomedical sensors used to monitor a patient undergoing clinical therapy.

EEE 5265. Biomedical Effects and Applications of Electromagnetic Energy 3(3,0). PR: EEL 3470 or C.I. RF and microwave energy and their interaction with biological materials. Specific biomedical effects such as absorption, thermal therapy, hyperthermia, etc., will be discussed

CAP 5510 – Bioinformatics 3(3,0) PR: Background in programming language or molecular biology. This course introduces problems, concepts, algorithms, and applications in Bioinformatics. It covers essential topics such as sequence alignment and prediction of gene and protein structure. Occasional

CAP 5516 – Medical Image Computing 3(3,0) PR: MAS 3105 and COP 4020 or COT 4210. This course provides students with the foundation necessary for understanding, visualizing, and quantifying medical images with computational methods. Spring

OSE 6118. Optical Propagation in Inhomogeneous Media 3(3,0). PR: Graduate standing or C.I. Basic concepts of optical wave scattering and propagation in inhomogeneous media with applications to material sciences, optical remote sensing, biomedical optics, imaging, and image analysis.

IDS 5127. Foundation of Bio-Imaging Science 3(3,0). PR: Graduate standing. Fundamental theory, design, and practice of modern bio-imaging techniques used for basic biomedical research applications.

IDS 6252. Biomedical Nanotechnology (3,0). PR: Admission to the Professional Science Master's in Nanotechnology and IDS 6250, UG General and Organic Chemistry, or C.I. Synthesis and properties of nanomaterials related to biomedical applications, nanotechnology for in vitro and in vivo diagnostics, and therapeutics.

IDS 6253. Bioanalytical Technology (3,0). PR: IDS 6250, or C.I. Analytical technologies and products for biomolecular detection and analysis, nanotechnology-based medical diagnostics.

ESI 5219. Engineering Statistics 3(3,0). PR: C.I. Discrete and continuous probability distributions, hypothesis testing, regression, nonparametric stats and ANOVA.

ESI 6247. Experimental Design and Taguchi Methods 3(3,0). PR: STA 3032 or ESI 4234. Introduction to Taguchi Concepts and Methodologies, use of design of experiments for quality design and improvement.

ESI 6609. Industrial Engineering Analytics for Healthcare 3(3,0). PR: ESI 5219 or C.I. Course includes an overview of major data analytics algorithms and methods introduced through examples from Healthcare.

Independent Study, Doctoral Research, and Doctoral Dissertation

BME 6908 Independent Study Variable credit hours. Prerequisite(s): PhD student status. Doctoral dissertation. May be repeated for credit. Fall, Spring, Summer

BME 7919 Doctoral Research Variable credit hours. Prerequisite(s): PhD student status. Doctoral dissertation. May be repeated for credit. Fall, Spring, Summer

BME 7980 Doctoral Dissertation Variable credit hours. Prerequisite(s): Candidacy status. Doctoral dissertation. May be repeated for credit. Fall, Spring, Summer

MAE Seminar Course

EML 5090 - Mechanical and Aerospace Seminar (0 hours). PR: Graduate standing or C.I. The course is intended to help MAE graduate students practice public speaking, learn skills of scientific communication, expand their width of knowledge, and promote collaborations. May be repeated.

- F. **For degree programs in the science and technology disciplines, discuss how industry-driven competencies were identified and incorporated into the curriculum and indicate whether any industry advisory council exists to provide input for curriculum development and student assessment.**

The BME curriculum was designed by the diverse BME faculty members recruited from top BME national programs and national research labs over the past 5 years in MAE. The BME faculty also consulted medical professionals with whom they had research collaborations, for example Dr. William DeCampi, MD, PhD at Orlando Health and Dr. Mohtashem Samsam, MD at Advent Health. An example of such interactions is in the framing of the Biostructures I and II courses which were developed in close consultation with Dr. Mohtashem Samsam and aimed to deliver the anatomy and physiology content to bioengineering students. The program aims to train and prepare PhD graduates for successful careers in research and development in the biomedical industry, in academia, and in government research laboratories and agencies. Our PhD graduates will have the advanced ability to apply their knowledge of mathematics, engineering, and science to

formulate and solve relevant biomedical engineering problems and conduct high-quality research at the interface of engineering and medicine, the ability to communicate scientific and technical research effectively in writing and oral presentations, and the ability to conduct independent cutting-edge research and contribute to the existing body of knowledge.

The MAE Department has an Industrial Advisory Board (IAB) that reviews the curriculum and informs the department and department chair annually regarding industry needs and trends. The IAB is comprised of 16 members who are drawn from the local industry to represent stakeholders who are employers of our students, who provide internship opportunities for our undergraduates, and who may support our senior design I and II capstone courses. Represented industries include large companies such as Siemens Power Generation, Mitsubishi Hitachi Power Systems Americas, ABB Inc., Lockheed Martin Missiles and Fire Control, and Walt Disney World as medium size companies such as DotDecimal, Medicomp, and Guard Dog Valves. The IAB meets with the MAE Chair and select faculty representing the department in the course of the academic year to receive an overview of the department status and to discuss issues and provide industry input concerning the department academic program.

The following is a tentative advisory committee to be constituted upon the approval of the PhD in BME program. This committee will serve to guide and provide input on the program and will provide a connection for the program to the COM and the local biomedical industry. The following have provided verbally interest in participating in this board that tentatively will consist of:

Ted Conway, PhD, Chair BME program FIT
William DeCampi, MD, PhD, UCF-COM and Arnold Palmer Hospital
TY Hsia, MD, MSME, UCF-COM and Arnold Palmer Hospital
Mohtashem Samsam, MD, Advent Health
Richard Sandler, MD, UCF-COM and Nemours Hospital
Kevin Erhart, PhD, DotDecimal
Tony Balda, BS, MBA, CEO and President Medicomp

Kevin Erhart and Tony Balda serve on the MAE IAB. The PhD in BME program advisory board may be expanded as the PhD in BME program grows to address additional curriculum and research needs. The PhD in BME program will also be evaluated via the Annual UCF Institutional Effectiveness Assessment process for SACSCOC accreditation.

- G. For all programs, list the specialized accreditation agencies and learned societies that would be concerned with the proposed program. Will the university seek accreditation for the program if it is available? If not, why? Provide a brief timeline for seeking accreditation, if appropriate. For degree programs in medicine, nursing, and/or allied health, please identify the courses that meet the requirements in Section 1004.08, Florida Statutes for required patient safety instruction.**

The PhD in BME is accredited along with all other graduate programs at UCF through the Southern Accreditation of Colleges and Schools Commission on Colleges (SACSCOC) process. Moreover, the PhD in BME program is reviewed by the State of Florida through the seven-year program review of the College of Engineering and Computer Science and the MAE Department. There are no PhD in BME program-specific accreditation agencies and learned societies that would be concerned with the proposed program.

- H. For doctoral programs, list the accreditation agencies and learned societies that would be**

concerned with corresponding bachelor's or master's programs associated with the proposed program. Are the programs accredited? If not, why?

The proposed PhD in BME will be accredited along with all other graduate programs at UCF through the Southern Accreditation of Colleges and Schools Commission on Colleges (SACSCOC) process. The masters in BME (MSBME) program as well as the Master in Mechanical Engineering (MSME) and Aerospace Engineering (MSAE) in the home department are also accredited by SACSCOC, along with the PhD in Mechanical Engineering and the PhD in Aerospace Engineering. UCF does not have a Bachelor's in BME program, however, all engineering bachelor's degrees at UCF are accredited by the Accreditation Board for Engineering and Technology, Inc. (ABET) <https://www.abet.org/>. The MAE Department recently underwent an ABET review of both of its bachelor's degrees BSME and BSAE. It is expected that students admitted into the PhD in BME program who have engineering degrees including a BSBME from other institutions will have obtained these from ABET accredited programs.

- I. **Briefly describe the anticipated delivery system for the proposed program (e.g., traditional delivery on main campus; traditional delivery at branch campuses or centers; or nontraditional delivery such as distance or distributed learning, self-paced instruction, or external degree programs). If the proposed delivery system will require specialized services or greater than normal financial support, include projected costs in Table 3 in Appendix A. Provide a narrative describing the feasibility of delivering the proposed program through collaboration with other universities, both public and private. Cite specific queries made of other institutions with respect to shared courses, distance/distributed learning technologies, and joint-use facilities for research or internships.**

The courses will be conducted on the main UCF campus and the UCF-COM utilizing classrooms and course delivery facilities currently existing at UCF. Wherever possible, courses will be available at remote UCF sites through the FEEDS distance learning system. As a research-intensive doctoral program requiring specific lab space as well as direct oversight by faculty during the dissertation phase, no queries for were made with respect to collaborating on the program with other institutions.

IX. Faculty Participation

- A. **Use Table 2 in Appendix A to identify existing and anticipated full-time (not visiting or adjunct) faculty who will participate in the proposed program through Year 5. Include (a) faculty code associated with the source of funding for the position; (b) name; (c) highest degree held; (d) academic discipline or specialization; (e) contract status (tenure, tenure-earning, or multi-year annual [MYA]); (f) contract length in months; and (g) percent of annual effort that will be directed toward the proposed program (instruction, advising, supervising internships and practica, and supervising thesis or dissertation hours).**

All BME faculty members are on 9-month contracts on tenured or tenure-earning lines in MAE, except Dr. Sudeshna Pal who is an associate lecturer with a line in MAE.

Full Professors

Alain Kassab *Ph.D.* Mechanical Eng., UF 1989, Biofluids – multiscale cardiovascular CFD and congenital heart disease. BME Program Director. Tenured. Member of the Graduate Faculty can chair and supervise MS and PhD Theses. 9 months contract and 0.1FTE.

Olusegun Ilegbusi *PhD* Mechanical Engineering, Imperial College, Biofluids – respiratory flow and lung modeling. Tenured. Member of the Graduate Faculty can chair and supervise

MS and PhD Theses. 9 months contract and 0.1 FTE.

Associate Professors:

Sam Song (joined 2015): Ph.D. in Mechanical Engineering, Imperial College, Research Associate in the School of Engineering and Applied Sciences (SEAS), Wyss Institute for Biologically Inspired Engineering at Harvard University, Research Fellow at Boston Children's Hospital, Harvard Medical School, Boston. Associate Research Scientist at NSF Engineering Research Center (ERC) and Laboratory for Computational Sensing and Robotics (LCSR), Whiting School of Engineering, Johns Hopkins University, Baltimore. Tenure-earning. Member of the Graduate Faculty can chair and supervise MS and PhD Theses. 9 months contract and 0.1 FTE.

Hansen Mansy PhD Mechanical Engineering, Illinois Institute of Technology, Chicago, IL, 1990, Bioacoustics and cardiovascular device development. Tenured. Member of the Graduate Faculty can chair and supervise MS and PhD Theses. 9 months contract and 0.05 FTE.

Assistant Professors

Robert Steward (joined 2015): Ph.D. (Mechanical Eng.), Carnegie Mellon University, Postdoc, T.H. Chan Harvard School of Public Health, Boston, MA. Cell Mechanics, mechanotransduction, and biomechanics. Tenure-earning. Member of the Graduate Faculty can chair and supervise MS and PhD Theses. 9 months contract and 0.2FTE.

Helen Huang (joined 2016): Ph.D. in Biomedical Engineering, University of Michigan, 2009, Assistant Research Scientist 06/2012-2016, University of Michigan Ann Arbor, School of Kinesiology Post-doctoral Fellow / Research Associate 08/2009-10/2012, University of Colorado Boulder, Department of Integrative Physiology. Brain computer interface, rehabilitation, lower body biomechanics. Tenure-earning. Member of the Graduate Faculty can chair and supervise MS and PhD Theses. 9 months contract and 0.2FTE

Quishi Fu* (joined Fall 2017): Ph.D. in Biomedical Engineering, Arizona State University, 2013. Research Assistant Professor, Biomedical Engineering, Arizona State University 2013-2015. * *Biiionix Cluster (formerly Prosthetics Interfaces Cluster)*. Upper body mechanics, hand prosthetics, and bio-robotics. Tenure-earning. Member of the Graduate Faculty can chair and supervise MS and PhD Theses. 9 months contract and 0.2 FTE

Hwan Choi* (joined Fall 2018): PhD Mechanical Engineering, University of Washington, 2016, Postdoctoral Research Fellowship University of Michigan School of Kinesiology. * *Biiionix Cluster (formerly Prosthetics Interfaces Cluster)*. Gait mechanics, inverse kinematics of locomotion. Member of the Graduate Faculty can chair and supervise MS and PhD Theses. 9 months and 0.1 FTE

Luigi Perotti (joined Fall 2018): Ph.D., California Institute of Technology; Associate Project Scientist in Radiological Sciences and Bioengineering (07/2016-12/2018) Postdoctoral Scholar in Radiological Sciences and Bioengineering (07/2014 - 06/2016) University of California, Los Angeles. Cardiac mechanics, Left Ventricular Fibrillation, Electrophysiology, and Biomechanics. Tenure-earning. Member of the Graduate Faculty can chair and supervise MS and PhD Theses. 9 months and 0.2FTE

Joon-Hyuk Park (joined Fall 2019) *Ph.D. in mechanical engineering from Columbia University, wearable robotics, human-robot interaction, assistive and rehabilitative devices in wearable forms. * Disability, Aging and Technology Cluster. Tenure-earning. Member of the Graduate Faculty can chair and supervise MS and PhD Theses. 9 months contract and 0.1 FTE.

Wendy Shen (joined in Fall 2020) PhD Materials Engineering, 2011, Auburn University. Development of functional materials-based microelectronics for biomedical interfacing and biosensors. Micro/nanofabrication techniques for flexible bioelectronics and drug delivery systems based on various biomaterials, including natural materials, biodegradable materials and synthetic biomaterials. Tenure-earning. Member of the Graduate Faculty can chair and supervise MS and PhD Theses. 9 months contract and 0.1 FTE.

Associate Lecturer:

Sudeshna Pal: Ph.D. in biosystems and agricultural engineering from Michigan State University in 2009. Rehabilitation engineering and biosensors. Member of the Graduate Faculty can co-chair MS and PhD Theses and serve on graduate MS theses and PhD dissertation committees. 9 months contract and 0.1 FTE.

- B. Use Table 3-Appendix A to display the costs and associated funding resources for existing and anticipated full-time faculty (as identified in Table 2-Appendix A). Costs for visiting and adjunct faculty should be included in the category of Other Personnel Services (OPS). Provide a narrative summarizing projected costs and funding sources.**

The proposed PhD in BME program benefits from existing UCF faculty members who are either tenured or tenure-earning with lines in MAE and who will support its curricular and research needs. These twelve (12) BME faculty members have been identified throughout the report and are repeated here (Kassab, Ilegbusi, Mansy, Song, Steward, Huang, Choi, Fu, Shen, Park, Perotti, and Pal). The workload by budget classification is 1.13 FTE for Year 1 and it is 1.16 FTE for Year 5 as we do not anticipate additional hires in years 1-5, however the increase does reflect additional FTE for advising on the part of the BME program director. This workload reflects a one course assignment per year for each listed faculty member as well as time for the appointed Biomedical Engineering Program Director (currently Dr. Alain Kassab) and this approximately is equivalent to total a little over a full faculty member's workload. Academic program support for MAE programs (Undergraduate Program Director, Graduate Program Director, Advising Director, Admission Specialist, etc...) is housed within the MAE Academic Advising Office in Engineering 1 Room 381 (<https://mae.ucf.edu/advising/>). This suite consists of 6 offices, a waiting room, and a conference room.

- C. Provide in the appendices the abbreviated curriculum vitae (CV) for each existing faculty member (do not include information for visiting or adjunct faculty).**

The NIH style 5-page CV's of the twelve BME faculty in MAE are provide in Appendix E. These faculty members are listed in section A of the Faculty Participation section of the PhD in BME program proposal.

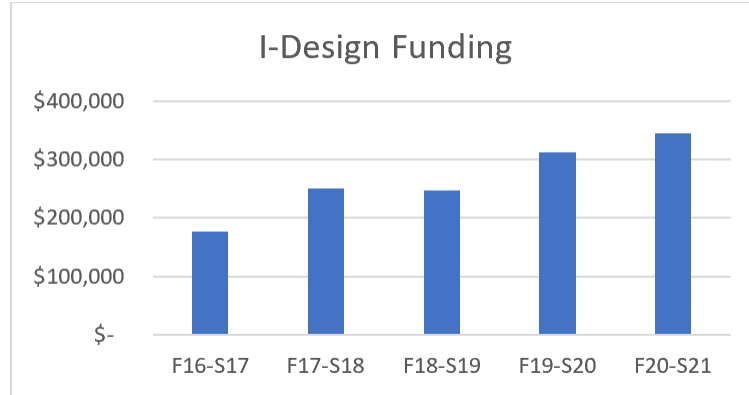
- D. Provide evidence that the academic unit(s) associated with this new degree have been productive in teaching, research, and service. Such evidence may include trends over time for average course load, FTE productivity, student HC in major or service courses, degrees granted, external funding attracted, as well as qualitative indicators of excellence.**

By all measures and indicators, the MAE Department is currently one of the most highly productive units at UCF and has a track record of excellence and productivity. The MAE faculty currently consists of 38 full-time tenured or tenure-track faculty members including the chair supported by 7 lecturers and instructors. The MAE faculty counts a recent addition, Dr. Wen Shen who joined the department in Fall 2020.

The department offers a BS, MS and PhD in Mechanical Engineering and a BS, MS and PhD in Aerospace Engineering and recently launched the MS in BME in Fall 2017. In Fall 2020, the MAE faculty educated a student body of 4,381 comprised of 3,980 ME and AE undergraduates and 401 MS and PhD students.

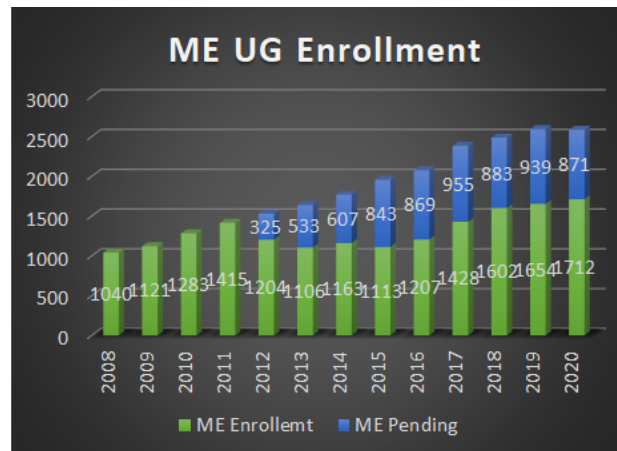
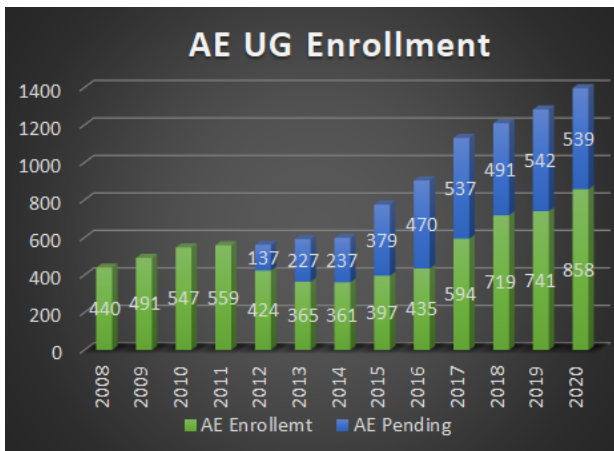
The department has developed an innovative and highly successful heavily subscribed large 2 semester senior design program (over 1,000 students/year) under the guidance and Dr. Mark Steiner and Dr. Kurt Stresau who have secured recurring local industry support (I-Design) for the program that tripled since 2016 and averaged over 300K/year in 2019-2021 (see the historical past

5-years of expenditures graphed below). Moreover, the MAE department is seeking funds from the President's 2021-2022 Strategic Investment Program: Jump Start Fund to obtain a university-supported annual expenditure of \$2M for our senior design courses.



Quantitative measures of productivity of the MAE faculty are provided below in terms of student head count at the undergraduate and graduate levels, degree productions, external funding, and journal publications:

- (1) **Undergraduate student head count (UGSHC)** has been steadily increasing over the years. The undergraduate student head count has more than doubled from 1,830 in AY 2010-2011 to a current enrollment of 3,980 in Fall 2020.



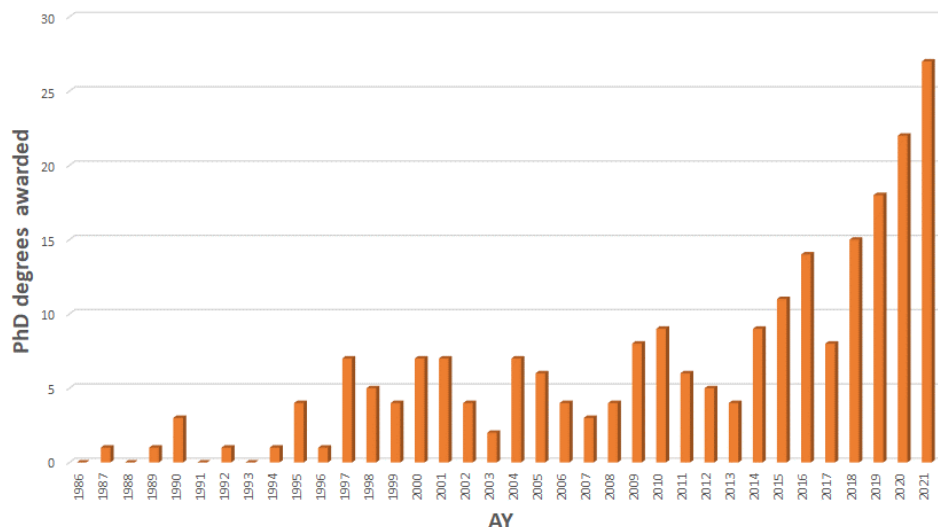
- (2) **Graduate student head count (GSHC)** has also steadily increased over the years. Remarkably, the graduate student count has more than doubled from 170 (118 MS and 52 PhD) in AY 2010-2011 to 401 (254 MS and 147 PhD) in Fall 2020. In AY 2019-2020 the MAE faculty graduated 114 graduate students (the AE PhD is a newly launched PhD program).

MAE Graduation in 2019-2020

Semester	ME PhD	AE PhD	MS ME	MS AE	MS BME
Fall 2019	7	1	13	9	4
Spring 2020	6	1	24	20	4
Summer 2020	11	1	3	6	2
Total	24	3	40	35	10

- (3) **The MAE PhD graduation productivity** is high with a remarkable growth over the past 5 years. This is reflection of the increased research activity and outstanding grantsmanship of our dynamic faculty.

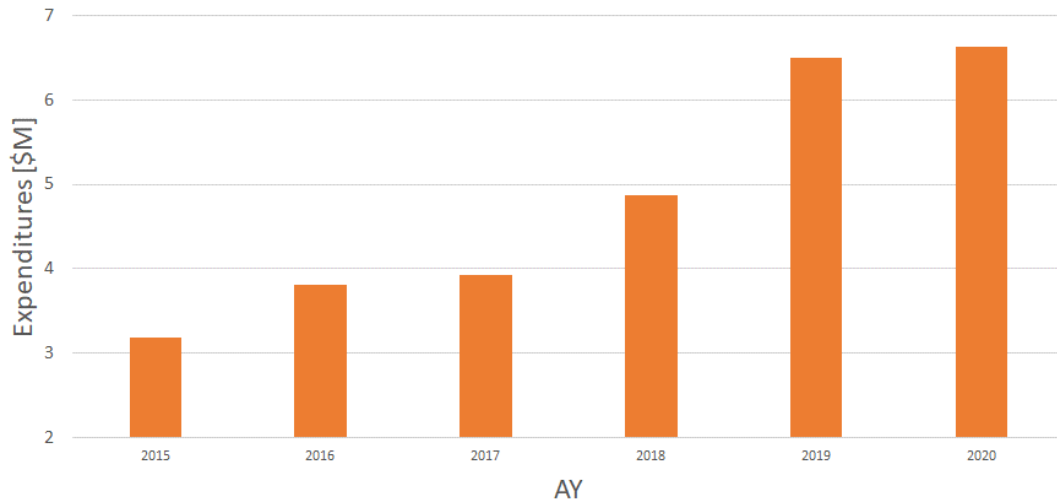
PhD degrees awarded



- (4) **The MAE annual research expenditures** have also steadily increased over the past

decade nearly doubling from \$3.6M in AY 2010-2011 to \$6.8M in AY 2020-2021.

MAE research expenditure



The MAE faculty has consistently demonstrated a high scholarly productivity currently with an average of 3+ journal papers published per faculty member per year.

Although the department undergraduate enrollment grew from 1,830 students in AY 2010-2011 to over 4,400 students in Fall 2021, the MAE department significantly grew both its research and PhD programs and number of graduate degrees awarded. Clearly, the MAE program delivers highly sought-after BS degrees in ME and AE all the while being a highly productive research active department. In AY 2020-2021, on average, a MAE faculty member educated 97 students, produced 3 graduate students, generated 180K in research expenditures, and published 3 journal papers.

It is also a measure of the quality of the MAE Department that members of its faculty are Fellows or Associate Fellows of national and international professional societies. A list is provided below:

American Association for the Advancement of Science (AAAS) Fellow: *Louis Chow*

American Society for Engineering Education (ASEE) Fellow: *Louis Chow*

American Society of Mechanical Engineers (ASME) Fellows: *Louis Chow, Alain Kassab, Ranganathan Kumar, Yoav Peles, Jayanta Kapat, Olusegun Ilegbusi*

American Institute of Medical and Biological Engineering (AIMBE) Fellow: *Alain Kassab*

American Institute of Aeronautics and Astronautics (IAAA) Associate Fellows: *Subith Vasu, Jayanta, Kapat, Yunjun Xu Associate, Seetha Raghavan, Kareem Ahmed, Louis Chow*

Electron Microscope Society of India Fellow: *Suryanarayana Challapalli*

Institute of Materials, Minerals and Mining (IMMM) Fellow: *Suryanarayana Challapalli*

International Association of Advanced Materials (IAAM) Fellow: *Jihua Gou*

American Society for Metals (ASM) International Fellow: *Challapalli Suryanarayana*

Wessex Institute of Technology (WIT) Fellow: *Alain Kassab*

Many of our faculty members serve as Editors and Associate Editors and are on the Editorial

Boards of numerous professional journals. A sample list is provided below:

Kareem Ahmed

Associate Editor and Colloquium Co-Chair, Proceedings of the Combustion Institute, Detonations, Explosions and Supersonic Combustion

Suryanarayana Challapalli

Editor, Transactions of the Indian Institute of Metals
Associate Editor, RESEARCH (AAAS Science Partner Journal)
Associate Editor/ Editorial Board Member, International Materials Reviews
Associate Editor/Editorial Board Member, Metallurgical and Materials Transactions A
Associate Editor/Editorial Board Member, Materials Design and Processing Communication
Associate Editor/Editorial Board Member, Nanoscience & Nanotechnology – ASIA
Associate Editor/Editorial Board Member, Madridge Journal of Nanotechnology
Associate Editor/Editorial Board Member, Materials Science and Engineering A
Associate Editor/Editorial Board Member, Materials and Manufacturing Processes
Associate Editor/Editorial Board Member, Journal of Materials Engineering and Performance

Louis Chow

Associate Editor, ASME Journal of Heat Transfer

Tuhin Das

Associate Editor, ASME Journal of Mechanisms and Robotics

Jan Gou

Associate Editor, International Journal of Smart and Nano Materials

Helen Huang

Associate Editor, IEEE Transactions on Neural Systems and Rehabilitation Engineering

Alain Kassab

Editor, Engineering Analysis with Boundary Elements
Associate Editor, Inverse Problems in Science and Engineering
Associate Editor, Advances in Boundary Elements
Associate Editor of Critical Reviews in Biomedical Engineering
Editorial Board, International Journal of Computational Methods and Experimental Measurements
Editorial Board, Thermopedia, Science and Engineering Area Editor
Editorial Board, International Journal for Engineering Modeling
Editorial Board, Journal of Applied Mathematics and Computational Mechanics

Ranganathan Kumar

Associate Editor, ASME Journal of Thermal Sciences and Engineering Applications

Faissal Moslehy (Emeritus)

Associate Editor, Journal of Management and Engineering Integration

Yoav Peles

Associate Editor, Nanoscale and Microscale Thermophysical Engineering (NMTE)
Editorial Board member, Interfacial Phenomena and Heat Transfer

Our faculty members are actively organizing and chairing national and international conferences and participating on Scientific Organizing Committees and Chairing sessions at national and international conferences.

The MAE Department has been successful in attracting research funds not only from national

agencies (NSF, ONR, NIH, NSASA, etc..) but also from local and national industries (Siemens, ULA, MHI, Orlando Health, Nemours...). An example of successful industry collaboration is the Siemens Energy Center and the CATER turbomachinery center. Our faculty has won numerous highly prestigious early career awards. A list is provided below:

Air Force Fellowship Program Award: *Kareem Ahmed*
American Chemical Society Doctoral New Investigator Award: *Kareem Ahmed*
DARPA/MTO Young Faculty Award: *Yoav Peles, Subith Vasu*
NAE Frontiers of Engineering Selections: *Helen Huang (FOE-U.S.-China)*
NASA-Virginia Space Grant Consortium New Investigator Program Award: *Kareem Ahmed*
NSF CAREER Awards: *Samik Bhattacharya, Hyoung Jin Cho, Andrew Dickerson, Ranajay Ghosh, Helen Huang, Nina Orlovskaya, Shawn Putnam, Robert Steward, Lucille Gianuzzi.*
Office of Naval Research Young Investigator Awards: *Yoav Peles*
U.S. Defense Threat Reduction Agency Young Investigator Award: *Subith Vasu*

Our faculty members have been recognized and awarded the highest academic honors at UCF.

UCF Pegasus Professors: *Jayanta Kapat, Alain Kassab, Ranganathan Kumar*
UCF Trustee Chair Professorship: *Alain Kassab, Jayanta Kapat*

X. Non-Faculty Resources

- A. Describe library resources currently available to implement and/or sustain the proposed program through Year 5. Provide the total number of volumes and serials available in this discipline and related fields. List major journals that are available to the university's students. Include a signed statement from the Library Director that this subsection and subsection B have been reviewed and approved.

Reproduced below are elements for the memo from Terrie Sypolt and Buenaventura Basco, Research and Information Services Librarians regarding the library report of the PhD in BME program. The complete memo and report are found in Appendix B. There are no projected costs needed to acquire library materials to support the new Biomedical Engineering PhD.

Memo

To: Dr. Alain Kassab, Professor, Mechanical & Aerospace Engineering
Dr. Yoav Peles, Chair, Department of Mechanical and Aerospace Engineering
Dr. Michael Georgiopoulos, Dean, College of Engineering & Computer Science
Ms. Tina Buck, Interim Dept. Head, Acquisitions & Collections
Ms. Sara Duff, Acquisitions Librarian
Ms. Ying Zhang, Assoc. Director, Collection Services & Resource Management
Mr. Frank Allen, Interim Director of Libraries
Dr. Devon Jensen, Associate Dean, College of Graduate Studies
Ms. Emily Stettner, Assistant Director, Graduate Curriculum

From: Terrie Sypolt and Buenaventura Basco, Research and Information Services Librarians

Subject: Library Evaluation of the Proposal to add a Biomedical Engineering PhD., in the Mechanical & Aerospace Engineering Department

Date: October 1, 2019; Updated July 23, 2021

Peer Comparisons

When reviewing library support (databases, journal titles, and books) for the proposed Biomedical Engineering PhD, the faculty and I selected the following institutions for comparison:

- **University of Florida Biomedical Engineering, PhD**
- **University of Pennsylvania, Bioengineering, PhD**
- **Texas A&M University, Biomedical Engineering, PhD**
- **Purdue University, Biomedical Engineering, PhD**

Summary and Projected Costs for New Library Resources

The UCF Libraries' current journal and database holdings will meet the needs for the proposed PhD, and therefore no immediate subscription costs are requested (see full analysis below). The only databases we lack are EMBASE and Scopus that multiple peer institutions have. While EMBASE database would be beneficial, it is not crucial to this program since much of the material is duplicated in Medline. A large percentage of unique material is drug-disease and drug-drug interactions which is not related to our proposed program and therefore not needed by UCF at this time. In the event any new key journal or database becomes critical for the PhD program in the future, additional recurring funding will need to be provided to the libraries to add these resources. Also note that in the unfortunate event library budget shortfalls occur, some existing resource subscriptions may be cut or scaled back.

UCF's program is divided between Biomedical Sciences (Molecular Biology, Cancer, Immunity and pathogenesis, metabolic and cardiovascular, and neuroscience) and Biomedical Engineering (medical devices). UCF does need to purchase Cold Spring Harbor Protocols. EBSCO quoted a price of \$5,089.00 for the first year with a price increase of 5% each year thereafter. While this is a database needed, it is needed by Biomedical Sciences and NOT Biomedical Engineering. Therefore, we will not charge this to Biomedical Engineering.

Should the PhD program begin to develop medical devices and patent them, the program/Biomedical Engineering Department will need to purchase IEC Standards for the medical devices from the Techstreet Store. Since these standards will be housed in their lab, the department will need to purchase those, as needed. Library funds will not be used for these.

Book comparison with the peer institutions chosen shows that UCF compares favorably with them and has the books needed to support the PhD program in Biomedical Engineering. We set the foundation for the PhD program when we did the library evaluation for the MS degree proposal, and when we purchased books and an e-book database for the MS program. Therefore, we do not currently need additional funds for books.

Our Reference books compare favorably to the chosen peer institutions. We have made a \$445.15 one-time purchase for the **Encyclopedia of Medical Robotics** 4v set 2018 from Amazon. "The Encyclopedia of Medical Robotics combines contributions in four distinct areas of medical robotics, namely: Minimally Invasive Surgical Robotics, Micro and Nano Robotics in Medicine, Image-guided Surgical Procedures and Interventions, and Rehabilitation Robotics. The volume on Minimally Invasive Surgical Robotics focuses on robotic technologies geared towards challenges and opportunities in minimally invasive surgery and the research, design, implementation, and clinical use of minimally invasive robotic systems. The volume on Micro and Nano robotics in Medicine is dedicated to research activities in an area of emerging interdisciplinary technology that is raising new scientific challenges and promising revolutionary advancement in applications such as medicine and biology. The size and range of these systems are at or below the micrometer scale and comprise assemblies of micro and nanoscale components. The volume on Image-guided Surgical Procedures and Interventions focuses primarily on the use of image guidance during surgical procedures and the challenges posed by various imaging environments and how they related to the design and development of robotic systems as well as their clinical applications. This volume also has significant contributions from the clinical viewpoint on some of the challenges in the domain of image-guided interventions. Finally, the volume on Rehabilitation Robotics is dedicated to the state-of-the-art of an emerging interdisciplinary field where robotics, sensors, and feedback are used in novel ways to re-learn, improve, or restore functional movements in humans." Biomedical Engineering has already transferred funds to cover the cost of this encyclopedia set.

Additional reference books that the department could purchase, if they want to do so, include a new edition of Encyclopedia of Medical Devices and Instrumentation (2006) for 2276.00 and Biomedical photonics handbook, v 1 Fundamentals, Devices & Techniques (2015) for \$59.96.

PhD:

	2020-2021	2021-2022	2022-2023	2023-2024	2024-2025	2025-2026
Databases	0	0	0	0	0	0
Journals	0	0	0	0	0	0
Protocols	5,089.00*	5,343.00*	5,610.00*	5,890.50*	6,185.00*	6,494.00*
Books	0	0	0	0	0	0
Reference Books	0	0	0	0	0	0
IEC Industry Standards (selected as needed by Biomedical Engineering. Since these will be housed in the Biomed Engineering Lab, they are not considered a library purchase. Biomedical Engineering will purchase as needed from their departmental funds**	0	0	0	0	0	0
Total	0.00	0.00	0.00	0.00	0.00	0.00

*While these protocols are needed, they are needed by the Biomedical Sciences PhD program and NOT the Biomedical Engineering PhD program and are therefore not charged to Biomedical Engineering.

**While the Biomedical Engineering PhD will need the IEC Industry standards for the medical devices they develop, these will be selected by the Biomedical Engineering faculty and housed in their lab so they will not be considered library materials and therefore the funds needed are not reflected in this request. Additional standards, AAMI (Association for the Advancement of Medical Instrumentation) and BSOL Standards Online (British Standards Online) can be purchased by the department as needed.

Recurring Subscriptions Supporting the Biomedical Engineering PhD:

Databases

Database Name	UCF	UF	U Penn	Texas A&M	Purdue
AccessMedicine	X	X	X	X	
arXiv (Physics) via SCIRUS http://arxiv.org/ free	X	X	X	X	X
ASM Medical Materials Database https://www.asminternational.org/home/-/journal_content/56/10192/15467873/DATABASE		X			
Biomedical SCIENCEnet BASE					X
Biomedical Reference Collection (EBSCOhost) basic/comprehensive https://health.ebsco.com/products/biomedical-reference-collection-basic-edition		X		X	
BIOSIS Citation Index	X				X
BioTechnology & BioEngineering Abstracts (ProQuest)	X	X	X		
Biotechnology Research Abstracts (ProQuest)	X	X	X	X	X
Cochrane Library	X	X	X	X	X
Compendex (Engineering Index)	X	X	X	X	X

Database Name	UCF	UF	U Penn	Texas A&M	Purdue
EMBASE		X	X	X	
Engineering & SciTech	X				
Google Scholar	X	X	X	X	X
IEEE Computing and Engineering Collection				X	
IEEE Xplore	X	X	X	X	X
INSPEC	X	X	X	X	X
JoVE (Journal of Visualized Experiments)	X	X	X	X	X
Materials Science & Engineering (SAGE)	X				
Materials Science & Engineering Database UCF has combination of Engineering Database, Materials Science Collection and Materials Research Database)	X				
Medical Device Databases https://www.fda.gov/MedicalDevices/DeviceRegulationandGuidance/Databases/default.htm	X	X	X	X	X
Materials Science & Engineering Database (ProQuest)	X		X		X
Medline (via PubMed/EBSCOhost)	X	X	X	X	X
ProQuest Dissertations and Theses Global	X	X	X	X	
PubMed	X	X	X	X	X
Science Direct (Including Elsevier Freedom Collection)	X	X		X	X
SCOPUS			X	X	X
SpringerLINK	X	X	X	X	
Web of Science (Web of Knowledge)	X	X	X	X	X
Academic Search Complete/Academic Search Premier	X	X	X	X	X
ACM Digital Library	X	X			X
Annual Reviews	X	X		X	X
Applied Science & Technology Source	X	X			X
ASTM Compass (formerly ASTM Standards & Engineering Digital Library)	X				X
BioMed Central open access https://www.biomedcentral.com/	X	X	X	X	X
BIOSIS Citation Index	X	X	Previews	Previews	X
ChemSpider http://www.chemspider.com/	X	X	X	X	X
CINAHL	X	X	X	X	X
Clinical Key	X		X	X	
Consumer Health Complete/Health Source: Consumer and Nursing ed	X	X	X		X
Data Citation Index	X			X	X
Derwent Innovations Index (Patents) Part of Web of Science	X		X	X	X
DynaMed Plus	X		X	X	
Engineering Materials Abstracts	X		X		
Gene (NCBI) https://www.ncbi.nlm.nih.gov/gene	X	X	X	X	X
Journal Citation Index (JCR)	X	X	X		X
Knovel: Engineering & Scientific Online References		X			X
MathSciNet	X	X	X	X	X
MedGen Portal (NCBI) https://www.ncbi.nlm.nih.gov/medgen/	X	X	X	X	X
Microedex			X		

Database Name	UCF	UF	U Penn	Texas A&M	Purdue
NTIS (Free public access to a very small portion of the database)		X	X		
PEDro Physiotherapy Evidence Database	X	X	X	X	X
ProQuest Dissertations and Thesis Full-Text	X	X	X	X	X
ProQuest Materials Science Collection	X				
PsychiatryOnline	Me d sch ool onl y				
PsycINFO	X	X	X	X	X
PubChem https://pubchem.ncbi.nlm.nih.gov/	X	X	X	X	X
Reaxys (formerly Beilstein/Gmelin)		X	X	X	X
SciFinder	X	X	X	X	X
SciTech Premium Collection (ProQuest)	X				
SPIE Digital Library	X			X	X
SportDiscus	X	X			X
Springer Nature Experiments	X	X	X	X	X
Up to Date (Medical school only; others must go to that library for access)	Me d sch ool	X	Med school	X	
Wiley Online Library	X				X
WorldCat	X	X	X	X	X
Zoological Record		X		X	X

Biomedical Engineering Protocols

	UCF	UF #33	U Penn #5	Texas A&M #38	Purdue #28
Springer Nature Experiments (Springer Protocols) Principle source	X	X	X	X	X
Cold Spring Harbor Protocols		X	X	X	X
Bio- protocol (Stanford) free (Life science protocols)	X	X	X	X	X
Current Protocols (Wiley)		X		X	X
JoVE: Journal of Visualized Experiments	X	X	X	X	X
Nature Methods	X	X	X	X	X
BIOSIS Previews	X	X	X	X	X
Biological Procedures Online free (Techniques & methods in medical &	X	X	X	X	X

biological sciences)					
Protocol Online free (Links to protocols hosted by research labs, biotech companies, individual researchers protocols and websites)	x	x	x	x	x
ProtocolExchange open repository of detailed methodologies in experimental science	x	x	x	x	x

Books (2000-2018)

Subject Heading	UCF	UF	U Penn	Texas A&M	Purdue
Biocompatible materials	93	86	89	84	130
Bioinformatics	623	604	216	552	601
Biological transport	57	58	62	46	68
Biomechanics	147	92	183	105	442
Biomedical engineering	1,157	330	1,083	732	1,248
Biomedical engineering—Computer simulation	9	6	11	6	8
Biomedical engineering—Mathematical models	5	9	5	5	4
Biomedical Materials	272	284	385	294	300
Biomedicine	1,850	343	1,185	119	973
Biotechnology	651	642	1,184	726	1,089
Body Fluid Flow	7	5	12	8	11
Computational Biology	429	244	297	146	402
Computational neuroscience	83	70	95	58	70
Computer simulation	539	341	874	641	817
Continuum mechanics	151	134	207	148	140
Diagnostic imaging	176	188	398	141	392
Engineering—Statistical methods	105	59	94	78	79
Gene Therapy	130	83	176	29	144
Genetic Engineering	258	175	204	155	178
Genomics	278	292	31	199	202
Hemodynamics	24	27	30	21	16
Human mechanics	109	103	84	89	113
Medical instruments and apparatus	32	40	247	48	85
Medical Technology	60	60	239	55	92
Molecular biology	1,041	342	1,069	199	496
Nanotechnology	469	880	1,404	900	1,408
Rheology	164	198	39	46	190
Robotics	509	388	350	322	352
Robotics in medicine	30	35	13	27	23
Simulation and modeling	503	161	453	340	600
Surgical robots	19	22	18	7	6

Subject Heading	UCF	UF	U Penn	Texas A&M	Purdue
Tissue engineering	241	218	206	93	278
Total	10,222	6,519	10,638	5,783	10,226
	1.0	.64	1.04	.57	1.0

E-Books

	UCF	UF	UPENN	Texas A&M	Purdue
Access Engineering http://www.accessengineeringlibrary.com/subject/bio_engineering				X	
Access Medicine	X	X	X	X	X
Morgan & Claypool Synthesis Collection includes Biomedical Engineering, Biomaterials, Tissue Engineering, etc./Synthesis: The Digital Library of Engineering and Computer Science	X	X	X	X	X
Springer E-Books	X	X	X		X
IEEE Wiley E-books	X	X	X	X	
Cambridge Biomedical Engineering Books	X	X	X		X
Clinical Key	X		X	X	
DynaMed Plus	X		X	X	
EBSCO eBooks	X	X	X	X	X
Genetics Home Reference (free) http://ghr.nlm.nih.gov/	X	X	X	X	X
Knovel		X	X	X	X
CRCnetBASE formerly ENGnetBASE	X	X		X	
National Academies Press https://www.nap.edu/	X	X	X	X	X
ProQuest Ebook Central	X	X		X	
Books24x7	X	X	X		
R2 Digital Library	Se lectiv e med scho ol	X			
Referex Engineering/ now part of Science Direct E-Books Engineering Village Selected individual titles.	X	X	X		X

	UCF	UF	UPENN	Texas A&M	Purdue
Stat!Ref		X		X	
Taylor & Francis ebooks	X	X		X	
ChemNetBase		X		X	X
Oxford Scholarship Online	X	X	X		

Reference Books

	UCF	UF	U Penn	Texas A&M	Purdue
Acland's Atlas of Human Anatomy	dvd		X		
ASM Handbook	X	X			
Comprehensive Biophysics (Elsevier)				X	
Encyclopedia of Biomaterials and Biomedical Engineering	X	X	X	X	X
Encyclopedia of Bioethics	X				
Encyclopedia of Bioprocess Technology					
Encyclopedia of Life Sciences (Wiley)			X	X	X
Encyclopedia of Medical Robotics	X		X		
Encyclopedia of Membrane Science and Technology (Wiley)		X	X	X	
Encyclopedia of Polymer Science and Technology (Wiley)	X	X	X	X	X
Encyclopedia of Science, Technology and Ethics	2002				
Encyclopedia of Toxicology (Elsevier)	X	X	X	X	X
Kirk-Othmer Encyclopedia of Chemical Technology (Wiley)	X	X	X	X	X
Biomaterials and bioengineering handbook	X				
The biomedical engineering handbook	X	X	X	X	X
Biomaterials and bioengineering handbook (2000)	X (print and online)	X	X	X	X
Biomedical engineering and design handbook I & II 250.00 set (2009)		X	X	X	X
Biomedical engineering handbook	X				
Biomedical photonics handbook	X	X	X	X	X
Biomedical technology and devices handbook (2004)		X	X	X	
Handbook on advanced design and manufacturing technologies for biomedical devices	X	X	X	X	X
Materials for Medical Devices	X	X	X	X	X
PEEK Biomaterials Handbook		X		X	

	UCF	UF	U Penn	Texas A&M	Purdue
Standard handbook of biomedical engineering and design	x	x	x	x	x
Ullmann's Encyclopedia of Industrial Chemistry	x	x	x	x	x
Wiley Encyclopedia of Biomedical Engineering			x		

Reference book analysis: UCF has the reference books needed to support the proposed PhD program.

Journals (Comparisons made with UF, UPENN, and Purdue. Unable to compare with Texas A&M because of library block.

	UCF	UF	U Penn	Texas A&M	Purdue
ACS Biomaterial Science and Engineering	x	x	x		
ACS Synthetic Biology	x	x	x		
Acta Biomaterialia	x	x	x		x
Acta Biotechnologica	x	x	x		x
Acta of Bioengineering and Biomechanics		x			
Advanced Healthcare Materials	x	x	x		
Advances in Biomedical Engineering thru 1981	x	x	x		x
Advances in Biotechnical Processes		x			
American Journal of Physiology: Cell Physiology http://ajpcell.physiology.org/ open access may not be complete	x	x	x		x
American Journal of Physiology: Heart and Circulatory Physiology open access may not be complete	x	x	x		x
American Journal of Physiology: Lung Cellular and Molecular Physiology http://grweb.coalliance.org/oaddl/oaddl.html open access may not be complete	x	x	x		x
American Journal of Physiology: Regulatory, Integrative, and Comparative Physiology http://grweb.coalliance.org/oaddl/oaddl.html open access may not be complete	x	x	x		x
American Journal of Physiology: Renal Physiology	x	x	x		x
Analysis of Research Publications Supported by NIH and NEI HE20,3039:NEI 1970-1976		x	x		
Annual Review of Biomedical Engineering**	x	x	x		x
Annual Review of Neuroscience	x	x	x		x
Annuals of Biomedical Engineering		x			
Applied Biochemistry and Biotechnology	x	x	x		x
Applied Bionics and Biomechanics			x		
Applied Mathematics and Computation	x	x	x		x
Applied Optics	x	x	x		x

	UCF	UF	U Penn	Texas A&M	Purdue
Arteriosclerosis, Thrombosis, and Vascular Biology	X	X	X		X
ASME Journal of Biomechanical Engineering	X	X	X		X
ASME Journal of Biomedical Engineering	X	X	X		X
Bio-Medical Materials and Engineering	X	X	X		X
Bioautomation DOA Journals	X	X	X		X
Bioconjugate Chemistry	X	X	X		X
Biocybernetics and Biomedical Engineering	X	X	X		X
Bioengineered Bugs (Open access)	X	X	X		X
Biofabrication	X	X	X		
Biomaterials	X	X	X		X
Biomaterials Science	X	X	X		X
Biomedical Business & Technology	X	X	X		X
Biomedical Engineering	X	X	X		X
Biomedical Engineering and Computational Biology	X	X	X		X
Biomedical Instrumentation & Technology	X	X	X		X
Biomedical Microdevices	X	X	X		X
Biomedical Sciences Instrumentation 100.00 ea volume 49 vols. Selective	X	X	X		X
Biomedical Signal Processing and Control	X	X	X		X
Biophysical Journal	X	X	X		X
Biorheology 950.00	1962-83	1962-99	1962-99		
Biosensors	X	X	X		X
Biosensors & bioelectronics	X	X	X		X
Biosurface and Biotribology**	X	X	X	X	
Biotechnology Advances	X	X	X		X
Cardiovascular Engineering ceased in 2010		X	X		X
Cardiovascular Research	X	X	X		X
Cell Biochemistry and biophysics	X	X	X		X
Cell Motility and the cytoskeleton	X	X	X		X
Cells, Tissues, Organs	X	X	X		X
Chest http://journal.publications.chestnet.org/issues.aspx http://grweb.coalliance.org/oadl/oadl.html	X	X	X		X
Clinical biomechanics	X	X	X		X
Computer Methods in Biomechanics and Biomedical Engineering	X	X			X
Computers in biology and medicine	X	X	X		X
Continuum Mechanics and Thermodynamics**	X		X		
Current Opinion in Biotechnology	X	X			X
European Cells and Materials	X	X			
Frontiers in Bioengineering and Biotechnology	X				
Frontiers in Neuroengineering	X	X			X
Frontiers in Neuroinformatics	X	X	X	X	

	UCF	UF	U Penn	Texas A&M	Purdue
Frontiers in Neurorobotics	X	X			X
Gait & Posture	X	X			X
IEEE Engineering in Medicine and Biology Magazine: the Quarterly MagazineP*P*	X	X			
IEEE Pulse	X	X			X
IEEE Journal of Translational Engineering in Health and Medicine	X	X	X		X
IEEE Photonics Journal	X	X	X		X
IEEE Reviews in Biomedical Engineering*	X	X	X		X
IEEE Transactions on Bio-Medical Engineering*	X	X	X		X
IEEE Transactions on Bio-Medical Electronics*	X	X	X		X
IEEE Transactions on Biomedical Circuits and Systems	X	X	X		
IET Synthetic Biology	X	X	X		X
International Journal of Computer Assisted Radiology and Surgery add to list	X	X	X		X
International Journal of Damage Mechanics**	X		X		
International Journal of Medical Robotics and Computer Assisted Surgery	X	X	X		X
International Journal of Numerical Methods in Biomedical Engineering needs in list	X	X	X		
International Journal of Medical Robotics and Computer Assisted Surgery**	X		X		
International Journal of Robust and Nonlinear Control	X	X	X		
Journal of Applied Biochemistry			1979-1985	1979-1985	1979-1985
Journal of Applied Biomaterials & Biomechanics**				X	X
Journal of Applied Biomechanics	X	X			X
Journal of Applied Physiology (open access. May not be complete)	X	X	X		X
Journal of Biochemical Technology	X	X			X
Journal of Bioenergetics and Biomembranes**	X		X		
Journal of Bioengineering (older journal-not current, 1976-78) Now Annuals of Biomedical Engineering					X
Journal of Biological Engineering	X	X	X		X
Journal of Biomaterials Applications*	X	X	X		
Journal of Biomaterials Science. Polymer edition**	X	X	X		
Journal of Biomechanical Engineering	X	X	X		X
Journal of Biomechanics	X	X	X		X
Journal of Biomedical Applications	X	X	X		X
Journal of Biomedical Materials Research A**	X	X	X		
Journal of Biomedical Materials Research B: Applied Biomaterials**	X	X	X		X

	UCF	UF	U Penn	Texas A&M	Purdue
Journal of Biomedical Optics	X		X		X
Journal of Biomedical Physics & Engineering	X	X	X		X
Journal of Bionic Engineering	X	X	X		X
Journal of Bioscience and Bioengineering	X		X		X
Journal of Biotechnology	X		X		X
Journal of Computer Aided Molecular Design**	X				
Journal of Developmental Biology and Tissue Engineering		X			
Journal of Fermentation and Bioengineering	X		X		X
Journal of Fluids and Structures	X		X		X
Journal of Materials Chemistry B: Materials for Biology and Medicine	X	X	X		
Journal of Materials Science/ Materials in Medicine	X		X		X
Journal of Mechanics in Medicine and Biology	X (1 year embargo)		X		
Journal of Medical Devices (ASME)	X	X	X		
Journal of Medical Engineering & Technology	X	X	X		X
Journal of Medical Engineering	X	X	X		
Journal of Medical Signals and Sensors	X	X	X		X
Journal of Nanobiotechnology	X		X		
Journal of Neural Engineering	X	X	X		X
Journal of Neuroengineering and Rehabilitation	X	X	X		X
Journal of Robotic Surgery**	X	X	X		
Journal of Sound and Vibration	X	X	X		X
Journal of the Acoustical Society of America	X	X	X		X
Journal of the American Medical Association	X	X	X		X
Journal of Thoracic and Cardiovascular Surgery	X	X	X		X
Journal of Tissue Engineering	X	X	X		
Journal of Tissue Engineering and Regenerative Medicine	X	X	X		
Journal of Vibration and Acoustics (ASME)	X	X	X		
Journal of Visualized Experiments	X	X	X		X
Lab on a Chip - Miniaturisation for Chemistry and Biology			X		X
Lancet	X	X	X		X
Medical & Biological Engineering & Computing	X	X	X		X
Medical Electronics & Biological Engineering until 1966. Now Medical & Biological Engineering & Computing	X	X	X		
Medical Engineering & Physics	X	X	X		X
Medical Image Analysis	X	X	X		X
Metabolic Engineering	X	X			X
Metabolic Engineering Communications	X	X	X		
Microcirculation**	X		X		
Molecular Engineering	X	X	X		X

	UCF	UF	U Penn	Texas A&M	Purdue
Nano Communication Networks	X	X	X		
Nanomedicine: Nanotechnology, Biology and Medicine	X	X	X		
Nanotechnology, Science and Applications	X	X	X		
Nanotoxicology	X	X			
Nano Today	X		X		
Nature Biomedical Engineering**	X		X		
Nature Biotechnology	X	X	X		X
Nature Nanotechnology	X		X		
Neural Systems and Rehabilitation Engineering	X	X	X		X
Open Biomedical Engineering Journal	X	X	X		X
Open Tissue Engineering and Regenerative Medicine Journal	X	X	X		
Osteoarthritis and Cartilage	X	X	X		X
Physics in Medicine and Biology	X	X	X		X
Physiological Measurement	X	X	X		X
Polymer Chemistry	X	X	X		
Proceedings of the Institution of Mechanical Engineers. Part H Journal of Engineering in Medicine	X	X	X		X
Progress in Biomaterials	X	X	X		X
RBM	X	X	X		X
Receptors & Channels**	X	X	X		
ReCIBE	X	X	X		
Regenerative Biomaterials**	X	X	X		X
Robotic Surgery. Research and Reviews **	X	X	X		X
Science	X	X	X		X
Science Translational Medicine http://stm.sciencemag.org/ Add to list	X	X	X		X
Skin Research and Technology	X	X	X		X
Soft Robotics**	X	X	X		
Technology and Health Care	X	X	X		X
Tissue Barriers**	X		X		
Tissue Engineering, Part A, B, and C	X	X	X		X
Traffic**	X		X		
Wiley interdisciplinary reviews. Nanomedicine and nanobiotechnology	X	X	X		

Journal cost analysis: Comparison of core journal titles provided by the department as well as a comparison of journal titles in the chosen institutions show that UCF has most of the needed currently published journals in biomedical engineering. While we do not have back files of some of the titles, Interlibrary loan can be used to acquire needed older journal articles.

Patents

	UCF	UF	U Penn	Texas A&M	Purdue
USPTO U S Patent and Trademark Office https://www.uspto.gov/patents-application-process/search-patents	X	X	X	X	X
Canadian Intellectual Property Office	X	X	X	X	X

	UCF	UF	U Penn	Texas A&M	Purdue
http://www.ic.gc.ca/opic-cipo/cpd/eng/introduction.html					
Derwent Innovations Index (Web of Science)	X	X	X	X	X
European and World Patents (Espacenet) https://worldwide.espacenet.com/?locale=en_EP	X	X	X	X	X
Free Patents Online http://www.freepatentsonline.com/	X	X	X	X	X
Google Patents https://patents.google.com/	X	X	X	X	X
Lens (formerly Patent Lens) https://www.lens.org/lens/	X	X	X	X	X
PAT2PDF http://www.pat2pdf.org/	X	X	X	X	X
Patent Fetcher https://free.patentfetcher.com/Patent-Fetcher-Form.php	X	X	X	X	X
PatentScope	X	X	X	X	X
Reaxys		X	X	X	X
Reports of patent design and trademark cases	X	X	X		X
SciFinder	X	X	X	X	X

B. Describe additional library resources that are needed to implement and/or sustain the program through Year 5. Include projected costs of additional library resources in Table 3-Appendix A. Please include the signature of the Library Director in Appendix B.

None required indicated by an extensive library study of needs for the PhD in BME program. The report is signed by the Library Director and provided in Appendix B.

C. Describe classroom, teaching laboratory, research laboratory, office, and other types of space that are necessary and currently available to implement the proposed program through Year 5.

There are adequate classrooms and teaching laboratories in Engineering I, II, and III to deliver the proposed PhD BME curriculum and support the research enterprise. We are currently delivering all courses for the PhD in BME curriculum. Classroom space is shared throughout UCF and assigned each semester to optimize classroom size and course-specific student enrollment.

The MAE Department has 7,272 sq feet of teaching lab space that will support the PhD in BME program. These labs and locations are listed below:

- ENGR1 Room 168, Measurements I & II Lab** (1463 sq. ft.)
- ENGR 1 Room 468, Controls & Measurement Lab** (640 sq. ft.)
- ENGR 1 Rooms 368 and 370, Sr. Design Studio** (981 sq ft and 638 sq. ft.)
- ENGR 2 Room 304, MAE Computer lab** (500 sq ft)
- ENGR 2 Room 101, Manufacturing Lab** (2950 sq. ft.)

In addition, all current faculty have adequate office and laboratory space to conduct office hours, student advising, and research. All BME faculty are provided standard office space located in the Engineering I (building 40). Laboratories will be described below in section F below.

- D. Describe additional classroom, teaching laboratory, research laboratory, office, and other space needed to implement and/or maintain the proposed program through Year 5. Include any projected Instruction and Research (I&R) costs of additional space in Table 3-Appendix A. Do not include costs for new construction because that information should be provided in response to X (E) below.**

No additional space is anticipated to be needed for the PhD in BME program as this program will utilize classroom, teaching and research lab space already available to the Mechanical and Aerospace Engineering Department.

- E. If a new capital expenditure for instructional or research space is required, indicate where this item appears on the university's fixed capital outlay priority list. Table 3-Appendix A includes only Instruction and Research (I&R) costs. If non-I&R costs, such as indirect costs affecting libraries and student services, are expected to increase as a result of the program, describe and estimate those expenses in narrative form below. It is expected that high enrollment programs in particular would necessitate increased costs in non-I&R activities.**

There are no new capital expenditures required for the new PhD in BME program. The groundwork for the program was set in the creation of our MSBME program and in the investments made by the university in the hiring of the Bionix and DAT cluster faculty and the investment in their laboratories (Q. Fu, Hwan Choi, Joon Park) as well the hiring of four BME faculty members in MAE (H. Huang, R. Steward, S. Song, and L. Perotti). The MAE department has invested in the required infrastructure and research space. The PhD program does not place an additional burden on instructional delivery as the courses and curriculum have been developed and are currently being delivered under the MSBME program and the PhD in ME program. The library report indicates further that no additional expenditures are required.

- F. Describe specialized equipment that is currently available to implement the proposed program through Year 5. Focus primarily on instructional and research requirements.**

The proposed PhD in BME program will have access to the UCF-COM anatomy lab for the prosection experiences in Mechanics of Biostructures I and II under the direction of Dr. Emily Bradshaw at the UCF COM. Currently, these courses are offered as part of the required courses for the MSBME program at UCF. The courses comprising the proposed PhD curriculum are currently being delivered to the graduate students under face-to-face mode and video-streamed mode using Panopto facilities currently existing at the CECS at UCF. Panopto Essentials is an online course for faculty who would like to incorporate some asynchronous content delivery using the online delivery platform.

The college offers adequate support of the graduate curriculum. The staff of the graduate advising office at the MAE department coordinates and schedules the graduate course offerings and assignment of faculty to these courses following a 5-year course plan that has been reviewed and adopted by the BME faculty. The courses are currently offered under existing faculty staffing and graduate course offering. Moreover, courses external to MAE are offered by departments such Electrical and Computer Engineering (ECE) and Computer Science (CS) as who have committed to offering such courses in support of the PhD in BME program as stated in support letters.

Course delivery is supported by the online delivery staff at the College of Engineering and Computer Science. Course management is offered via UCF Webcourses via Canvas. The course delivery and continuous development and improvement benefit from the Center for Distributed Learning (CDL) which is a powerful and unique resources available to all members of the UCF faculty (<https://cdl.ucf.edu/>).

The CDL helps ensure success in teaching online by providing importance and essential training and resources. Teach Online contains the latest information on course design, professional development, and educational resources for UCF faculty who teach online or supplement face-to-face courses with online instruction. CDL empowers the faculty to be current on the latest advancements in teaching online, some of which are happening right here at UCF. Moreover, at the CDL Webcourses support is available online, in person by phone, or via live chat interaction with support hours on Monday – Friday from 8:30 am – 6:00 pm and with evening/weekend support available as well.

The PhD in BME program will benefit from access to the CECS Ideas innovative suites, machine shop, and 3D printing facilities as well as access to specialize characterization equipment at the UCF Materials Characterization Facility (MCF (<http://www.ampac.ucf.edu/facilities/MCF.php>) and collaboration with the UCF Nano Science and Technology Center (<https://www.nanoscience.ucf.edu/>). The PhD in BME faculty have access to UCF Central Cleanroom facility located in the CECS which has a class 1000 clean with more than 3500 sq. feet and a class 1200 clean room with more than 1200 sq. feet.

In addition, the PhD in BME program will benefit from access to several existing BME laboratories and their research equipment to pursue research projects. The 12 BME faculty members in MAE have collectively 11,210 sq. feet of specialized research lab space located mainly in the College of Engineering and Computer Science and also at the UCF College of Medicine, and the UCF Nano Science and Technology Center. These research lab facilities, their specialized capabilities, and their directors are listed below:

The Computational Mechanics Lab (CML Lab ENGR1-room 183: 660 sq. ft.) and the Applied Biofluids Lab (ABL ENGR2-room 182: 730 sq. ft.). Lab Director: Dr. Alain Kassab. The CML is located in room 183 of the Engineering I building at UCF. The computational facility houses and operates a 338 CPU cluster of high-end Dell PowerEdge and AMD 64 bits servers with 1.7T of RAM (with 4GB of RAM or better per core), and 14TB of Hard Disk storage. The cluster operates under the Rocks 6.1 / CentOS 6.3 Operating System and 30 TB Tape Back-Up system. The lab has 12 workstations operating under Windows 7 Enterprise. Installed compilers for C and FORTRAN are also supplied with MPICH libraries for parallel computing. Current licenses for commercial computational fluid dynamics software suites include STARCCM+(3.5) from CDAdapco, LSDYNA and ABAQUS FEM software, as well the Mimics (v. 12.1.1) and 3Matics medical imaging software from Materialise. The CML has access to solid modeling software ProE and SolidWorks. A variety of computational fluid flow, heat transfer, fracture and thermoelastic codes (boundary elements and meshless methods codes) are also routinely utilized for analysis and are under continuous stages of evolution. We also have access to UCF's Stokes Advanced Research Computing Center (ARCC) 3100 computer cores cluster equipped with 144TB storage, 250kW UPS and generator.

The ABL is located in ENGR2-182 and has the facilities and space to carry out experiments with 400 sq ft currently dedicated to an LVAD benchtop flowloop, driven by a pulsatile Harvard Medical pump and a programmable Shelly Med. Im. Tech. PhysioPulse pump. The flowloop has an array of 3D printed aortic beds that can be interchange for experiments and is fitted with pressure sensors and rotary (turbine) flowmeters. The lab is acquiring 12 ultrasonic flowmeters to be utilized on the LVAD benchtop experiment. The CML has dedicated computers with digital acquisition boards (counter/timer and analog inputs/digital I/O boards), and Labview for data acquisition and manipulation. The lab also has some machining capabilities with a 3-axis CNC mill, Dremmel tools/drill press, and various standard tools required for laboratory experiments, and has access to the College of Engineering and Computer Science machine shop and 3D printing facilities. The lab has a rotating cone digital viscometer (LVDV-III ULTRA CP,115 VAC,50/60 HZ) from Brookfield Engineering Labs, Inc. as well as several Millar Mikro-Tip® research pressure catheters and DAQs for pressure measurements.

Biosystems Modeling Research Laboratory (BRL), ENG-1 Room 416: 640 sq. ft.). Director: Dr. Illegbusi. The BRL provides key facilities for physiological computational fluid and structural dynamics, and biosensor materials processing. Such facilities include 15 high-performance workstations, and several commercial CFD and FEM codes and grid generators including ADINA, CFD-ACE code, FLUENT, ANSYS STAR-CM, and PhysPro. It is also equipped with advanced image processing software including MIMICS, and 3-MATIC, as well as laboratory analysis software. BRL is also one of few laboratories in the USA selected to house NASA's highly classified IMACS machine-learning software. The laboratory personnel utilize and have access to several solid modeling codes such as Pro-E, IDEAS and AUTOCAD. Network access is also provided from the laboratory to a vast network of computing facilities within the University. The laboratory also has a physical (experimental) modeling component on biomedical systems including nanocomposite biosensors and bio-implant materials. This component of the laboratory is equipped with a variety of biomaterials processing and measurement systems including: Renishaw RM1000B Micro-Raman Spectrometer with Imaging CCD Detector and Ar-514nm Excitation Unit, CM 1710 Rapid High Temperature (1700°C) Furnace with Vertical Cycling Capability, Yamato Scientific America Inc, Vacuum Drying Ovens, Model DP43/63, Fisher Scientific, Isotemp Programmable

Muffle Furnace, 650-750 Series, ELENCO & PRECISION, Variable Regulated Power Supply, Model XP-581, Keithly 2700 Multimeter/Data Acquisition System plus Software, Optical microscopes, Chemical Spray pyrolysis facility BRL fosters inter-disciplinary research across disciplines of Engineering, Medicine, Physics, Computer Science, Materials Science, and Optics. It currently collaborates with Health and Public Affairs at UCF, Eye, Nose and Throat (Orlando), M.D. Anderson (Orlando), Florida Hospital, the UCF College of Medicine (Biomolecular Science), UCLA Department of Radiation Oncology (Los Angeles). It has been involved in collaborative research with the Harvard Medical School (Brigham and Women's Hospital, and Massachusetts General Hospital, Boston) and the University of Florida Cardiovascular Center, and the UCF College of Optics.

Biomedical Acoustic Research Lab (Engr. 1-room 248: 974 sq. ft.). Lab Director: Dr. Hansen Mansy. This lab specializes in translational research on developing new concepts and methodologies for patient monitoring and bedside diagnosis using low frequency vibration and acoustics. State of the art acoustic and vibration sensors including Laser vibrometry, and optimized contact sensors equipment currently available for this research includes: Laser system for non-contact measurement of surface velocity and vibration; system for calibrating electronic stethoscopes and accelerometers; modal analysis device for measuring the frequency response of dynamic systems; miniature microphones for measure acoustic fields in open space as well as confined ducts; stress-strain measurement system for small specimens; single beam ultrasound time-of-flight measurement system; 64-channel high speed data acquisition system with amplifiers for piezoelectric microphones; custom low-noise airflow source generation system; reflectometry system for determining areas of the airways; vibration isolation platform capable of handling objects up to 110 kg.

Multiscale Biomechanics Lab (MBL BSBS – room 463: 500 sq. ft.). Lab Director: Dr. Robert Steward. The Multiscale Biomechanics Lab located in the Burnett School of Biomedical Sciences (BSBS) Building on UCF's Health Sciences campus at Lake Nona. The main goal of his lab is to elucidate the physical mechanisms that drive biological processes and pathologies critical to human health. To this end he has focused his research efforts primarily on investigating the effects of mechanical forces on the endothelium. His research has implications in many areas within the cardiovascular field including atherosclerosis, thrombosis, and angiogenesis. Current equipment in Dr. Steward's lab includes a fully automated, Zeiss fluorescence microscope, chemical fume hood, two UV lamps for hydrogel preparation, two computer workstations, a Cannon network printer, 3 peristaltic flow pumps, and standard equipment used for cell culture including two CO2 incubators, a biological safety cabinet, cell observation microscope, benchtop centrifuge, and waterbath. Dr. Steward's lab also has access to shared resources within the BSBS building including a Perkin Elmer spinning disk live cell confocal microscope, two Zeiss 710 confocal microscopes, Perkin Elmer UltraVIEW confocal imaging system, BD FACSAria cell-sorter, BD FACSCanto II flow cytometer, two BD FACSCalibur flow cytometers, two Biorad Bio-Plex 200 with wash stations, BD FACSCanto II flow cytometry analyzer, BD FACS Aria cell sorter.

Interventional Robotics Lab (IRL, Eng. 1-room 324: 974 sq. ft.). Lab Director: Dr. Sang-Eun Song. Interventional Robotics Laboratory (<https://mae.ucf.edu/irl/>) focuses on clinical impact oriented surgical and healthcare innovations. Research area include robotic orthopedic surgery, image-guided intervention, advanced telemedicine, soft robotics for healthcare, and biomedical devices. The lab is equipped with mechatronics fabrication and testing facilities with medical devices and models. Major equipment includes 6-DOF robot arm integrated with force/torque sensor, optical tracking system for motion/location digitization, robotic digitizer, soft robotics toolkit, desktop 3D Printers for in-house rapid prototyping, surgical operating table, and various real-scale medical models. The lab has four power supplied workbenches, nine cubicle spaces, and a meeting space equipped with video conferencing.

Biomechanics, Rehabilitation, and Interdisciplinary Neuroscience (BRaIN Lab, University Tower, Suite 150B: 930 sq. ft.) Lab Director: Dr. Helen Huang. The BRaIN Lab research focuses on the brain dynamics and neuromechanics of human locomotion and locomotor adaptation. The lab also explores and develops new methods to expand electroencephalography (EEG) capabilities to study human movement. The goal is to develop gait and lower limb rehabilitation approaches based on brain dynamics and multimodal neuromechanics. The BRaIN Lab is ~930 sq. ft. and has two separate co-located rooms, with the larger room designated for data collection and a smaller room designated primarily as an office space for personnel and data processing. The BRaIN Lab is located on the ground floor of the building and is adjacent to the parking lot for easy access for

participants. The lab has a dual belt instrumented treadmill that can translate side-to-side and incline/decline in real-time (Motek Medical M-Gait with high performance mode and pitch/sway options). The treadmill's software, D-Flow, integrates and synchronizes with the motion capture system and electromyography (EMG) system. Users can write custom application programs to control the treadmill, change speeds and slopes in real-time. The lab has a passive motion capture system (9 cameras positioned overhead of the treadmill to record EEG electrode and head movements, 12 cameras positioned around the laboratory to record whole body dynamics, OptiTrack Prime13 and Prime13W). There is also a robotic recumbent stepper, which is a modified NuStep recumbent stepper that has force measuring handles and pedals and computer-controlled resistance. To study neural control, the lab has a 128-channel electroencephalography (EEG) system (BioSemi, ActiveTwo) with a 128-channel daisy chain option for recording simultaneous scalp EEG and motion artifact signals (i.e., dual-layer EEG), a 16-channel wireless EMG system with sensors that are also inertial measurement units (Delsys Trigno IM), and a Qubit Q-Track mobile indirect calorimetry (metabolic cost) system. Additionally, the lab has 2 3D scanners (EinScan Pro 3D Scanner PROPLUS, Occipital Structure sensor), a Pupil Labs Invisible eye tracker, a MakerBot Replicator+ 3D printer, and a Lockheed Martin FORTIS Industrial Exoskeleton. The lab has multiple workstations, iPads, Sony Digital Paper Tablets, and an 8-bay Network Attached Storage (NAS). The lab's software includes custom EEGLAB scripts, Matlab, Python, Affinity Designer vector graphics editor, and Paperpile reference manager.

NeuroMechanical Systems Lab (NMS Lab BSBS room 107B and 107D: 510 sq. ft.) Lab

Director: Dr. Qiushi Fu. The NMS lab is dedicated to human motor control research. The NMS Laboratory provides a setting for undergraduate, graduate, and postgraduate research on the interaction between human neuromuscular control, biomechanics, and mechatronic systems. The major research foci of the laboratory are control and cortical mechanisms of hand-object interaction, sensorimotor integration, psychophysics, as well as assistive technologies including virtual reality and robotics. Major equipment includes: 12-camera optical motion tracking system (OptiTrack Prime 13W) constructed for upper-body motion tracking. HTC VIVE virtual reality headset, two controllers, and three trackers. CyberGlove TM (Virtual Technologies) for measuring up to 17 joint angles of the hand. 16-channel wireless EMG systems for surface recording (Delsys Inc., Boston, MA). Two PhantomTM Premium 1.5 High Force haptic devices (SensAble Technologies). Four Nano-17 and two Nano-25 miniature force/torque sensor systems (ATI). BrainProduct 64 channel electroencephalography (EEG) recording system with active electrode compensation. Structure sensor for electrode position mapping, optimized for EEG source analysis. Gazepoint GP3 HD desktop eye tracking system. We have developed a collection of programs that combine virtual reality, robotics control, and motion/force data acquisition effectively for data collection and experimental task presentation via C++ and LabView programs. Additionally, we have developed customized MATLAB code to process kinematic, kinetic, and neuroimaging data.

Rehabilitation Engineering and Assistive device Lab (REAL, BSBS room 106: 909 sq. ft.) Lab

Director: Dr. Hwan Choi. The REAL studies the interplay between assistive devices and the human musculoskeletal system as well as developing optimal assistive devices. We are particularly interested in 1) the analyses of how different assistive designs and controls impact musculoskeletal systems to individuals with amputation and neurologically impaired, 2) developing an assistive device that can provide optimal tuning parameters for impaired individuals, and 3) developing machine learning algorithm which can provide optimal control to the assistive device. The research topics are highly interdisciplinary, which integrates human movement study, electromyography, robotics, and computational modeling (OpenSim and Finite Element Analysis). Major equipment includes: a 12-camera Vero22 digital motion analysis systems (Vicon, Oxford, UK), for collecting kinematic and analog data, three force platforms (AMTI, Watertown, MA), a Tandem instrumented treadmill (AMTI, Watertown, MA), a 16-channel wireless electromyography system (Delsys Inc., Boston, MA), an ultrasound system (Logicscan 128, Telemed, IT), and a fuse deposition type 3D printer (Raise3D, Irvine, CA).

Wearable Engineering and Assistive Robotics (WEAR lab, Research 1, 313: 1435 sq. ft.) Lab

Director: Dr. Joon-Hyuk Park. The WEAR lab (<http://mae.ucf.edu/joonpark/>) focuses on assistive technologies for disabled and aging populations. Research and development of new tools and techniques to enhance the effectiveness and utility of wearable assistive devices is the main effort pursued in this lab. The facility has an electrical workbench (soldering station, microscope, heatbed, testing devices) and mechanical workbench (bandsaw, lathe, milling machine, drill press, sander, 3D printer) for in house prototyping of a wearable device. Other equipment includes wearable sensors, full body motion capture system (myoMotion, Noraxon), 8-channel surface

electromyography (myoMuscle, Noraxon), foot plantar pressure sensors (Ultium, Noraxon; Loadsol, Novel) – as well as robotic platforms, force sensors and real-time controllers to implement and evaluate wearable assistive technologies while studying human-robot interactions, ergonomics, and user acceptance and adaptation.

Computational Biomechanics Lab (Eng 1, Room 339: 234 sq. ft.) Lab Director: Dr. Luigi Perotti. The Computational Biomechanics Lab focuses on understanding the mechanisms governing macro- and micro-scale biological systems using the tools of continuum and computational mechanics. In particular, we are interested in cardiac mechanics and electrophysiology, and in the assembly and maturation of viral capsids and the morphing/deployable structures they inspire. Heart failure (HF) is a leading cause of death worldwide, yet its underlying mechanisms are not well understood. This lack of understanding limits our ability to diagnose the onset of HF and to identify effective therapies. In this context, computational models are able to interpret patient specific data, expose the causal factors of different types of HF, and provide insights into interventional and pharmacological therapies. One of our main research areas focuses on combining voxel displacement information acquired via DENSE MRI and cardiac microstructure information based on DT-MRI to estimate aggregate cardiomyocyte (myofiber) strains based exclusively on in vivo data. As cardiomyocyte shortening drives cardiac contraction, myofiber strain is a promising biomarker to directly characterize cardiac function and dysfunction. Using the same computational tools, we investigate new bio-inspired structures, such as self-assembling and deployable thin shells, based on the maturation of viral capsids. Starting from a hexagonal template that is easily folded, these structures can be deployed in 3D and evolve to a final shape previously encoded in their flat templates. In order to support this effort, Dr. Perotti and his team have access to several high-end workstations, a Raid-6 Network-Attached Storage (NAS) system, and a 3D printer for quick prototyping and outreach activities. Key software is installed and maintained on these lab machines including Matlab, Python, Abaqus Finite Element Analysis software, the Medical Imaging Interaction Toolkit MITK; 3D Slicer image analysis and scientific visualization software; and ParaView open-source scientific visualization software.

Functional Materials and Devices Laboratory (FMDL, NSTC – room 437: 900 sq. ft.) Lab Director: Dr. Wen Shen. The equipment in the FMDL include a dynamic mechanical analyzer (DMA 850, TA Instruments, DE, USA), and a vibrating sample magnetometer (EZ7 VSM, MicroSense, MA, USA). The DMA 850 measures the dynamic mechanical properties of a wide range of sample stiffness over broad frequency, temperature and humidity ranges. The EZ7 VSM measures the magnetic properties of liquid, powder, solid, bulk and thin film samples. Major equipment to be acquired for in the FMDL lab will include an impedance analyzer and a vector network analyzer for characterizing wireless devices, a humidity and temperature stability chamber for fabrication of biological materials, and a high-power electrochemical system for thin film deposition.

Motion Analysis Laboratory (Eng 1, Room 267: 950 sq. ft.) Lab Director: Dr. Sudeshna Pal. The motion analysis laboratory has an approximate shared space of 900 square ft. The lab is equipped with a state-of-the-art eight-camera Vicon T10 motion capture system (Vicon Motion Systems Ltd., UK) that performs high speed infra-red (IR) based tracking and imaging. The system offers millimeter scale resolution of 3D spatial displacement and is capable of full-body 3D gait analysis on an approximately 6-meter walk-space. The T-10 system can also be configured to different work-space volumes for detailed 3D motion analysis of different body segments. Additionally, the lab has a six-axis biomechanics force platform (AMTI, Inc., MA, USA) designed for balance and ground reaction force studies in static postures and during dynamic gait analysis. The lab computers have the following biomechanics software available for motion analysis and modeling: Vicon Nexus, Visual 3D-C-Motion, OpenSim and MATLAB.

G. Describe additional specialized equipment that will be needed to implement and/or sustain the proposed program through Year 5. Include projected costs of additional equipment in Table 3-Appendix A.

None is noted. Much the required equipment has been acquired by investments from the MAE Department to foster the MSBME program and to prepare for the PhD in BME program. Consumables and miscellaneous lab supplies will be funded via our existing course lab fees. Any needed research equipment will be acquired by BME faculty through competitive grant proposal submissions to local and national funding agencies and BME industry (NSF-BET, NSF-BES, NIH NHLBI, NIH NIBIB, American Heart Association, Medtronics, Heartware, Johnson and Johnson,

etc...) aimed at acquiring BME laboratory equipment for research and development.

H. Describe any additional special categories of resources needed to implement the program through Year 5 (access to proprietary research facilities, specialized services, extended travel, etc.). Include projected costs of special resources in Table 3-Appendix A.

None required. The proposed PhD program in BME will have access to many research facilities and personnel at the COM's affiliated hospitals and clinics (such as those of Orlando Health and Advent Health). These personnel, many of whom are affiliated faculty members of the COM, may serve as guest lecturers in the core courses of the program, or mentors for student theses. An example of such facility is the Nicholson Center for Research and Simulation (associated with Advent Health). We have previously had access to an accredited large animal facility at Orlando Health. These hospitals house advanced imaging facilities such as catheterization/fluoroscopy, computed tomography, magnetic resonance imaging, and positron emission tomography.

There are numerous precedents for collaboration between UCF teachers and researchers, and the physician and allied staff of these hospitals and related healthcare facilities. The use of these facilities has most often occurred "at cost for research", or even gratis. For example, Dr. William DeCampi, MD, PhD who is Chief of Pediatric Thoracic Surgery and Director of the Heart Center at Orlando Health as well as Professor of Surgery at the UCF COM and Dr. T.Y. Hsia, MD, MSME, Senior Pediatric Thoracic Surgeon and as Professor of Surgery at the UCF COM both hold secondary joint appointments in the MAE Department and have active research grants from the American Heart Association and Additional Ventures. They closely collaborate with Professor Kassab and other faculty members in MAE and provide the bridge to the clinical aspects for our ongoing cardiovascular research projects.

Costs associated with the research in the graduate program are usually covered by grants and may include contributions from the hospitals' foundations. An example is the successful 12-year collaboration between the CECS Department of Mechanical Engineering, COM, and the Heart Center at Arnold Palmer Hospital for Children. Orlando Health has supported our BME research over the years by supporting graduate students and acquisition of research equipment and medical professionals have collaborated on joint proposals that have been critical in maintaining our BME research and graduate program. It is expected that this partnership will evolve and grow significantly with the advent of our PhD in BME program. We refer to the support letter written by Dr. William DeCampi.

No actual direct costs to the proposed PhD program in BME are expected. Given the history of creative collaboration among these institutions, that is, a combination of physician volunteerism and institutional foundation financial support that have enabled many of UCF's teaching enterprises, we expect this will be the case for the proposed program.

I. Describe fellowships, scholarships, and graduate assistantships to be allocated to the proposed program through Year 5. Include the projected costs in Table 3-Appendix A.

No formal commitment/allocation is made in terms of fellowships, scholarships, and graduate teaching assistantships to be allocated to the proposed program through Year 5. The MAE department has an allocation of Office of Research Fellowships for which our PhD in BME students will be eligible to apply. UCF also has competitive Presidential and Trustee Fellowships to which the Department nominates worthy candidates. The BME Engineering Program Director, Alain Kassab, will work in concert with the MAE Graduate Program Director to nominate such candidates.

However, if the program is approved, we will seek with the aid of our CECS Program Development Office (Ms. Robyn Knight, Director) and our PhD in BME Program Advisory Board to seek industry support for annually awarded 2-year Fellowships, and resources to be accessed include Orlando Health and Florida Hospital Health Systems, Nemours Hospital, the VA- Hospital and regional as well as state-wide bio medical engineering industry. Moreover, as noted above, our BME faculty is highly successful in grant proposal award from a variety of national and regional agencies. Our faculty hold NIH RO1 and K25 grants as well as NSF Career Awards and research grants from diverse sources such as the American Heart Association and charitable foundations such as Additional Ventures. The research portfolio of the faculty currently supports PhD students pursuing BME research in the MAE program and it is expected that the future success of grants submitted by our faculty will expand the number of students supported by the PhD in BME program.

Moreover, there are opportunities to support development of the education mission of the BME program through grant proposal opportunities such as the NIH R25 and T32 solicitations. Dr, Sudeshna Pal currently holds such an award supporting the delivery of a rehabilitation engineering immersive experiential at UCF. It is anticipated that future successful grant proposals will support MSBME students engaged by MSBME faculty in their sponsored research projects.

J. Describe currently available sites for internship and practicum experiences, if appropriate to the program. Describe plans to seek additional sites in Years 1 through 5.

Students in the PhD in BME program will be able to utilize multiple cities for internship and practicum experiences throughout Orlando including the UCF-College of Medicine, The Burnett School of Biomedical Sciences, VA Hospital, Nemours Hospital, and various hospitals part of the Orlando Health and Florida Hospital Health Systems. Moreover, there will be opportunities for PhD in BME students to be engaged in clinically relevant experiences at the UCF Lake Nona Medical Center, a partnership academic hospital between the College of Medicine and HCA Healthcare. This facility is located at 6700 Lake Nona Blvd., adjacent to the UCF College of Medicine in Orlando's Medical City, UCF Lake Nona Medical Center provides 24/7 emergency care and comprehensive inpatient and outpatient hospital services.



Although, these experiences are not built in the proposed curriculum, there exists the possibility of formalizing such experiences as summer electives in the future once the program is established and the need is identified from student requests, by the BME faculty, and/or by the Program Advisory Board members. Such experiences can receive formal recognition via the graduate internship special courses designation which is submitted by a student under the guidance of an academic mentor.

We also are working with the Faculty Coordinator at the UCF Office of Experiential Learning who works directly with CECS students in gaining internships and co-ops. Moreover, innovative enterprises such as Limbitless Solutions (<https://limbitless-solutions.org/>) a highly successful non-profit, founded at UCF by a MAE PhD student, engage PhD and MS in BME graduate students in internship and in practicum experiences.

Another such site is the GuideWell Innovation Center (<https://guidewellinnovation.com/>) at the Lake Nona Medical City that offer not only avenues for internship but also entrepreneurship and innovation through the Health Care spectrum. In addition, local industry such as Nanovation Partners LLC (<https://www.nanovationpartners.com/index.php/pages/our-team/>) whose president is Dan Justin (BSME and MSME graduate of MAE at UCF) is a nanotechnology organization specialized in the development, production and distribution of high purity nanotubes for the MedTech industry, has provided internship opportunities for our BME students

APPENDIX B

Please include the signature of the Equal Opportunity Officer and the Library Director.

 Signature of Equal Opportunity Officer Frank Allen	 Date
<small>Digitally signed by Frank Allen Date: 2021.07.28 09:21:44 -04'00'</small>	
Signature of Library Director	Date

This appendix was created to facilitate the collection of signatures in support of the proposal. Signatures in this section illustrate that the Equal Opportunity Officer has reviewed section II.E of the proposal and the Library Director has reviewed sections X.A and X.B.

APPENDIX A
TABLE 1-A
PROJECTED HEADCOUNT FROM POTENTIAL SOURCES
(Baccalaureate Degree Program)

Source of Students (Non-duplicated headcount in any given year)*	Year 1 HC	Year 1 FTE	Year 2 HC	Year 2 FTE	Year 3 HC	Year 3 FTE	Year 4 HC	Year 4 FTE	Year 5 HC	Year 5 FTE
Upper-level students who are transferring from other majors within the university**	0	0	0	0	0	0	0	0	0	0
Students who initially entered the university as FTIC students and who are progressing from the lower to the upper level***	0	0	0	0	0	0	0	0	0	0
Florida College System transfers to the upper level***	0	0	0	0	0	0	0	0	0	0
Transfers to the upper level from other Florida colleges and universities***	0	0	0	0	0	0	0	0	0	0
Transfers from out of state colleges and universities***	0	0	0	0	0	0	0	0	0	0
Other (Explain)***	0	0	0	0	0	0	0	0	0	0
Totals	0	0	0	0	0	0	0	0	0	0

* List projected annual headcount of students enrolled in the degree program. List projected yearly cumulative ENROLLMENTS instead of admissions.

** If numbers appear in this category, they should go DOWN in later years.

*** Do not include individuals counted in any PRIOR CATEGORY in a given COLUMN.

APPENDIX A
TABLE 1-B
PROJECTED HEADCOUNT FROM POTENTIAL SOURCES
(Graduate Degree Program)

Source of Students (Non-duplicated headcount in any given year)*	Year 1 HC	Year 1 FTE	Year 2 HC	Year 2 FTE	Year 3 HC	Year 3 FTE	Year 4 HC	Year 4 FTE	Year 5 HC	Year 5 FTE
Individuals drawn from agencies/industries in your service area (e.g., older returning students)	2	1.5	3	2.25	3	2.25	3	2.25	5	3.75
Students who transfer from other graduate programs within the university**	5	3.75	4	3	3	2.25	2	1.5	1	0.75
Individuals who have recently graduated from preceding degree programs at this university	1	0.75	2	1.5	3	2.25	4	3	5	3.75
Individuals who graduated from preceding degree programs at other Florida public universities	1	0.75	2	1.5	3	2.25	4	3	5	3.75
Individuals who graduated from preceding degree programs at non-public Florida institutions	1	0.75	2	1.5	3	2.25	4	3	5	3.75
Additional in-state residents***	0	0	0	0	0	0	0	0	0	0
Additional out-of-state residents***	0	0	1	0.75	0	0	1	0.75	1	0.75
Additional foreign residents***	1	0.75	2	1.5	3	2.25	4	3	5	3.75
Other (Explain)***	0	0	0	0	0	0	0	0	0	0
Totals	11	8.25	16	12	18	13.5	22	16.5	27	20.25

* List projected annual headcount of students enrolled in the degree program. List projected yearly cumulative ENROLLMENTS instead of admissions.

** If numbers appear in this category, they should go DOWN in later years.

*** Do not include individuals counted in any PRIOR category in a given COLUMN.

APPENDIX A

**Table 2
Anticipated Faculty Participation**

Faculty Code	Faculty Name or "New Hire" Highest Degree Held Academic Discipline or Specialty	Rank	Contract Status	Initial Date for Participation in Program	Mos. Contract Year 1	FTE Year 1	% Effort for Prg. Year 1	PY Year 1	Mos. Contract Year 5	FTE Year 5	% Effort for Prg. Year 5	PY Year 5
A	Alain Kassab, Ph.D. Mechanical Engineering	Professor	Tenured	Fall 2022	9	0.75	0.10	0.08	9	0.75	0.15	0.11
A	Olusegun Ilegbusi, Ph.D. Mechanical Engineering	Professor	Tenured	Fall 2022	9	0.75	0.10	0.08	9	0.75	0.10	0.08
A	Robert Steward, Ph.D. Mechanical Engineering	Assistant Professor	Tenure Earning	Fall 2022	9	0.75	0.20	0.15	9	0.75	0.20	0.15
A	Hansen Mansy, Ph.D. Mechanical Engineering	Associate Professor	Tenured	Fall 2022	9	0.75	0.05	0.04	9	0.75	0.05	0.04
A	Sang-Eun "Sam" Song, Ph.D. Mechanical Engineering	Associate Professor	Tenured	Fall 2022	9	0.75	0.10	0.08	9	0.75	0.10	0.08
A	Helen Huang, Ph.D. Biomedical Engineering	Assistant Professor	Tenure Earning	Fall 2022	9	0.75	0.20	0.15	9	0.75	0.20	0.15
A	Hwan Choi, Ph.D. Mechanical Engineering	Assistant Professor	Tenure Earning	Fall 2022	9	0.75	0.10	0.08	9	0.75	0.10	0.08
A	Luigi Perotti, Ph.D. Mechanical Engineering	Assistant Professor	Tenure Earning	Fall 2022	9	0.75	0.20	0.15	9	0.75	0.20	0.15
A	Wen Shen, Ph.D. Materials Engineering	Assistant Professor	Tenure Earning	Fall 2022	9	0.75	0.10	0.08	9	0.75	0.10	0.08
A	Sudeshna Pal, Ph.D. Biosystems Engineering	Associate Lecturer	Non Tenure	Fall 2022	9	0.75	0.05	0.04	9	0.75	0.05	0.04
A	Joon-Hyuk Park, Ph.D. Mechanical Engineering	Assistant Professor	Tenure Earning	Fall 2022	9	0.75	0.10	0.08	9	0.75	0.10	0.08
A	Qiushi Fu, Ph.D. Biomedical Engineering	Assistant Professor	Tenure Earning	Fall 2022	9	0.75	0.20	0.15	9	0.75	0.20	0.15
Total Person-Years (PY)							1.50	1.13			1.55	1.16

Faculty Code	Code Description	Source of Funding	PY Workload by Budget Classification	
			Year 1	Year 5
A	Existing faculty on a regular line	Current Education & General Revenue	1.13	1.16

APPENDIX A

Table 2

Anticipated Faculty Participation

B	New faculty to be hired on a vacant line	Current Education & General Revenue	0.00		0.00
C	New faculty to be hired on a new line	New Education & General Revenue	0.00		0.00
D	Existing faculty hired on contracts/grants	Contracts/Grants	0.00		0.00
E	New faculty to be hired on contracts/grants	Contracts/Grants	0.00		0.00
F	Existing faculty on endowed lines	Philanthropy & Endowments	0.00		0.00
G	New faculty on endowed lines	Philanthropy & Endowments	0.00		0.00
H	Existing or New Faculty teaching outside of regular/tenure-track line course load	Enterprise Auxiliary Funds	0.00		0.00
Overall Totals for			1.13		1.16

APPENDIX A
TABLE 3
PROJECTED COSTS AND FUNDING SOURCES

Budget Line Item	Reallocated Base* (E&G) Year 1	Enrollment Growth (E&G) Year 1	New Recurring (E&G) Year 1	New Non-Recurring (E&G) Year 1	Contracts & Grants (C&G) Year 1	Philanthropy/Endowments Year 1	Enterprise Auxiliary Funds Year 1	Subtotal Year 1	Continuing Base** (E&G) Year 5	New Enrollment Growth (E&G) Year 5	Other*** (E&G) Year 5	Contracts & Grants (C&G) Year 5	Philanthropy/Endowments Year 5	Enterprise Auxiliary Funds Year 5	Subtotal Year 5
Faculty Salaries and Benefits	\$ 130,013	0	0	0	0	0	0	\$130,013	\$ 154,262	0	0	0	0	0	\$154,262
A & P Salaries and Benefits	0	0	0	0	0	0	0	\$0	0	0	0	0	0	0	\$0
USPS Salaries and Benefits	0	0	0	0	0	0	0	\$0	0	0	0	0	0	0	\$0
Other Personal Services	0	0	0	0	0	0	0	\$0	0	0	0	0	0	0	\$0
Assistantships & Fellowships	0	0	0	0	\$ 200,000	0	0	\$200,000	0	0	0	\$ 472,727	0	0	\$472,727
Library	0	0	0	0	0	0	0	\$0	0	0	0	0	0	0	\$0
Expenses	0	0	0	0	0	0	0	\$0	0	0	0	0	0	0	\$0
Operating Capital Outlay	0	0	0	0	0	0	0	\$0	0	0	0	0	0	0	\$0
Special Categories	0	0	0	0	0	0	0	\$0	0	0	0	0	0	0	\$0
Total Costs	\$130,013	\$0	\$0	\$0	\$200,000	\$0	\$0	\$330,013	\$154,262	\$0	\$0	\$472,727	\$0	\$0	\$626,989

*Identify reallocation sources in Table 3.

**Includes recurring E&G funded costs ("reallocated base," "enrollment growth," and "new recurring") from Years 1-4 that continue into Year 5.

***Identify if non-recurring.

Faculty and Staff Summary

Total Positions	Year 1	Year 5
Faculty (person-years)	1.13	1.16
A & P (FTE)	0	0
USPS (FTE)	0	0

Calculated Cost per Student FTE

	Year 1	Year 5
Total E&G Funding	\$130,013	\$154,262
Annual Student FTE	8.25	20.25
E&G Cost per FTE	\$15,759	\$7,618

APPENDIX A
TABLE 3
PROJECTED COSTS AND FUNDING SOURCES

Table 2 Column Explanations

Reallocated Base* (E&G)	1	E&G funds that are already available in the university's budget and will be reallocated to support the new program. Please include these funds in the Table 3 – Anticipated reallocation of E&G funds and indicate their source.
Enrollment Growth (E&G)	2	Additional E&G funds allocated from the tuition and fees trust fund contingent on enrollment increases.
New Recurring (E&G)	3	Recurring funds appropriated by the Legislature to support implementation of the program.
New Non-Recurring (E&G)	4	Non-recurring funds appropriated by the Legislature to support implementation of the program. Please provide an explanation of the source of these funds in the budget section (section III. A.) of the proposal. These funds can include initial investments, such as infrastructure.
Contracts & Grants (C&G)	5	Contracts and grants funding available for the program.
Philanthropy Endowments	6	Funds provided through the foundation or other Direct Support Organizations (DSO) to support the program.
Enterprise Auxiliary Funds	7	Use this column for continuing education or market rate programs and provide a rationale in section III.B. in support of the selected tuition model.
Continuing Base** (E&G)	9	Includes the sum of columns 1, 2, and 3 over time.
New Enrollment Growth (E&G)	10	See explanation provided for column 2.
Other*** (E&G)	11	These are specific funds provided by the Legislature to support implementation of the program.
Contracts & Grants (C&G)	12	See explanation provided for column 5.
Philanthropy Endowments	13	See explanation provided for column 6.
Enterprise Auxiliary Funds	14	Use this column for continuing education or market rate programs and provide a rationale in section III.B. in support of the selected tuition model.

APPENDIX A

TABLE 4



ANTICIPATED REALLOCATION OF EDUCATION GENERAL FUNDS*

Program and/or E&G account from which current funds will be reallocated during Year 1	Base before reallocation	Amount to be reallocated	Base after reallocation
Department of Mechanical and Aerospace	\$ 8,086,988.00	\$ 130,012.99	\$ 7,956,975.01
	\$ -	\$ -	\$ -
	\$ -	\$ -	\$ -
	\$ -	\$ -	\$ -
	\$ -	\$ -	\$ -
	\$ -	\$ -	\$ -
	\$ -	\$ -	\$ -
	\$ -	\$ -	\$ -
Totals	\$ 8,086,988.00	\$ 130,012.99	\$ 7,956,975.01

* If not reallocating E&G funds, please submit a zeroed Table 4

APPENDIX B

Please include the signature of the Equal Opportunity Officer and the Library Director.

 _____ Signature of Equal Opportunity Officer	 _____ Date
Frank Allen _____ Signature of Library Director	Digitally signed by Frank Allen Date: 2021.07.28 09:21:44 -04'00' _____ Date

This appendix was created to facilitate the collection of signatures in support of the proposal. Signatures in this section illustrate that the Equal Opportunity Officer has reviewed section II.E of the proposal and the Library Director has reviewed sections X.A and X.B.

-

Library Evaluation of the Proposal to add a Biomedical Engineering PhD
in the
Mechanical & Aerospace Engineering Department at the University of Central Florida

Below is the Library Evaluation of the Proposal to add a Biomedical Engineering PhD in the Mechanical & Aerospace Engineering Department prepared by Terrie Sypolt and Buenaventura Basco who are Research and Information Services Librarians at the John Hitt Library at the University of Central Florida. The report was originally prepared October 1, 2019 and was updated and signed July 23, 2021.

Memo

To: Dr. Alain Kassab, Professor, Mechanical & Aerospace Engineering
Dr. Yoav Peles, Chair, Department of Mechanical and Aerospace Engineering
Dr. Michael Georgiopoulos, Dean, College of Engineering & Computer Science
Ms. Tina Buck, Interim Dept. Head, Acquisitions & Collections
Ms. Sara Duff, Acquisitions Librarian
Ms. Ying Zhang, Assoc. Director, Collection Services & Resource Management
Mr. Frank Allen, Interim Director of Libraries
Dr. Devon Jensen, Associate Dean, College of Graduate Studies
Ms. Emily Stettner, Assistant Director, Graduate Curriculum

From: Terrie Sypolt and Buenaventura Basco, Research and Information Services Librarians

Subject: Library Evaluation of the Proposal to add a Biomedical Engineering PhD., in the Mechanical & Aerospace Engineering Department

Date: October 1, 2019; Updated July 23, 2021

Peer Comparisons

When reviewing library support (databases, journal titles, and books) for the proposed Biomedical Engineering PhD, the faculty and I selected the following institutions for comparison:

- University of Florida Biomedical Engineering, PhD
- University of Pennsylvania, Bioengineering, PhD
- Texas A&M University, Biomedical Engineering, PhD
- Purdue University, Biomedical Engineering, PhD

Summary and Projected Costs for New Library Resources

The UCF Libraries' current journal and database holdings will meet the needs for the proposed PhD, and therefore no immediate subscription costs are requested (see full analysis below). The only databases we lack are EMBASE and Scopus that multiple peer institutions have. While EMBASE database would be

beneficial, it is not crucial to this program since much of the material is duplicated in Medline. A large percentage of unique material is drug-disease and drug-drug interactions which is not related to our proposed program and therefore not needed by UCF at this time. In the event any new key journal or database becomes critical for the PhD program in the future, additional recurring funding will need to be provided to the Libraries to add these resources. Also note that in the unfortunate event library budget shortfalls occur, some existing resource subscriptions may be cut or scaled back.

UCF's program is divided between Biomedical Sciences (Molecular Biology, Cancer, Immunity and pathogenesis, metabolic and cardiovascular, and neuroscience) and Biomedical Engineering (medical devices). UCF does need to purchase Cold Spring Harbor Protocols. EBSCO quoted a price of \$5,089.00 for the first year with a price increase of 5% each year thereafter. While this is a database needed, it is needed by Biomedical Sciences and NOT Biomedical Engineering. Therefore, we will not charge this to Biomedical Engineering.

Information about CSH Protocols:

- The online source of trusted techniques in molecular and cellular biology
- Contains new and classic protocols presented step-by-step with recipes and troubleshooting
- Frequently updated and annotated
- Interactive, customizable, and fully searchable

The development of *CSH Protocols* is a response to requests from scientists for authoritative information about techniques with a broad editorial scope, delivered through a state-of-the-art online interface. At this site, you will find methods from Molecular Cloning along with selected protocols from many of our best-selling manuals, such as *Cells* and *Antibodies*, as well as protocols from Cold Spring Harbor's renowned on-site courses. In addition, you will discover new cutting-edge protocols submitted by and commissioned from laboratories worldwide. A peer-reviewed online journal, *CSH Protocols* is updated monthly.

<https://www.cshpress.com/default.tpl?action=full&--eqskudatarq=727>

<http://cshprotocols.cshlp.org/>

Features include:

- Step-by-step, uniformly structured formats for ease of use and printing, with clearly linked materials, cautions, recipes, and troubleshooting
- Customizable, topic-based e-mail alerts for the latest updates in a particular field
- Personal folders for storing favorite protocols and searches
- Navigation tools including a specifically designed taxonomy for browsing and a variety of full-text search options
- A kit search tool for fast access to time-saving resources
- An online manuscript submission system for authors to contribute new protocols

Should the PhD program begin to develop medical devices and patent them, the program/Biomedical Engineering Department will need to purchase IEC Standards for the medical devices from the Techstreet Store. Since these standards will be housed in their lab, the department will need to purchase those, as needed. Library funds will not be used for these.

Book comparison with the peer institutions chosen shows that UCF compares favorably with them and has the books needed to support the PhD program in Biomedical Engineering. We set the foundation for the PhD program when we did the library evaluation for the Masters proposal, when we purchased books and an e-book database for the Masters program. Therefore, we do not need additional funds for books at this time.

Our Reference books compare favorably to the chosen peer institutions. We have made a \$445.15 one-time purchase for the **Encyclopedia of Medical Robotics 4v set 2018** from Amazon. “The Encyclopedia of Medical Robotics combines contributions in four distinct areas of Medical robotics, namely: Minimally Invasive Surgical Robotics, Micro and Nano Robotics in Medicine, Image-guided Surgical Procedures and Interventions, and Rehabilitation Robotics. The volume on Minimally Invasive Surgical Robotics focuses on robotic technologies geared towards challenges and opportunities in minimally invasive surgery and the research, design, implementation, and clinical use of minimally invasive robotic systems. The volume on Micro and Nano robotics in Medicine is dedicated to research activities in an area of emerging interdisciplinary technology that is raising new scientific challenges and promising revolutionary advancement in applications such as medicine and biology. The size and range of these systems are at or below the micrometer scale and comprise assemblies of micro and nanoscale components. The volume on Image-guided Surgical Procedures and Interventions focuses primarily on the use of image guidance during surgical procedures and the challenges posed by various imaging environments and how they related to the design and development of robotic systems as well as their clinical applications. This volume also has significant contributions from the clinical viewpoint on some of the challenges in the domain of image-guided interventions. Finally, the volume on Rehabilitation Robotics is dedicated to the state-of-the-art of an emerging interdisciplinary field where robotics, sensors, and feedback are used in novel ways to re-learn, improve, or restore functional movements in humans.” Biomedical Engineering has already transferred funds to cover the cost of this encyclopedia set.

Additional reference books that the department could purchase, if they want to do so, include a new edition of Encyclopedia of Medical Devices and Instrumentation (2006) for 2276.00 and Biomedical photonics handbook, v 1 Fundamentals, Devices & Techniques (2015) for \$59.96.

Projected costs needed to acquire library materials to support the new Biomedical Engineering PhD:

	2020-2021	2021-2022	2022-2023	2023-2024	2024-2025	2025-2026
Databases	0	0	0	0	0	0
Journals	0	0	0	0	0	0

Protocols	5,089.00*	5,343.00*	5,610.00*	5,890.50*	6,185.00*	6,494.00*
Books	0	0	0	0	0	0
Reference Books	0	0	0	0	0	0
IEC Industry Standards (selected as needed by Biomedical Engineering. Since these will be housed in the Biomed Engineering Lab they are not considered a library purchase. Biomedical Engineering will purchase as needed from their departmental funds**	0	0	0	0	0	0
Total	0.00	0.00	0.00	0.00	0.00	0.00

*While these protocols are needed, they are needed by the Biomedical Sciences PhD program and NOT the Biomedical Engineering PhD program and are therefore not charged to Biomedical Engineering.

**While the Biomedical Engineering PhD will need the IEC Industry standards for the medical devices they develop, these will be selected by the Biomedical Engineering faculty and housed in their lab so they will not be considered library materials and therefore the funds needed are not reflected in this request.

Additional standards, AAMI (Association for the Advancement of Medical Instrumentation) and BSOL Standards Online (British Standards Online) can be purchased by the department as needed.

Recurring Subscriptions Supporting the Biomedical Engineering PhD:

Databases

Database Name	UCF	U F	U Penn	Texas A&M	Purd ue
AccessMedicine	x	x	x	x	
arXiv (Physics) via SCIRUS http://arxiv.org/ free	x	x	x	x	x
ASM Medical Materials Database https://www.asminternational.org/home/-/journal_content/56/10192/15467873/DATABASE		x			
BioMed Central (Open Access Central)	x	x	x	x	x
Biomedical SCIENCEnet BASE					x
Biomedical Reference Collection (EBSCOhost) basic/comprehensive https://health.ebsco.com/products/biomedical-reference-collection-basic-edition		x		x	
BIOSIS Citation Index	x	x			x
BIOSIS Previews	x		x		x
BioTechnology & BioEngineering Abstracts (ProQuest)	x	x	x		
Biotechnology Research Abstracts (ProQuest)	x	x	x	x	x
Cochrane Library	x	x	x	x	x
Compendex (Engineering Index)	x	x	x	x	x
EMBASE		x	x	x	
Engineering & SciTech	x				
Google Scholar	x	x	x	x	x
IEEE Computing and Engineering Collection				x	
IEEE Xplore	x	x	x	x	x
INSPEC	x	x	x	x	x
JoVE (Journal of Visualized Experiments)	x	x	x	x	x
Materials Science & Engineering (SAGE)	x				
Materials Science & Engineering Database UCF has combination of Engineering Database, Materials Science Collection and Materials Research Database)	x				
Medical Device Databases https://www.fda.gov/MedicalDevices/DeviceRegulationandGuidance/Databases/default.htm	x	x	x	x	x
Materials Science & Engineering Database (ProQuest)	x		x		x
Medline (via PubMed/EBSCOhost)	x	x	x	x	x
ProQuest Dissertations and Theses Global	x	x	x	x	
PubMed	x	x	x	x	x
Science Direct (Including Elsevier Freedom Collection)	x	x		x	x
SCOPUS			x	x	x
SpringerLINK	x	x	x	x	
Web of Science (Web of Knowledge)	x	x	x	x	x
Academic Search Complete/Academic Search Premier	x	x	x	x	x
ACM Digital Library	x	x			x
Annual Reviews	x	x		x	x
Applied Science & Technology Source	x	x			x

Database Name	UCF	U F	U Penn	Texas A&M	Purd ue
ASTM Compass (formerly ASTM Standards & Engineering Digital Library)	x				x
BioMed Central open access https://www.biomedcentral.com/	x	x	x	x	x
BIOSIS Citation Index	x	x	Previe ws	Previe ws	x
ChemSpider http://www.chemspider.com/	x	x	x	x	x
CINAHL	x	x	x	x	x
Clinical Key	x		x	x	
Consumer Health Complete/Health Source: Consumer and Nursing ed	x	x	x		x
Data Citation Index	x			x	x
Derwent Innovations Index (Patents) Part of Web of Science	x		x	x	x
DynaMed Plus	x		x	x	
Engineering Materials Abstracts	x		x		
Gene (NCBI) https://www.ncbi.nlm.nih.gov/gene	x	x	x	x	x
Journal Citation Index (JCR)	x	x	x		x
Knovel: Engineering & Scientific Online References		x			x
MathSciNet	x	x	x	x	x
MedGen Portal (NCBI) https://www.ncbi.nlm.nih.gov/medgen/	x	x	x	x	x
Microedex			x		
NTIS (Free public access to a very small portion of the database)		x	x		
PEDro Physiotherapy Evidence Database	x	x	x	x	x
ProQuest Dissertations and Thesis Full-Text	x	x	x	x	x
ProQuest Materials Science Collection	x				
PsychiatryOnline	Me d sch ool only				
PsycINFO	x	x	x	x	x
PubChem https://pubchem.ncbi.nlm.nih.gov/	x	x	x	x	x
Reaxys (formerly Beilstein/Gmelin)		x	x	x	x
SciFinder	x	x	x	x	x
SciTech Premium Collection (ProQuest)	x				
SPIE Digital Library	x			x	x
SportDiscus	x	x			x
Springer Nature Experiments	x	x	x	x	x
Up to Date (Medical school only; others must go to that library for access)	Me d sch ool	x	Med schoo l	x	
Wiley Online Library	x				x
WorldCat	x	x	x	x	x

Database Name	UCF	U F	U Penn	Texas A&M	Purd ue
Zoological Record	197 8- 200 7	x		x	x

EMBASE Embase is a biomedical and pharmaceutical database containing bibliographic records with abstracts from Embase (1974-present) and MEDLINE (1966-present) deduplicated and searchable with Emtree. The following fields are covered: drug research, pharmacology, pharmaceuticals, toxicology, clinical and experimental human medicine, health policy and management, public health, occupational health, environmental health, drug dependence and abuse, psychiatry, forensic medicine, and biomedical engineering/instrumentation.

NTIS (National Technical Information Service) NTIS is the preeminent resource for accessing the latest US government sponsored research, and worldwide scientific, technical, engineering and business related information. **NTIS** is the central source for the sale of unclassified and publicly available information from research reports, journal articles, data files, computer programs and audiovisual products from Federal sources. Additionally, information is available from international government departments and other international organizations including those from Canada, Japan, the former Soviet Union, Western and Eastern European countries. Coverage: 1964-present.

Reaxys Synthesis planning with easily searchable chemistry data, literature and reactions; includes medicinal chemistry. It provides access to chemical property, structure, and reaction data from the Beilstein (organic chemistry), Gmelin (inorganic and organometallic chemistry), and Patent Chemistry databases.

The Beilstein database contains information on over 8 million compounds and more than 5 million chemical reactions. It provides comprehensive coverage of reactions, structures, and properties in organic chemistry; as well as references to the literature. For each compound, up to 350 chemical and physical data fields of critically evaluated data are available.

The Gmelin database contains information on over 1.4 million compounds, including: coordination compounds, alloys, solid solutions, glasses and ceramics, polymers, and minerals. It provides comprehensive coverage of structures and properties in inorganic and organometallic chemistry; references to the literature and information on reactions (over 900,000) are also included.

The Patent Chemistry database contains patents from 1975 and is included in Reaxys.

Database Analysis: Comparison shows that databases at UCF compares favorably with other institutions. We do not need to pick up an **institutional subscription to NTIS but must be prepared to departmentally purchase the items on a need basis from the NTIS store.**

While I thought we needed **Reaxys**, based upon the recommendation of a professor at UF, I have since changed my mind after talking with several other institutions. The following persons from John Hopkins

University: Susan M. Vazakas, Biomedical Engineering Librarian, Rob Wright, Medical Librarian, and Stephen Stich, Chemistry Librarian, talked with me as a group. Susan said that all the biomedical engineering faculty need for chemical reactions is SciFinder (Chem Abstracts) and Web of Science BIOSIS Citation Index (BIOSIS Previews), and the safety protocols in Springer Protocols and Cold Spring Harbor Protocols. They could also use the free protocols listed below. Rob White, Medical Librarian, said “I don’t have any experience with Reaxys, and only limited experience searching SciFinder for substances and literature.” He uses Web of Science and some of the free biomedical protocols listed below.

Kathleen Venit, BE Graduate Coordinator, University of Pennsylvania, Bioengineering, said that with their biomedical engineers it is a matter of preference for finding chemical reactions whether one uses Chem Abstracts or Reaxys. Either will contain the substances and reactions biomedical engineers would need in the lab or for projects.

Sara Park, Biomedical Engineering Librarian, Duke University said that Reaxys is not needed. The databases UCF has will suffice. She did suggest that, as the PhD program develops, the program may need to purchase IEC (International Electrotechnical Commission) Industry Standards for medical devices if the plan is to develop medical devices and patent them. They can be purchased from the Techstreet Store https://www.techstreet.com/publishers/iec?sid=goog&gclid=EAlaIqobChMIx_2pnNTT5QIVGYiGCh0d4AD2EAAYAiAAEgKOUvD_BwE.

UCF has both SciFinder and Web of Science and the free database PubChem as well as the main protocols in Springer Nature Experiments and several free protocols listed below. Cold Spring Harbor protocols is something we need to consider purchasing. The EBSCOhost platform has it available for \$5,089.00 annually. We do NOT need Reaxys for the proposed program

Many academic libraries are now dropping **SCOPUS** as other bibliometric methods are being developed and are freely available such as Taylor & Francis and Web of Science as well as inclusion of SCOPUS information in other databases such as Science Direct. Libraries also are dropping Knovel.

Biomedical Sciences need to pick up is Cold Spring Harbor Protocols NOT Biomedical Engineering. (See discussion above.) These protocols deal with molecular biology and topics covered in the Biomedical Sciences PhD. Safety standards for medical devices are covered in the IEC Standards. Should the PhD program begin to develop medical devices and patent them, the program/Biomedical Engineering Department will need to purchase IEC Standards for the medical devices from the Techstreet Store https://www.techstreet.com/publishers/iec?sid=goog&gclid=EAlaIqobChMIx_2pnNTT5QIVGYiGCh0d4AD2EAAYAiAAEgKOUvD_BwE.

Biomedical Engineering Protocols and Standards

	UCF	UF #33	U Pen #5	Tex as A&M #38	Purd ue #28
Springer Nature Experiments (Springer Protocols) Principle source	x	x	x	x	x
Cold Spring Harbor Protocols		x	x	x	x

	UCF	UF #33	U Penn #5	Texas A&M #38	Purdue #28
Bio-protocol (Stanford) free (Life science protocols)	x	x	x	x	x
Current Protocols (Wiley)		x		x	x
JoVE: Journal of Visualized Experiments	x	x	x	x	x
Nature Methods	x	x	x	x	x
BIOSIS Previews	x	x	x	x	x
Biological Procedures Online free (Techniques & methods in medical & biological sciences)	x	x	x	x	x
Protocol Online free (Links to protocols hosted by research labs, biotech companies, individual researchers protocols and websites)	x	x	x	x	x
ProtocolExchange open repository of detailed methodologies in experimental science	x	x	x	x	x
AAMI (Association for the Advancement of Medical Instrumentation) standards					
ASTM Compass (full-text standards, current and historical)	x	x	x	x	x
FDA 21 CFR Part 820 (Mandatory for medical device distribution in the US) https://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfcfr/CFRSearch.cfm?CFRPart=820	x	x	x	x	x
BSOL Standards Online (British Standards Online)					

Books (2000-2019) This comparison was not updated because UCF, UF, U Penn and Texas A&M all got new library catalogs very recently and the bugs have not been worked out of any of them. Given the numbers below and the eBook packages we have, UCF has the books it needs to support the Biomedical Engineering PhD.

Subject Heading	UCF	UF	U Penn	Texas A&M	Purdue
Biocompatible materials	117	86	89	84	130
	117	68	182	120	117
Bioinformatics	623	604	216	552	601
	2,809	1,309	1,161	528	114
Biological transport	57	58	62	46	68
	93	77	107	46	66
Biomechanics	147	92	183	105	442
Biomedical engineering	1,157	330	1,083	732	1,248
	4,168	2,040	15	1011	2,684
Biomedical engineering—Computer simulation	9	6	11	6	8
	12	9			10
Biomedical engineering—Mathematical models	5	9	5	5	4

Subject Heading	UCF	UF	U Penn	Texas A&M	Purdue
Biomedical Materials	272	284	385	294	300
Biomedicine	1,850	343	1,185	119	973
Biotechnology	651	642	1,184	726	1,089
Body Fluid Flow	7	5	12	8	11
Computational Biology	429	244	297	146	402
Computational neuroscience	83	70	95	58	70
Computer simulation	539	341	874	641	817
Continuum mechanics	151	134	207	148	140
Diagnostic imaging	176	188	398	141	392
Engineering—Statistical methods	105	59	94	78	79
Gene Therapy	130	83	176	29	144
Genetic Engineering	258	175	204	155	178
Genomics	278	292	31	199	202
Hemodynamics	24	27	30	21	16
Human mechanics	109	103	84	89	113
Medical instruments and apparatus	32	40	247	48	85
Medical Technology	60	60	239	55	92
Molecular biology	1,041	342	1,069	199	496
Nanotechnology	469	880	1,404	900	1,408
Rheology	164	198	39	46	190
Robotics	509	388	350	322	352
Robotics in medicine	30	35	13	27	23
Simulation and modeling	503	161	453	340	600
Surgical robots	19	22	18	7	6
Tissue engineering	241	218	206	93	278
Total	10,222	6,519	10,638	5,783	10,226
	1.0	.64	1.04	.57	1.0

E-Books

	UCF	U F	UPEN N	Texas A&M	Purdue
Access Engineering http://www.accessengineeringlibrary.com/subject/bio_engineering				x	
Access Medicine	x	x	x	x	x
Morgan & Claypool Synthesis Collection includes Biomedical Engineering, Biomaterials, Tissue Engineering, etc./Synthesis: The Digital Library of Engineering and Computer Science	x	x	x	x	x
Springer E-Books	x	x	x		x

	UCF	UF	UPEN N	Texas A& M	Purdu e
IEEE Wiley E-books	x	x	x	x	
Cambridge Biomedical Engineering Books	x	x	x		x
Clinical Key	x		x	x	
DynaMed Plus	x		x	x	
EBSCO eBooks	x	x	x	x	x
Genetics Home Reference (free) http://ghr.nlm.nih.gov/	x	x	x	x	x
Knovel		x	x	x	x
CRCnetBASE formerly ENGnetBASE	x	x		x	
National Academies Press https://www.nap.edu/	x	x	x	x	x
ProQuest Ebook Central	x	x		x	
Books24x7	x	x	x		
R2 Digital Library	Selectiv e med school	x			
Referex Engineering/ now part of Science Direct E-Books Engineering Village Selected individual titles.	x	x	x		x
Stat!Ref		x		x	
Taylor & Francis ebooks	x	x		x	
ChemNetBase		x		x	x
Oxford Scholarship Online	x	x	x		

Reference Books

	UCF	UF	U Penn	Texas A&M	Purdue
Acland's Atlas of Human Anatomy	dvd		x		
ASM Handbook	x	x			

	UCF	UF	U Penn	Texas A&M	Purdue
Comprehensive Biophysics (Elsevier)				x	
Encyclopedia of Biomaterials and Biomedical Engineering	x	x	x	x	x
Encyclopedia of Bioethics	x				
Encyclopedia of Bioprocess Technology					
Encyclopedia of Life Sciences (Wiley)			x	x	x
Encyclopedia of Medical Devices and Instrumentation	1988	--	2006	2006	2006
Encyclopedia of Medical Robotics	x		x		
Encyclopedia of Membrane Science and Technology (Wiley)		x	x	x	
Encyclopedia of Polymer Science and Technology (Wiley)	x	x	x	x	x
Encyclopedia of Science, Technology and Ethics	2002				
Encyclopedia of Toxicology (Elsevier)	x	x	x	x	x
Kirk-Othmer Encyclopedia of Chemical Technology (Wiley)	x	x	x	x	x
Biomaterials and bioengineering handbook	x				
The biomedical engineering handbook	x	x	x	x	x
Biomaterials and bioengineering handbook (2000)	x (print and online)	x	x	x	x
Biomedical engineering and design handbook I & II 250.00 set (2009)		x	x	x	x
Biomedical engineering handbook	2003	2000	1995	2003	2018
Biomedical photonics handbook, v 1 Fundamentals, Devices & Techniques 2d ed 2015	2003	2003	2015	2015	2015
Biomedical technology and devices handbook (2004)		x	x	x	
Handbook on advanced design and manufacturing technologies for biomedical devices	x	x	x	x	x
Materials for Medical Devices	x	x	x	x	x
PEEK Biomaterials Handbook		x		x	
Standard handbook of biomedical engineering and design	x	x	x	x	x
Ullmann's Encyclopedia of Industrial Chemistry	x	x	x	x	x
Wiley Encyclopedia of Biomedical Engineering			x		

Reference book analysis: UCF has the reference books needed to support the proposed PhD program. Additional reference books that the department could purchase, if they want to do so, include a new edition of Encyclopedia of Medical Devices and Instrumentation (2006) for 2276.00 but it is about time for a new edition. Biomedical photonics handbook, v 1 Fundamentals, Devices & Techniques (2015) for \$59.96

Journals (Comparisons made with UF, UPENN, and Purdue. Unable to compare with Texas A&M because of library block.

	UCF	UF	U Penn	Texas A&M	Purdue
ACS Biomaterial Science and Engineering	x	x	x		
ACS Synthetic Biology	x	x	x		
Acta Biomaterialia	x	x	x		x
Acta Biotechnologica	x	x	x		x
Acta of Bioengineering and Biomechanics		x			
Advanced Healthcare Materials	x	x	x		
Advances in Biomedical Engineering thru 1981	x	x	x		x
Advances in Biotechnical Processes		x			
American Journal of Physiology: Cell Physiology http://ajpcell.physiology.org/ open access may not be complete	x	x	x		x
American Journal of Physiology: Heart and Circulatory Physiology open access may not be complete	x	x	x		x
American Journal of Physiology: Lung Cellular and Molecular Physiology http://grweb.coalliance.org/oadl/oadl.html open access may not be complete	x	x	x		x
American Journal of Physiology: Regulatory, Integrative, and Comparative Physiology http://grweb.coalliance.org/oadl/oadl.html open access may not be complete	x	x	x		x
American Journal of Physiology: Renal Physiology	x	x	x		x
Analysis of Research Publications Supported by NIH and NEI HE20,3039:NEI 1970-1976		x	x		
Annual Review of Biomedical Engineering**	x	x	x		x
Annual Review of Neuroscience	x	x	x		x
Annals of Biomedical Engineering		x			
Applied Biochemistry and Biotechnology	x	x	x		x
Applied Bionics and Biomechanics			x		
Applied Mathematics and Computation	x	x	x		x
Applied Microbiology & Biotechnology	x	x	x	x	x
Applied Optics	x	x	x		x
Arteriosclerosis, Thrombosis, and Vascular Biology	x	x	x		x
ASME Journal of Biomechanical Engineering	x	x	x		x
ASME Journal of Biomedical Engineering	x	x	x		x
Bio-Medical Materials and Engineering	x	x	x		x
Bioautomation DOA Journals	x	x	x		x

	UCF	UF	U Penn	Texas A&M	Purdue
Bioconjugate Chemistry	x	x	x		x
Biocybernetics and Biomedical Engineering	x	x	x		x
Bioengineered Bugs (Open access)	x	x	x		x
Biofabrication	x	x	x		
Biomaterials	x	x	x		x
Biomaterials Science	x	x	x		x
Biomedical Business & Technology	x	x	x		x
Biomedical Engineering	x	x	x		x
Biomedical Engineering and Computational Biology	x	x	x		x
Biomedical Engineering Days, International	x	x	x		x
Biomedical Instrumentation & Technology	x	x	x		x
Biomedical Microdevices	x	x	x		x
Biomedical Sciences Instrumentation 100.00 ea volume 49 vols. Selective	x	x	x		x
Biomedical Signal Processing and Control	x	x	x		x
Biophysical Journal	x	x	x		x
Biorheology 950.00	1962-83	1962-99	1962-99		
Biosensors	x	x	x		x
Biosensors & bioelectronics	x	x	x		x
Biosurface and Biotribology**	x	x	x	x	
Biotechnology Advances	x	x	x		x
BMC Biomedical Engineering (open access)	x	x	x	x	x
Cardiovascular Engineering ceased in 2010		x	x		x
Cardiovascular Research	x	x	x		x
Cell Biochemistry and biophysics	x	x	x		x
Cell Motility and the cytoskeleton	x	x	x		x
Cells, Tissues, Organs	x	x	x		x
Chest http://journal.publications.chestnet.org/issues.aspx http://grweb.coalliance.org/oaddl/oaddl.html	x	x	x		x
Clinical biomechanics	x	x	x		x
Computer Methods in Biomechanics and Biomedical Engineering	x	x			x
Computers in biology and medicine	x	x	x		x
Continuum Mechanics and Thermodynamics**	x		x		
Current Opinion in Biotechnology	x	x			x
European Cells and Materials	x	x			
Frontiers in Bioengineering and Biotechnology	x				
Frontiers in Neuroengineering	x	x			x
Frontiers in Neuroinformatics	x	x	x		
Frontiers in Neurorobotics	x	x			x
Gait & Posture	x	x			x

	UCF	UF	U Penn	Texas A&M	Purdue
IEEE Engineering in Medicine and Biology Magazine: the Quarterly MagazineP*P*	x	x			
IEEE Pulse	x	x			x
IEEE Journal of Translational Engineering in Health and Medicine	x	x	x		x
IEEE Photonics Journal	x	x	x		x
IEEE Reviews in Biomedical Engineering*	x	x	x		x
IEEE Transactions on Bio-Medical Engineering*	x	x	x		x
IEEE Transactions on Bio-Medical Electronics*	x	x	x		x
IEEE Transactions on Biomedical Circuits and Systems	x	x	x		
IEEE Transactions on Medical Imaging	x	x	x		x
IET Synthetic Biology	x	x	x		x
International Journal of Computer Assisted Radiology and Surgery add to list	x	x	x		x
International Journal of Damage Mechanics**	x		x		
International Journal of Medical Robotics and Computer Assisted Surgery	x	x	x		x
International Journal of Numerical Methods in Biomedical Engineering needs in list	x	x	x		
International Journal of Medical Robotics and Computer Assisted Surgery**	x		x		
International Journal of Robust and Nonlinear Control	x	x	x		
Journal of Applied Biochemistry			1979-1985	1979-1985	1979-1985
Journal of Applied Biomaterials & Biomechanics**				x	x
Journal of Applied Biomechanics	x	x			x
Journal of Applied Physiology (open access. May not be complete)	x	x	x		x
Journal of Biochemical Technology	x	x			x
Journal of Bioenergetics and Biomembranes**	x		x		
Journal of Bioengineering (older journal-not current, 1976-78) Now Annuals of Biomedical Engineering					x
Journal of Biological Engineering	x	x	x		x
Journal of Biomaterials Applications*	x	x	x		
Journal of Biomaterials Science. Polymer edition**	x	x	x		
Journal of Biomechanical Engineering	x	x	x		x
Journal of Biomechanics	x	x	x		x
Journal of Biomedical Applications	x	x	x		x
Journal of Biomedical Materials Research A**	x	x	x		
Journal of Biomedical Materials Research B: Applied Biomaterials**	x	x	x		x

	UCF	UF	U Penn	Texas A&M	Purdue
Journal of Biomedical Optics	x		x		x
Journal of Biomedical Physics & Engineering	x	x	x		x
Journal of Bionic Engineering	x	x	x		x
Journal of Bioscience and Bioengineering	x		x		x
Journal of Biotechnology	x		x		x
Journal of Computer Aided Molecular Design**	x				
Journal of Developmental Biology and Tissue Engineering		x			
Journal of Fermentation and Bioengineering	x		x		x
Journal of Fluids and Structures	x		x		x
Journal of Materials Chemistry B: Materials for Biology and Medicine	x	x	x		
Journal of Materials Science/ Materials in Medicine	x		x		x
Journal of Mechanics in Medicine and Biology	X (1 year embargo)		x		
Journal of Medical Devices (ASME)	x	x	x		
Journal of Medical Engineering & Technology	X	x	x		x
Journal of Medical Engineering	x	x	x		
Journal of Medical Signals and Sensors	x	x	x		x
Journal of Nanobiotechnology	x		x		
Journal of Neural Engineering	x	x	x		x
Journal of Neuroengineering and Rehabilitation	x	x	x		x
Journal of Robotic Surgery**	x	x	x		
Journal of Sound and Vibration	x	x	x		x
Journal of the Acoustical Society of America	x	x	x		x
Journal of the American Medical Association	x	x	x		x
Journal of Thoracic and Cardiovascular Surgery	x	x	x		x
Journal of Tissue Engineering	x	x	x		
Journal of Tissue Engineering and Regenerative Medicine	x	x	x		
Journal of Vibration and Acoustics (ASME)	x	x	x		
Journal of Visualized Experiments	x	x	x		x
Lab on a Chip - Miniaturisation for Chemistry and Biology			x		x
Lancet	x	x	x		x
Medical & Biological Engineering & Computing	x	x	x		x
Medical Electronics & Biological Engineering until 1966. Now Medical & Biological Engineering & Computing	x	x	x		
Medical Engineering & Physics	x	x	x		x
Medical Image Analysis	x	x	x		x
Metabolic Engineering	x	x			x
Metabolic Engineering Communications	x	x	x		
Microcirculation**	x		x		

	UCF	UF	U Penn	Texas A&M	Purdue
Molecular Engineering	x	x	x		x
Nano Communication Networks	x	x	x		
Nanomedicine: Nanotechnology, Biology and Medicine	x	x	x		
Nanotechnology, Science and Applications	x	x	x		
Nanotoxicology	x	x			
Nano Today	x		x		
Nature Biomedical Engineering** (last yr not avail)	x		x		
Nature Biotechnology	x	x	x		x
Nature Nanotechnology	x		x		
Neural Systems and Rehabilitation Engineering	x	x	x		x
Open Biomedical Engineering Journal	x	x	x		x
Open Tissue Engineering and Regenerative Medicine Journal	x	x	x		
Osteoarthritis and Cartilage	x	x	x		x
Physics in Medicine and Biology	x	x	x		x
Physiological Measurement	x	x	x		x
Polymer Chemistry	x	x	x		
Proceedings of the Institution of Mechanical Engineers. Part H Journal of Engineering in Medicine	x	x	x		x
Progress in Biomaterials	x	x	x		x
RBM	x	x	x		x
Receptors & Channels**	x	x	x		
ReCIBE	x	x	x		
Regenerative Biomaterials**	x	x	x		x
Robotic Surgery. Research and Reviews **	x	x	x		x
Science	x	x	x		x
Science Translational Medicine http://stm.sciencemag.org/ Add to list	x	x	x		x
Skin Research and Technology	x	x	x		x
Soft Robotics**	x	x	x		
Technology and Health Care	x	x	x		x
Tissue Barriers**	x		x		
Tissue Engineering, Part A, B, and C	x	x	x		x
Traffic**	x		x		
Wiley interdisciplinary reviews. Nanomedicine and nanobiotechnology	x	x	x		

Journal cost analysis: Comparison of core journal titles provided by the department as well as a comparison of journal titles in the chosen institutions show that UCF has most of the needed currently published journals in biomedical engineering. While we do not have back files of some of the titles, Interlibrary loan can be used to acquire needed older journal articles.

Patents

	UCF	UF	U Penn	Texas A&M	Purdue
USPTO U S Patent and Trademark Office https://www.uspto.gov/patents-application-process/search-patents	x	x	x	x	x
Canadian Intellectual Property Office http://www.ic.gc.ca/opic-cipo/cpd/eng/introduction.html	x	x	x	x	x
Derwent Innovations Index (Web of Science)	x	x	x	x	x
European Patents (Espacenet) https://worldwide.espacenet.com/patent/search	x	x	x	x	x
Free Patents Online http://www.freepatentsonline.com/	x	x	x	x	x
Google Patents https://patents.google.com/	x	x	x	x	x
Lens (formerly Patent Lens) https://www.lens.org/lens/	x	x	x	x	x
PAT2PDF http://www.pat2pdf.org/	x	x	x	x	x
PatentScope	x	x	x	x	x
Reaxys		x	x	x	x
Reports of patent design and trade mark cases	x	x	x		x
SciFinder	x	x	x	x	x

Regulatory Agencies

Device Advice: Comprehensive Regulatory Assistance

<https://www.fda.gov/medical-devices/device-advice-comprehensive-regulatory-assistance>

Manufacturer and User Facility Device Experience (MAUDE) FDA

<https://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfMAUDE/search.CFM>

Medical Device Databases (FDA)

<https://www.fda.gov/medical-devices/device-advice-comprehensive-regulatory-assistance/medical-device-databases>

US Environmental Protection Agency: Laws & Regulations

<https://www.epa.gov/laws-regulations>

US FDA Guidance Documents (Medical Devices and Radiation-Emitting Products)

<https://www.fda.gov/medical-devices/device-advice-comprehensive-regulatory-assistance/guidance-documents-medical-devices-and-radiation-emitting-products>

Site:.gov Use to search regulations across agencies on Google

Statistics

CDC Wonder <https://wonder.cdc.gov/>

Health and Medical Care Archive

Appendix C –Data Showing Need for Program

In this Appendix are provided the data showing the need for an additional program. These data were utilized in the narrative of the program proposal. Also provided in this appendix are letters of support from the institution, from external sources, and from Florida institutions who have PhD in BME programs and provided support letters for our proposed program.

Data showing need for an additional program

1. Quotes from UF and FIU regarding the PhD in BME program pre-proposal reported by Dr. Paige Borden in her email to the CECS Dean Dr. Michael Georgiopoulos

“FIU and the FSU/FAMU engineering deans had no concerns and all agreed that additional, doctoral-trained Biomedical Engineers would be a positive.”

“UF – Also no concerns. UF has an excess of applicants and is only able to accept a fraction of their volume. There will definitely be applicant demand for any new program.”

From: Paige Borden
Sent: Thursday, October 5, 2017 11:37 AM
To: Michael Georgiopoulos <michaelg@ucf.edu>
Cc: John Weishampel <John.Weishampel@ucf.edu>; Gwen Ransom <gwen.ransom@ucf.edu>
Subject: Pre-proposal for PhD in Biomedical Engineering

Good morning Michael,

The Pre-Proposal for a PhD in Biomedical Engineering was discussed and approved for development by the statewide Council of Academic Vice President's - Academic Coordinating Committee.

Four universities did make comments that I wanted to pass back to you and your team as you continue this process.

1. FIU and the FSU/FAMU engineering deans had no concerns and all agreed that additional, doctoral-trained Biomedical Engineers would be a positive.
2. UF - Also no concerns. UF has an excess of applicants and is only able to accept a fraction of their volume. There will definitely be applicant demand for any new program.

I apologize for not providing this notification your associated chair or program director, but I wasn't able to read the signature block on the submission. I'd be grateful if you would manage those additional notifications.

Just a reminder that the CAVP review is only step one in the multi-phase approval process. I look forward to reviewing the full proposal, once your team has advanced to that stage.

Thanks, Paige

Dr. M. Paige Borden
Associate Provost, Academic Program Quality (APQ) and
Associate Vice President, Institutional Knowledge Management (IKM)
University of Central Florida

2. UCF Marketing Study carried out by Joshua Bedwell, Director of Marketing, UCF Market Study Report 5/23/2021

Program	No. Of Conferrals										No. Programs									
	Nationally					Florida					Nationally					Florida				
	Online	F2F	TOTAL	Online %	Changes in Time	Online	F2F	TOTAL	Online %	Changes in Time	Online	F2F	TOTAL	Online %	Changes in Time	Online	F2F	TOTAL	Online %	Changes in Time
Biomedical Engineering PhD	0	1128	1128	0.0%	24%	0	25	25	0.0%	14%	4	110	114	3.5%	3%	0	5	5	0.0%	0%

Avg. Tuition/Program Price			Occupational Demand				Degree-Specific Search Volume		Current OOS Mix for UCF F2F Program (Fall 2019)	
Nationally Source EMSI	Florida (24 Credit Hrs) Source FLBoG	UCF (24 Credit Hrs) Source student accounts	No. Jobs		Job Growth Projections		Nationally	Florida	OOS #'s	Mix
			Nationally	Florida	Nationally	Florida				
\$ 31,440	\$10,608	\$8,872	14,992	611	5.25%	13.92%	High	medium-low	N/A	N/A

Note: Data represented is accurate as of 2019. Change in time represents the change between 2015 and 2019. Source Burning-Glass.

Note: The numbers of applicants by program are listed for Fall 2019. The * denotes programs that are in progress to be considered available fully-online. The ** denotes the program will be launched in Fall 2020, and for this case Fall 2020 applicants thus far are shown. The *** denotes programs that have or will be proposed soon.

3. Growth of BME Industry in Florida – BioFlorida Database

[BioDatabase Industry Report .pdf \(ymaws.com\)](#)

BIOFLORIDA *Florida BioDatabase*

November 2019 Industry Report

INDUSTRY GROWTH

BioFlorida's Florida BioDatabase recently conducted its annual analysis of the biotechnology industry and the results show continued growth over the last year. The findings show:

- The number of companies in Florida's biotechnology industry grew 8.5% from 2018 through the first half of 2019 bringing the total number of biotechnology companies to 372 with the addition of 50 new companies.
- Florida's growth for 2018 is slightly greater than the nation's biotechnology sector which showed a growth rate of 7% over the same period according to Nature Biotechnology.
- Around 75% of Florida's biotech companies are involved in therapeutics, medical devices or diagnostics with 38% located in Southeast Florida, 22% in greater Tampa Bay, 20% in Gainesville, and 13% in Orlando-all remaining stable.
- Over the last decade, Florida's biotech companies have increased by 174%; whereas US biotech company growth over the past decade has been approximately 65%.

**The biotechnology companies tracked by the Florida BioDatabase are characterized by having a true research and development core that helps fuel the innovation of new products for Florida's growing life sciences industry.*

VENTURE FUNDING

Venture funding for 2018 was the best recorded year for Florida's life science industry-and 2019 may likely surpass it.

- Florida experienced an 85% growth in life science investments from 2017 as venture dollars for biotechnology and medical device rose to \$269.8M in 2018 with the average deal size at \$18M.
 - In the first 3 quarters of 2019, Florida venture funding for biotechnology and medical device was at \$216.9M--equaling 80% of venture funding for all of 2018.
- In 2018, there were 11 venture funding investments in the biotech sector, totaling \$192.9M, while the medical device segment saw 4 venture funding investments, totaling \$76.9M, for a total of 15 life science deals in 2018.
 - The industry has already seen 5 venture funding investments in the biotechnology sector in 2019, totaling \$165.6M, while the medical device segment has also seen 5 venture deals, totaling \$51.3M, for a total of 10 life science deals in 2019 YTD.
- Several noteworthy life science deals occurred this year in Florida including X-VAX Technology and TissueTech.
 - **X-VAX Technology** in Jupiter is focused on the discovery and development of herpes vaccines, received funding from J&J Innovation, Adjuvant Capital (Gates Foundation), Alexandria Venture Investments, Founders Fund and the Serum Institute of India in a \$56M deal in 2019.

- **TissueTech**, a biotechnology company based in Miami is developing innovative technologies using products derived from human amniotic and umbilical cord tissues announced \$82.4M in funding from EW Healthcare Partners in 2019.

ACQUISITIONS 2018-2019

A number of key life science company acquisitions took place in Florida during the past 2 years.

- **Mazor Robotics Orlando, FL** Focus: Guidance systems for robotic spine surgery. Acquired by Medtronic for \$1.7B (2018).
- **Agilis Biotherapeutics Tampa, FL** Focus: DNA therapeutics for rare genetic diseases. Acquired by PTC Therapeutics for \$200M with up to an additional \$750M based on milestones (2018).
- **Brammer Bio Alachua, FL** Focus: Viral vector manufacturing for gene and cell therapies. Acquired by Thermo Fisher for \$1.7B (2019).
- **Cytosen Orlando, FL** Focus: Cell-based cancer immunotherapy. Acquired by Kiadis with an upfront stock based and milestone deal valued at \$90M (2019).
- **Akron Biotechnology Boca Raton, FL** Focus: Akron is a leading materials manufacturer and services provider to the regenerative medicine industry, accelerating the development and commercialization of advanced therapies. Arcline Investment Management, a growth oriented private equity firm has acquired a majority interest in Akron Biotechnology (2019).

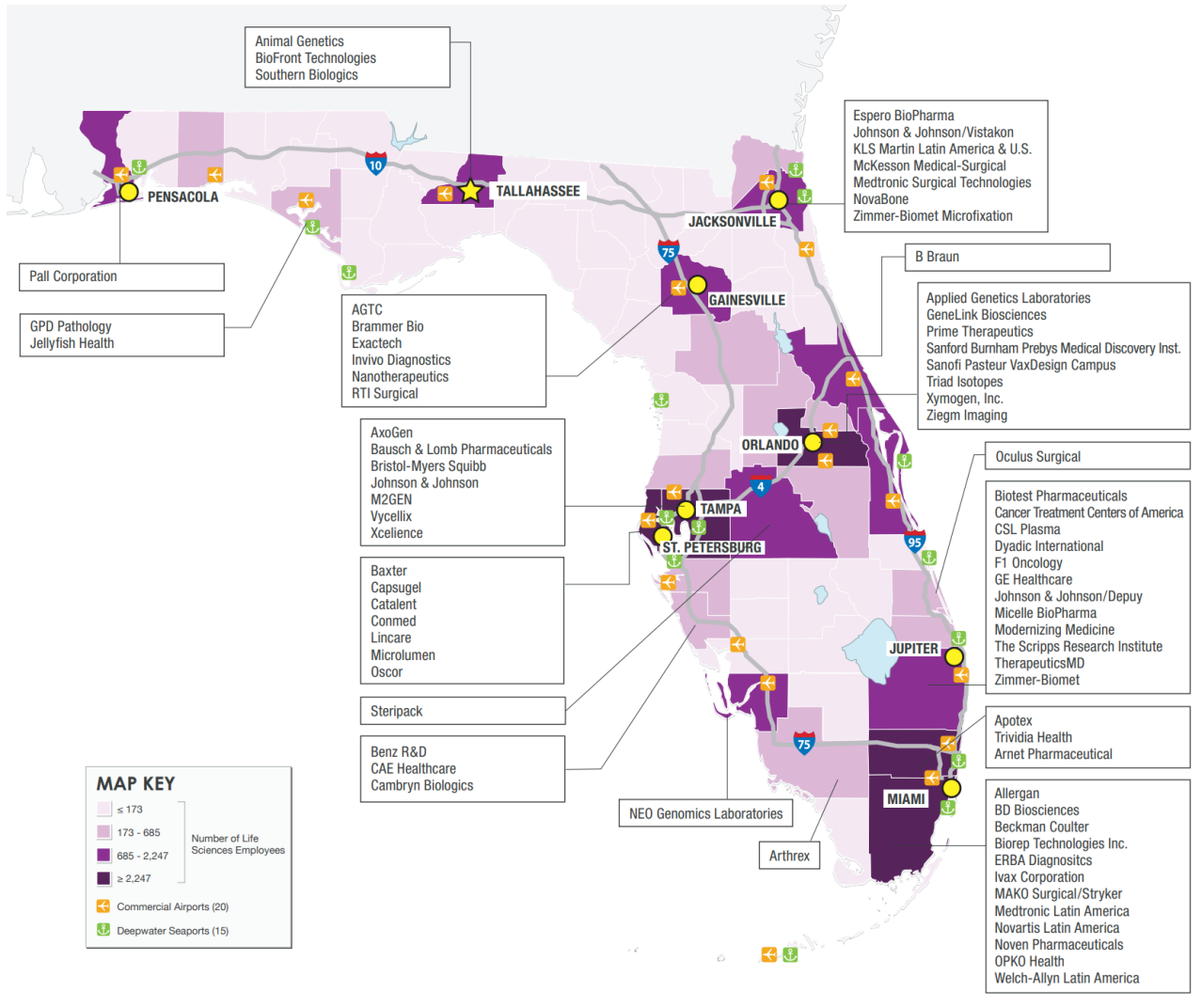
Visit the BioDatabase

Visit the [BioFlorida Florida BioDatabase](#) to access the latest information on Florida's bioscience industry, unique profiles of biopharmaceutical and biomedical technology companies, and the location of all [BioFlorida Florida BioDatabase](#) companies by [clicking here](#).

About the BioFlorida Florida BioDatabase

The BioFlorida Florida BioDatabase is a searchable resource which includes the latest information on Florida's bioscience industry and unique profiles of biopharmaceutical and biomedical technology companies. The location of all BioFlorida Florida BioDatabase companies are also shown on a distribution map. The BioDatabase follows the industry-held standard of defining a biotechnology company according to the Ernst & Young guidelines that include core R&D and involve the use of modern biological techniques to develop products or services for human health care, animal health care, agricultural productivity, food processing, renewable resources, industrial manufacturing and environmental management. The BioFlorida Florida BioDatabase does not include healthcare services companies, medical device companies without a biocomponent or biomed companies that are involved only in manufacturing and/or distribution of products.

4. Another such source showing the distribution of Bioengineering and Life Sciences companies and their specific locations in the state of Florida is provided from the Florida High Tech Corridor website (florida-life-sciences-companies-map.pdf (enterprise-florida.com))



5. National Need for BME from National Bureau of Labor Statistics
[Bioengineers and Biomedical Engineers \(bls.gov\)](https://www.bls.gov)

Occupational Employment and Wage Statistics



- BROWSE OEWS**
- OEWS HOME
- OEWS OVERVIEW ▶
- OEWS NEWS RELEASES
- OEWS DATA ▶
- OEWS CHARTS
- OEWS VIDEOS
- OEWS MAPS
- OEWS PUBLICATIONS ▶
- OEWS DATABASES
- OEWS FAQs
- CONTACT OEWS
- SEARCH OEWS**
-
- OEWS TOPICS**
- RESPONDENTS
- DOCUMENTATION
- SPECIAL NOTICES
- RELATED LINKS

Occupational Employment and Wages, May 2020

17-2031 Bioengineers and Biomedical Engineers

Apply knowledge of engineering, biology, chemistry, computer science, and biomechanical principles to the design, development, and evaluation of biological, agricultural, and health systems and products, such as artificial organs, prostheses, instrumentation, medical information systems, and health management and care delivery systems.

- [National estimates for Bioengineers and Biomedical Engineers](#)
- [Industry profile for Bioengineers and Biomedical Engineers](#)
- [Geographic profile for Bioengineers and Biomedical Engineers](#)

National estimates for Bioengineers and Biomedical Engineers: Top

Employment estimate and mean wage estimates for Bioengineers and Biomedical Engineers:

Employment (1)	Employment RSE (3)	Mean hourly wage	Mean annual wage (2)	Wage RSE (3)
18,660	4.9 %	\$ 47.28	\$ 98,340	1.1 %

Percentile wage estimates for Bioengineers and Biomedical Engineers:

Percentile	10%	25%	50% (Median)	75%	90%
Hourly Wage	\$ 27.21	\$ 34.54	\$ 44.53	\$ 57.18	\$ 71.85
Annual Wage (2)	\$ 56,590	\$ 71,830	\$ 92,620	\$ 118,930	\$ 149,440

Industries with the highest published employment and wages for Bioengineers and Biomedical Engineers are provided. For industries with employment in Bioengineers and Biomedical Engineers, see the [Create Customized Tables](#) function.

Industries with the highest levels of employment in Bioengineers and Biomedical Engineers:

Industry	Employment (1)	Percent of industry employment	Hourly mean wage	Annual mean wage (2)
Medical Equipment and Supplies Manufacturing	3,090	0.99	\$ 47.02	\$ 97,800
Scientific Research and Development Services	3,090	0.41	\$ 50.00	\$ 104,010
Pharmaceutical and Medicine Manufacturing	2,560	0.86	\$ 47.41	\$ 98,610
Navigational, Measuring, Electromedical, and Control Instruments Manufacturing	1,570	0.38	\$ 52.51	\$ 109,220
General Medical and Surgical Hospitals	1,170	0.02	\$ 39.38	\$ 81,910

Industries with the highest concentration of employment in Bioengineers and Biomedical Engineers:

Industry	Employment (1)	Percent of industry employment	Hourly mean wage	Annual mean wage (2)
Medical Equipment and Supplies Manufacturing	3,090	0.99	\$ 47.02	\$ 97,800
Pharmaceutical and Medicine Manufacturing	2,560	0.86	\$ 47.41	\$ 98,610
Scientific Research and Development Services	3,090	0.41	\$ 50.00	\$ 104,010
Electronic and Precision Equipment Repair and Maintenance	400	0.39	\$ 42.31	\$ 88,000
Navigational, Measuring, Electromedical, and Control Instruments Manufacturing	1,570	0.38	\$ 52.51	\$ 109,220

Top paying industries for Bioengineers and Biomedical Engineers:

Industry	Employment (1)	Percent of industry employment	Hourly mean wage	Annual mean wage (2)
Merchant Wholesalers, Nondurable Goods (4242 and 4246 only)	90	0.02	\$ 60.17	\$ 125,160
Management of Companies and Enterprises	760	0.03	\$ 53.53	\$ 111,340
Navigational, Measuring, Electromedical, and Control Instruments Manufacturing	1,570	0.38	\$ 52.51	\$ 109,220
Computer Systems Design and Related Services	250	0.01	\$ 52.43	\$ 109,060
Architectural, Engineering, and Related Services	820	0.05	\$ 50.47	\$ 104,980

Job Postings from Internet Search taken on 7/13/2021

Biomedical Engineer Jobs, Emplo x +

indeed.com/jobs?q=Biomedical%20Engineer&l=Orlando%2C%20FL&from=relatedQueries&saldx=1&rqf=1&parentQnorm=Biomedical&vjk=05b875ea6b29685

Working familiarity with all current accreditation standards such as TJC, DNV.
Today · More...

Biomechanical Engineer (Willing to Assist Relocation for the...

J.S. Held 2.7 ★
Orlando, FL 32817

Easily apply

- Minimum of 5 years of post-academic industry engineering experience.
- Manage engineering projects and project teams of **engineers**, scientists, and technicians.

11 days ago · More...

Product Development Engineer

AptarGroup 3.8 ★
Orlando, FL 32801 (Central Business District area)

- The Product Development **Engineer** is responsible for the design and development of non-invasive medical device mechanical and electro-mechanical systems.

30+ days ago · More...

Civil Design Engineer (Water Resources / Site Planning)

Kleinfelder, Inc. 3.4 ★
Mount Dora, FL

- Kleinfelder offers an excellent compensation and benefits

Biomechanical Engineer (Willing to Assist Relocation for the Right Candidate)

J.S. Held ★★★★★ 9 reviews
Orlando, FL 32817

Apply Now

Heart icon

QUALIFICATIONS FOR POSITION:

- Ph.D. in Biomechanical Engineering is required.
- Bachelor's or Master's degree in Mechanical Engineering is preferred.
- Minimum of 5 years of post-academic industry engineering experience.
- ACTAR certification or ability to obtain within 1 year.
- Foundation of testifying experience.
- Strong written and verbal communication skills. Experience in technical reports is preferred.
- Strong organizational skills and attitude to deliver results. Experience managing teams is preferred.
- Mathematically and technologically inclined with the ability to adapt to new environments or scenarios quickly.
- Skilled with software and technical systems.
- Willingness and ability to obtain additional licensure and certification.
- Ability to work remotely or while travelling to different job sites. (reliable cellular service, access to high-speed data, etc.)
- Must be able to travel to different regions in and outside of Florida. (have reliable transportation, etc.)
- Willingness and desire to work above and beyond the minimum performance and goal requirements.

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indeed.com/q-Johns-Hopkins-Biomedical-Engineering-jobs.html?vjk=6cd44b8643ad08c7

Postdoctoral scientists

The Johns Hopkins Institute For Fundamental...
Saint Petersburg, FL

\$45,000 - \$60,000 a year

Easily apply

- Types of tissues and organs that the lab is particularly interested in are mucosal tissue like intestine and lungs, liver, neuronal and adipose tissue as well...

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Johns Hopkins University 4.0 ★
Baltimore, MD 21231 (Fells Point area)

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- The laboratory of Dr. Mihaela Pertea seeks a Research Assistant to assist with analysis of large-scale genomic data analysis.

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Postdoctoral scientists

The Johns Hopkins Institute For Fundamental Biomedical Research
Saint Petersburg, FL

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Salary
\$45,000 - \$60,000 a year

Job Type
Full-time
Contract

Number of hires for this role
2

Full Job Description

The Trapecar Lab at the Johns Hopkins All Children's Hospital and Institute for Fundamental Biomedical Research in St. Petersburg, Florida, is looking to hire two postdoctoral scientists.

The focus of the group is the exploration of fundamental origins of immunometabolic diseases, such as IBD, metabolic syndrome and neurodegenerative disorders, by using exciting, multiorgan human-on-a-chip technologies and systems biology. To get a sense of the approach

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◦ . Ph.D. **Engineer** or scientist with a background in **biomedical** engineering, mechanical engineering, or respiratory or systems physiology.
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Kleinfelder, Inc. 3.4 ★
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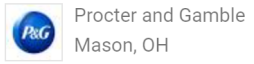
◦ Ph.D. Engineer or scientist with a background in biomedical engineering, mechanical engineering, or respiratory or systems physiology.
◦ Experience reviewing and synthesizing scientific information including journal articles, technical reports, research proposals, experimental protocols, and raw and compiled data files.
◦ (Highly Desired, but not required) Experience conducting human subject research.
◦ (Highly Desired, but not required) Experience and knowledge in diving and/or hyperbarics.
◦ (Highly Desired, but not required) Experience with C# .Net programming language.

Eligibility Requirements

- **Citizenship:** U.S. Citizen Only
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 - **Earth and Geosciences**
 - **Engineering**
 - **Environmental and Marine Sciences**
 - **Life Health and Medical Sciences**
 - **Mathematics and Statistics**
 - **Nanotechnology**
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PHD SCIENTIST/BIOENGINEER

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- design, implementation, and management of innovation plans for a broad range of conditions and various technologies.
- development of innovative ways in clinical design, testing methodologies, integration of connected devices or sensors
- data review, analysis and interpretation - working in close partnership with diverse project and marketing teams to deliver support for new claims, demos, visuals and insights on health-related quality of life and practices
- Clinical and Bioscience and platform application development for in-home data collection, co-developing cutting-edge clinical study models and measures, developing basic understanding to drive new insights and claims,
- working effectively with external clinical sites including global Universities and Contract Research Organizations (CROs).
- representing company and presenting scientific materials at professional meetings
- Global Travel will be required accordingly.

Appendix D – Consultant’s Report

Review of Proposed UCF PhD Program

Program: Biomedical Engineering
Reviewer: Ted Conway, PhD
Date: 6/24/2020

- Professor Conway is currently a Professor of Biomedical Engineering at Florida Tech and is a Fellow of the American Association for the Advancement of Science and an Elected Member of the College of Fellows in the American Institute for Medical and Biological Engineering. He was the Inaugural Head of the Biomedical and Chemical Engineering and Sciences Department (2017 – 2020) and the Inaugural Head of the Biomedical Engineering Department (2014 – 2017) at Florida Tech. Prior to returning to Florida he had a permanent appointment with the National Science Foundation (NSF) as the Program Director (2008 – 2014) for the: 1) General & Age Related Disabilities Engineering Program (GARDE); 2) CBET-National Robotics Initiative (NRI); 3) CBET-Broadening Participation Research Initiation Grant in Engineering Program (BRIGE); and 4) Science and Technology Center (STC): Emergent Behaviors of Integrated Cellular Systems (EBICS) in the Chemical, Bioengineering, Environmental and Transport Systems Engineering (CBET) Division of the Engineering Directorate.
- The creation of the PhD degree program at UCF will build on the successes of the MSBME degree program that is currently housed within the MAE Department. Collaboration with the UCF College of Medicine will further strengthen the program by providing resources that most other PhD BME programs at Universities across the country are not able to offer. Many of the required courses for the PhD program have already been approved for the MSBME program and are currently being offered. This minimizes the need for additional coursework resources that are often necessary to initiate a new graduate program.
- The structure of the proposed PhD degree program is similar to other PhD programs that are currently offered at UCF with the general structure of initial coursework requirements, Qualifying Exam and Dissertation Defense.
- The need for this new graduate degree program is well established and will further strengthen the partnerships between UCF and the medical industry by providing employment opportunities for graduates of the BME PhD program.
- Graduates of the new BME PhD Program will also be highly trained to seek competitive positions as post-doctoral researchers or academic faculty at research and teaching universities.
- The BME PhD program that is being proposed at UCF will complement the other BME PhD programs within the State of Florida and is aligned with many of the top Universities in other states that offer similar programs. The variety of

teaching and student mentoring modes (in-class presentation, virtual presentations, face-to-face and virtual student meetings, etc.) take advantage of 21st Century communication tools.

- It is well established that BME programs across the United States are the most diverse with respect to students' gender, ethnicity, disability status, etc. The proposed UCF BME PhD Program will leverage and build upon this diversity of students to create an inclusive environment that maximizes the opportunity to generate solutions to problems that currently exist in the Biomedical Engineering research community.

Summary

Overall, this is a well thought out graduate degree program. The UCF PhD Program in Biomedical Engineering will build on current resources in both the College of Engineering and Computer Science and the College of Medicine. This program is needed to fulfill the current and emerging research and teaching requirement for Universities and local, national and international industries. The proposed academic program is strong and will provide a strong research, educational and mentoring environment for students interested in pursuing an advanced degree in Biomedical Engineering.

Appendix E - Internal and External Letters of Support

Provided in this section are letters of support from within the University of Central Florida's College of Engineering and Computer Science from departments and the College Dean, from the College of Medicine and the College of Nursing Deans, the Founder and President of Limbitless, and from the State of Florida Institutions that have PhD in BME programs and who have submitted such letters.

UCF Institutional Letters from College of Engineering and Computer Science



UNIVERSITY OF CENTRAL FLORIDA

Department of Electrical and Computer Engineering

4328 Scorpius Street,
Orlando, Florida, 32816-2362

July 6, 2021

Dear Dr. Georgiopoulos:

I am currently the Interim Chair of the Department of Electrical and Computer Engineering at the University of Central Florida (UCF) and I am writing this letter to enthusiastically support the proposed PhD in Biomedical Engineering (BME) program. This program builds upon a currently existing Masters in BME program at UCF that, from my perspective has been quite successful, thus far. UCF is a premier research and academic institution, and we have the benefit of having a large and diverse student population, many of which have a strong interest in biomedical engineering.

I have reviewed the proposed curriculum and believe that this program will be of great benefit to UCF as well as Florida in general. Within my own department I have several faculty members who perform biomedical-related research. However, there is no formal biomedical doctoral program for our students to take, which I believe our students would benefit greatly from. Therefore, not only is there a need for a PhD in BME at UCF but such a program is in fact essential. Also, although the program will be based out of Mechanical and Aerospace Engineering, I foresee our department playing an active role in this program in the future when approved. In closing, I would like to once again state that I fully support this PhD in BME initiative, and I respectfully encourage its approval by the UCF BOT and SUS BOG.

Sincerely,

Murat Yuksel

Digitally signed by Murat Yuksel
DN: cn=Murat Yuksel, o=University of Central
Florida, ou=Electrical and Computer
Engineering, email=murat.yuksel@ucf.edu,
c=US
Date: 2021.07.06 14:29:40 -0400

Murat Yuksel
Professor and Interim Chair
Department of ECE

Phone: (407) 823-4181

Web: <https://www.ece.ucf.edu/> | UCF College of Engineering and Computer Science



UNIVERSITY OF CENTRAL FLORIDA

Department of Computer Science
4000 Central Florida Blvd.
Orlando, Florida, 32816-2362

April 7, 2020

Dear BME PhD committee:

As chair of the department of Computer of Science here at UCF, I wish to support the plans for a new PhD program in Biomedical Engineering (BME).

The department of Computer Science has been and will continue to offer two courses that will be included in the curriculum for the proposed BME Ph.D. program. Assuming we have the resources necessary, we will continue to offer the following courses:

- CAP 5510 - Bioinformatics
- CAP5516 - Medical Image Computing

Sincerely,

A handwritten signature in blue ink that reads "Gary T. Leavens".

Gary T. Leavens
Professor and Chair

Phone: +1(407)823-4758 • Fax: +1(407)823-1488 •
Web: <http://www.cs.ucf.edu/> | [UCF College of Engineering and Computer Science](#)



UNIVERSITY OF CENTRAL FLORIDA

Center for Research in Computer Vision
4328 Scorpius St.
Orlando, FL 32816-2365

June 21, 2021

Dear BME PhD committee:

As the director of the Center for Research in Computer Vision (CRCV) at UCF, I am writing this letter to provide my strong support to the proposed PhD program in Biomedical Engineering (BME).

I have reviewed the summary of the proposed BME PhD program. The curriculum consists of a solid foundation with seven core courses centered around engineering methods in biological systems, and a diverse list of elective courses. One of the electives is CAP5516: Medical Image Computing, which has been and will be continuously supported by faculty in CRCV. Overall, the curriculum is appropriate for the proposed program.

I believe the PhD in BME program is aligned with the strategic plan of the College of Engineering and Computer Science, and it will strengthen the biomedical engineering research at UCF and the central Florida region. I look forward to collaborating with the faculty of the proposed BME program in the area of biomedical image analysis.

Sincerely,

A handwritten signature in black ink that reads "Mubarak Shah".

Mubarak Shah
UCF Trustee Chair Professor



UNIVERSITY OF CENTRAL FLORIDA

Office of the Dean

College of Engineering and Computer Science (CECS)
4328 Scorpius Street
Orlando, FL 32816-2993

Thursday, June 24th, 2021

Dear members of the UCF Board of Trustees and members of the SUS Board of Governors:

I am writing this letter to provide my strong support of the Doctor of Philosophy (PhD) in Biomedical Engineering (PhD BME) program proposal. As a whole, the University of Central Florida has invested extensive resources (i.e., faculty hires, laboratory start-up packages, and facilities) towards the area Biomedical Engineering. To its credit, the College of Engineering and Computer Science has a number of vibrant BME related laboratories and is a lead partner in the Bionix Faculty Cluster Initiative and has been fully engaged in the and Bionformatics and Disability, Aging & Technology Faculty Clusters. Furthermore, other faculty that were not specifically hired with primary BME academic preparation also contribute to on-going BME research efforts at UCF. Research involvement in BME includes a number of topics such as: Bioinspired Engineering; Biomaterials and Biomanufacturing; Biomechanics, Neuroscience, Prosthetics and Rehabilitation; Biomedical Diagnostics and Devices; Cardiovascular and Biofluids; Cell Mechanics; Diabetes; Electrophysiology; Mechanical Properties of Tissues; Surgical Devices and Sensors; Virus Maturation and Assembly. Faculty involvement in this program includes three NSF CAREER Award winners, 2 ASME Fellows and a Fellow of AIBME. Our BME faculty are currently funded by the NIH, NSF, the American Heart Association and local hospitals.

The College of Engineering offers a number of academic programs for students who have an interest in BME. At the undergraduate level, the CECS offers a BME Minor and collaborates with the Burnett School of Biomedical Sciences in the Medical Engineering Dual Degree (MEDD) program. The Master of Science (MS) in Biomedical Engineering which was launched in Fall 2016 has four tracks: Biofluids track, Biomechanics track, the Accelerated BS-to-MS track, and the combined MD/MSMBE track. This academic program has grown in enrollment since its introduction in 2016. UCF's industry stakeholders (Advent Health, Orlando Health, Nemours, the Orlando VA, and many others) have a strong interest in the Biomedical Engineering talent pipeline.

The creation of a PhD program in Biomedical Engineering program is a step in the achieving our institutional goals for the growth of our BME teaching and research portfolios. The program will respond to the need expressed by our undergraduate and MS-level graduate students, who have an interest in Biomedical Engineering, to pursue a terminal degree in BME. It will be an opportunity for more students to contribute to the

Phone: 407.823.2156 • Web: cecs.ucf.edu | a division of the University of Central Florida

on-going BME research at UCF. It will create a pipeline of students for UCF's industry and government partners who are in need of graduates with advanced expertise in BME topics.

In summary, the PhD in Biomedical Engineering program will create a bigger and better graduate enterprise, will create a bigger and better research enterprise, will enhance partnerships with our stakeholders (industry and government) and will increase UCF's visibility nationally and internationally. All of the above are strategic goals for CECS and UCF. I applaud my colleagues' efforts in introducing this new degree program, wish them all the success and offer them the dean's office help to realize this endeavor.

Sincerely,

 Digitally signed by
michaelg
Date: 2021.08.20
17:48:31 -0400

Michael Georgiopoulos, PhD
ECE Professor and Dean CECS



UNIVERSITY OF CENTRAL FLORIDA

Vice President for Health Affairs

Dean, College of Medicine
Health Sciences Campus at Lake Nona
6850 Lake Nona Blvd.
Orlando, FL 32827-7408

June 29, 2021

Dear Members of the UCF Board of Trustees and Members of the SUS Board of Governors,

As the Dean of the College of Medicine, I am pleased to provide my strong support for the proposed Biomedical Engineering (BME) PhD Program. The addition of a BME PhD program is a natural and welcomed progression to support and amplify the increasing success and productivity of the UCF faculty members who conduct biomedical engineering research.

The College of Medicine is already committed and has invested in providing resources for the BME curriculum and research. As part of the Mechanics of Biostructures core BME courses, the College of Medicine provides prosection sessions of cadaver dissections for BME students to learn about the anatomy of the human body. The laboratories of several BME faculty members are in the College of Medicine. In just a few years, productive collaborations among College of Medicine faculty and BME faculty have been established resulting in innovations, publications, external funding, and industrial partnerships.

In reviewing the summary of the proposed BME PhD program, it is clear this BME PhD program will offer unique educational and research opportunities currently unavailable at other Florida universities. Top international, national, and regional students interested in BME related to biomechanics and biofluids will choose to come to UCF to gain unique educational and research experiences that will help prepare them to for successful careers in BME.

In conclusion, I fully support the proposed BME PhD program and anticipate that the BME PhD will help advance BME research at UCF, which will generate more innovations and discoveries in medicine and biomedical engineering.

Sincerely,

A handwritten signature in black ink that reads "Deborah C. German". The signature is written in a cursive, flowing style.

Deborah C. German, M.D.
Vice President for Health Affairs and Dean, College of Medicine



UNIVERSITY OF CENTRAL FLORIDA

College of Nursing | *Celebrating 40+ Years of Excellence*

Dean's Office

12201 Research Parkway, Suite 300
Orlando, FL 32826-2210

June 4, 2021

Dear Board of Trustees:

I am writing in support of the PhD in Biomedical Engineering (PhD in BME) program proposal. The University of Central Florida (UCF) is known for being innovative and rising to the needs of our student populations. I believe that this program is on the cutting edge, unique, and without question innovative. This advanced program will allow experts to continue providing outstanding research and healthcare support to communities in Florida, and throughout the nation.

The PhD in BME program at UCF will be housed in the Mechanical and Aerospace Engineering Department and will have research and teaching emphases in biofluids and biomechanics—very important areas in today's healthcare climate. The program builds upon Faculty cluster initiatives at UCF in the Bionix Cluster; Disability, Aging and Technology Cluster; and Genomics and Bioinformatics Cluster.

The proposed PhD in Biomedical Engineering promotes productive translational research collaborations with UCF's colleges within the Academic Health Sciences Center (Medicine, Nursing, and Health Professions and Sciences), with biomedical researchers throughout UCF and Central Florida.

As the dean of the UCF College of Nursing, I enthusiastically endorse the PhD in BME proposal. As a researcher who has needed BME expertise for prior and current studies, I acknowledge that this proposal will address an important gap at UCF. Thank you for your support!

Sincerely,

A handwritten signature in black ink that reads "Mary Lou Sole". The signature is written in a cursive, flowing style.

Mary Lou Sole, PhD, RN, CCNS, CNL, FAAN, FCCM
Dean and Orlando Health Endowed Chair in Nursing
Mary.sole@ucf.edu

External Letters from Florida Institutions with PhD in BME Programs: UCF, FIU and FSU/FAMU



Herbert Wertheim College of Engineering
J. Crayton Pruitt Family
Department of Biomedical Engineering
www.bme.ufl.edu

JG56 BMS Bldg.
PO Box 116131
Gainesville, FL 32611-6131
352.273.9222 Phone
352.273.9221 Fax

August 17, 2021

Michael Georgiopoulos, Ph.D.
Professor and Dean, College of Engineering and Computer Science
University of Central Florida
4000 Central Florida Boulevard
Orlando, FL 32816

Dear Dr. Georgiopoulos:

I serve as Chair of the J. Crayton Pruitt Family Department of Biomedical Engineering at the University of Florida (UF). I am writing this letter to express my support for the proposed Ph.D. in Biomedical Engineering (BME) program that will be housed in the Mechanical and Aerospace Engineering Department at the University of Central Florida (UCF). I have reviewed the proposed curriculum and program description that was provided to me.

The proposed curriculum and Ph.D. program structure are appropriate for a typical doctoral bioengineering program. There has been significant investment over the years at UCF in developing its health sciences programs, and a Ph.D. in BME is a natural and necessary addition in this effort. UCF has recruited a number of faculty members specializing in BME research and teaching and has importantly provided adequate resources for faculty success. The existing collaborations with the UCF College of Medicine, the Burnett School of Biomedical Sciences, and the large medical delivery systems in the Central Florida region are important components that will provide training and clinical access needed for the success of the proposed program.

The biomedical industry, which is growing at a rapid pace nationwide, is thriving as well in the state of Florida and relies heavily on a highly educated and trained workforce with advanced degrees. The Ph.D. in BME program at UCF will provide a valuable addition to the Florida SUS in serving these local and national needs.

I look forward to potential future collaboration between our two programs and institutions. I fully support the realization of a Ph.D. in BME program at UCF, and I respectfully encourage the UCF BOT and SUS BOG to approve such a program.

Sincerely,

A handwritten signature in black ink that reads 'Christine Schmidt' in a cursive script.

Christine E. Schmidt, Ph.D.
Pruitt Family Professor and Department Chair

July 5, 2021

Michael Georgiopoulos, PhD
Dean, College of Engineering and Computer Science
University of Central Florida
Orlando, FL

Ref: Biomedical Engineering doctoral program at UCF

Dear Dr. Georgiopoulos:

I am Professor and Chair of Biomedical Engineering at the Florida International University (FIU) and hold the Wallace H. Coulter Eminent Scholar Endowed Chair in Biomedical Engineering. I am writing this letter to provide my support for the proposed PhD in Biomedical Engineering (BME) program at University of Central Florida (UCF). I have reviewed the proposed curriculum and believe that this program will not only benefit UCF but Florida in general.

The proposed curriculum and the structure of the program, that will be housed in the Mechanical and Aerospace Engineering Department and will have research and teaching emphases in biofluids and biomechanics, is appropriate for doctoral bioengineering programs with a select focus. The existing collaborations of the engineering faculty at UCF with their College of Medicine and other medical delivery systems in the Central Florida region are also important and add value to this new program. UCF has significantly invested in terms of faculty and resources to enable the success of this program. The biomedical industry is growing nationwide and in the state of Florida and relies on a highly educated and trained workforce. The PhD in BME program will provide valuable addition to answering these needs.

Indeed, biomedical engineers with their rigorous cross-disciplinary training that spans engineering, basic biological sciences, and health and medical applications are very well positioned to be leaders as is evidenced by the recent appointment of a Biomedical Engineer as Head of the Engineering Directorate at the National Science Foundation. The program at UCF will add to the contributions of other successful Biomedical Engineering programs within the State, including ours at FIU, and help position Florida as a national leader. I look forward to potential collaboration between our two programs and institutions in the near future.

In closing, I fully support the creation of a PhD in BME at UCF, and I respectfully encourage its approval by the UCF BOT and SUS BOG.

Sincerely,



Ranu Jung, Ph.D., Fellow NAI, AIMBE, BMES
Wallace H. Coulter Eminent Scholar Endowed Chair in Biomedical Engineering
Professor and Chair of Biomedical Engineering



MEMORANDUM

To: Board of Governors, Florida - State University System

From: Professor Bruce R. Locke, Department Chair, Chemical and Biomedical Engineering

Date: June 17, 2021

RE: Support for the University of Central Florida PhD program in biomedical engineering

As chair of the Department of Chemical and Biomedical Engineering at the FAMU-FSU College of Engineering I am providing my strong support for the new PhD program in biomedical engineering (BME) at the University of Central Florida (UCF). The focus of this new program is in the biomechanical aspects of biomedical engineering. This can be contrasted with other programs in the SUS that focus more on cellular/biochemical or electrical (instrumentation) engineering topics in BME. While all programs will have some biomedical courses and research, the proposed curriculum has a deeper focus on the mechanics of biomedical systems through its development out of the Department of Mechanical and Aerospace Engineering at UCF. The other BME programs in the Florida university system do not have such focus on biomechanics in their doctoral programs and therefore, this program can provide a unique asset to the state through production of doctoral graduates with this expertise. Biomechanics is an important topic for the development of technologies for aging populations such as prostheses or prosthetic implants.

The curriculum proposed includes 72 credit hours consisting of 57 course credits and 15 dissertation credits. The courses include 7 core classes (21 credit hours) and the rest electives. The structure of the program is appropriate for doctoral engineering programs. The proposed collaborations with the UCF College of Medicine and other medical practices in Florida are also important and valuable parts to the new program.

Please feel free to contact me at locke@eng.famu.fsu.edu if I can provide further information.

Alexander N. Cartwright, PhD
Office of the President
P.O. Box 160002
Millican Hall, Room 308
University of Central Florida
Orlando, FL 32816-0002

4/13/2022

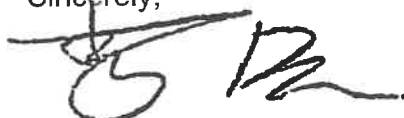
Dear Dr. Cartwright:

I am the President and CEO of Medicomp Inc. which is located in Melbourne, Florida. Since its inception in 1981, Medicomp has been at the forefront of the cardiac telemedicine industry as a developer, manufacturer, and service provider. We have serviced well over 1 million cardiac patients in our history using our proprietary medical devices. I have been an Industrial Advisory Board Member for the Department of Mechanical and Aerospace Engineering at the University of Central Florida since May 2020. I am writing this letter to express my support for the proposed PhD in Biomedical Engineering (BME) program which will be housed in the Mechanical and Aerospace Engineering Department at the University of Central Florida (UCF).

I am excited about the prospect of offering a PhD in BME at UCF. The biomedical industry is growing at a rapid pace nationwide, and this is also reflected in Florida. Using my company as an example, we regularly interact, and hire, biomedical engineers to help with the design and development of our cardiac monitoring devices. The success of the commercial enterprises in which the bioengineering industry engages is by its very nature at the forefront of developments in medicine and engineering and hinges critically upon a well-educated and highly trained interdisciplinary workforce with advanced MS and PhD degrees. I believe the PhD in BME program at UCF will be a valuable addition to the State of Florida by providing qualified graduates that can support the future workforce needs of the growing bioengineering industry at both the state and national levels.

I look forward to future fruitful collaboration with UCF and to interacting with BME research faculty and graduate students. I am excited at the prospect of the PhD in BME program within our own central Florida region. I respectfully encourage UCF and the State of Florida to approve this much needed program.

Sincerely,



Tony Balda, BS, MBA
President & CEO
Medicomp Inc.
600 Atlantis Road
Melbourne, FL 32904



Michael Georgiopoulos, PhD
Professor and Dean, College of Engineering and Computer Science
University of Central Florida
4000 Central Florida Boulevard
Orlando, FL 32816

4/18/2022

Dear Dr. Georgiopoulos:

I am writing you to provide my strong support for the proposed PhD in Biomedical Engineering program that has been approved by the UCF Board of Trustees and submitted to the Board of Governors of the State of University System of Florida for approval. We have been very encouraged to see the BME research and education grow over the years at UCF. The formal graduate training of BME students began with the inauguration of the MS in BME in 2017 and now is maturing with the prospect of the start of the PhD in BME program at UCF.

Biomedical Acoustics Research Company has been carrying cutting edge in bio-acoustics research and development in Orlando for over 8 years. We are part of a growing bioengineering and biotechnology industry in the Orlando metropolitan area and its vicinity. The BME industry is expanding at tremendous pace nationwide and Florida is increasingly attracting its share of such companies. The BME industry is highly interdisciplinary and relies upon a very highly educated workforce of well-trained engineers with PhD degrees. Biomedical industry hubs such as Boston and Minneapolis succeed because of the availability of a large pool of graduates in BME with advanced degrees, in particular PhDs to staff their research laboratories and lead the technological enterprises that are developing the future of this rapid-paced advanced industry.

It is critical for Florida and the central Florida to train and educate such a capable workforce in our own Orlando region enabling the realization of the vision of the Medical City at Lake Nona and the associated BME industries that are currently growing and thriving around three major medical entities: the UCF College of Medicine, the VA Hospital, and Nemours Children Hospital. The proposed PhD in BME at UCF is a valuable addition to bioengineering community in central Florida and state-wide. The PhD graduates from the PhD in BME program will supply the vital needs of the local industry.

I strongly endorse the PhD in BME program proposed by UCF, and I encourage the State of Florida to approve this critical program.

Sincerely,

Richard Sandler, MD
President

Alexander N. Cartwright, PhD
Office of the President
P.O. Box 160002
Millican Hall, Room 308
University of Central Florida
Orlando, FL 32816-0002

4/13/2022

Dear Dr. Cartwright:

I am the Program Manager for the Exoskeleton Technologies Program at Lockheed Martin Technologies Missiles and Fire Command in Orlando. Our program is at the forefront of assistive technologies development with our ONYX product designed for the military and first responder for applications, while our FORTIS product is designed for industrial applications.

ONYX® is a light weight, wearable robot that counteracts overstress on the lower back and legs. It provides additional leg strength which increases the user's endurance for climbing stairs, lifting heavy objects, squatting, crawling, and climbing over irregular terrain critical for field applications in military and first responder deployments. The FORTIS® exoskeleton transfers loads through the exoskeleton to the ground in standing or kneeling positions and allows operators to use heavy tools as if they were weightless. An advanced ergonomic design moves naturally with the body and adapts to different body types and heights. Using the FORTIS tool arm, operators can effortlessly hold heavy hand tools, increasing productivity by reducing muscle fatigue.

We have interacted over the years with research universities such as the University of Michigan and the University of Central Florida in collaborative research programs in biomechanics, kinesiology, and robotics. Clearly, our program is highly interdisciplinary and heavily reliant on a highly educated and specialized workforce with advanced MS and PhD degrees. We have collaborated with Dr. Helen Huang and her BRAIN lab in various aspects of our Exoskeleton Program.

We are very supportive of the proposal for a PhD in biomedical engineering at UCF. In our case, we are particularly interested in the growing biomechanics research group at UCF and the cadre of PhD students that they are training. The biomedical industry and biomedical related technology programs such as our exoskeleton program are growing at a very fast pace nationwide and in Florida for that matter. Our success and growth in industry in this highly technical area that blends various engineering and medicine rests on the availability of a well-educated workforce specifically trained in bioengineering who have earned at least MS degrees with preference to those who have earned PhD degrees. The proposed PhD in BME program at UCF answers such a need and is a welcomed addition to the State University System of Florida, and in particular, to the Orlando Metropolitan area.

Over the years, Lockheed Martin has been a large employer of UCF graduates at all levels BS through the PhD. I look forward to expanding our collaboration with UCF's

biomechanics program. I am very supportive of the prospective PhD in BME program within the Orlando metropolitan area. This program will be an asset to our Central Florida region, and I encourage the Board of Governors of the State of Florida to approve a PhD in BME program at UCF.

Sincerely,

A handwritten signature in black ink that reads "Keith Maxwell". The signature is written in a cursive, flowing style.

Keith Maxwell
Program Manager, Exoskeleton Technologies
Lockheed Martin Technologies, Missiles and Fire Command
5600 Sand Lake Road
Orlando, FL 32819

Alexander N. Cartwright, PhD
Office of the President
P.O. Box 160002
Millican Hall, Room 308
University of Central Florida
Orlando, FL 32816-0002

4/25/2022

Dear Dr. Cartwright:

My name is Aslam Raza and I am a Director at Johnson & Johnson Corporate Headquarters in New Brunswick, NJ. Our company was founded over 130 years ago and employs more than 145,000 employees across the world. J&J is the world's largest and most broadly based healthcare company that is committed to provide state of the art healthcare solutions and improve access and affordability to people worldwide. We accomplish this through science, innovation, and talented team members.

Our research and development portfolio spans over pharmaceuticals, medical devices, and consumer health. This includes health care delivery and new & advanced healthcare solutions. Our company interacts with biomedical engineering research labs and centers at many universities worldwide. We place high value on the availability of a large pool of graduates in biomedical engineering with advanced degrees, specifically PhD graduates and post-docs who bring much needed value to our research and development efforts.

At Johnson & Johnson across the world, we are engaged in discovery and development of new products and devices which requires highly educated, experienced, and innovated team members. Just in Florida, J&J has many medical device companies. This includes Vision which manufactures nearly 1.7 billion disposable contact lenses a year, Ethicon manufactures sutures & wound closure products, and DePuy Synthes manufactures spine & joint replacement devices.

At Johnson & Johnson, we engage biomedical engineers company-wide. Our industry, and the BME industry in general, relies on an educated workforce of well-trained engineers with advanced degrees. It is critical for the State of Florida to produce a pipeline of PhDs in BME to further attract and support the growth of the biomedical engineering industry in Florida.

The proposed PhD in BME program at the University of Central Florida supports the industrial enterprises at the Medical City in Lake Nona as well as the large health care system in the greater metropolitan Orlando area. The PhD in BME at UCF will be an invaluable asset to the bioengineering industry in central Florida and state-wide. The graduates from this PhD in BME program will fulfill the personnel needs of the local biomedical industry including J&J.

I am privileged to endorse the PhD in BME program for UCF. I encourage the State of Florida to approve this program and enable UCF to produce highly qualified bioengineers to meet the State of Florida's needs.

Sincerely,



Aslam Raza

Director, Finance Technology Solutions

Johnson & Johnson CORPORATE

10301 Deerwood Park East, Jacksonville, FL 32256 | USA

Cell: 904-294-7405 | Fax: 888-239-0403 | araza@its.jnj.com

Michael Georgiopoulos, PhD
Professor and Dean, College of Engineering and Computer Science
University of Central Florida
4000 Central Florida Boulevard
Orlando, FL 32816

4/18/2022

Dear Dr. Georgiopoulos:

I am writing this letter to express my strong support for the proposed PhD in Biomedical Engineering (BME) program that will be home-based in the Mechanical and Aerospace Engineering Department at the University of Central Florida (UCF).

I am President and Chief Technology Officer at .decimal, a company located in Sanford, Florida, that is a leading outsource manufacturer of patient-specific custom medical devices in the world. Our company provides patient-tailored treatment devices to the radiation oncology community worldwide with turnaround times of 24-48 hours on most products. To support the ordering and rapid manufacturing of these custom devices, we maintain a full staff of engineers and software developers. Our software and products are currently in use at over 600 cancer centers in the US, Japan, and Canada. Our products and services cover proton, electron, and photon therapies and are manufactured using a variety of techniques, including CNC milling & turning, 3D printing, and injection molding.

Over the years our company has interacted with members of the UCF College of Engineering in a variety of sponsored projects, and we have hired PhD and MS students who were carrying out BME research at UCF. As a matter of fact, I earned my own PhD in mechanical engineering at UCF under the mentorship of Professor Divo pursuing a project on machining of radiation therapy compensators sponsored by .decimal (a project which led to my hiring at the company). I currently serve actively on the MAE industrial advisory committee. My colleague Dr. Salvadore Gerace also earned his PhD at UCF with Dr. Kassab as mentor and through his position at .decimal directing R&D initiatives, he developed a product that was recently sold to a large radiation oncology company and he now holds a lead development position at that company.

Clearly, my industry and my own company's success relies upon talented and well-trained engineers with advanced degrees including PhD graduates in BME. We have seen BME research grow at UCF and the pace of research accelerate with the advent of the foundation of the College of Medicine over 15 years ago. We are excited with the growth of the formal graduate training of BME students with the launch of the MSBME in 2017 and now with the prospect of the start of the PhD in BME program at UCF.

The PhD in BME at UCF is a much needed and valuable addition to the growing bioengineering industry and community in central Florida and state-wide. I am confident that a PhD in BME program at UCF will produced qualified graduates that vitally support the regional, state, and national demands for a trained workforce of bioengineers with advanced degrees.

I look forward to growing and vibrant BME graduate programs at UCF, I strongly endorse the creation of the PhD in BME program in our own central Florida community, and I encourage the State of Florida to approve this critical program and I will continue to invest my own time in this endeavor through my involvement in the UCF MAE industrial advisor board.

Sincerely,



KEVIN ERHART, PH.D.

.decimal, LLC

President / Chief Technology Officer

407.330.3300 | kerhart@dotdecimal.com

April 29, 2022

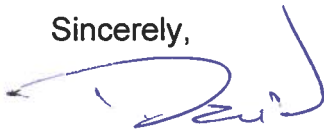
Alexander N. Cartwright, PhD
Office of the President
P.O. Box 160002
Millican Hall, Room 308
University of Central Florida
Orlando, FL 32816-0002

Dear Alex,

I hope you are well. I am writing this letter in support of the PhD in Biomedical Engineering (BME) program proposal that has been approved by the University of Central Florida's (UCF) Board and has been submitted to the Board of Governors of the State University System of Florida.

Orlando Health continues to be proud of its growing relationship with UCF and we are especially excited by the opportunity to develop an even stronger bridge between innovation in medicine and engineering. As you've personally experienced, combining medical expertise with the thought and skill of engineering minds yields significant value for patient outcomes. In our judgement, the addition of a BME PhD program will further that value.

Sincerely,



David Strong
President & CEO
Orlando Health, Inc.
1414 Kuhl Ave, MP 4
Orlando, FL 32806

CC: Dr. Bill DeCamp
Dr. Charles Price



MEMORANDUM

TO: Florida Office of Board of Governors
FROM: Tim Letzring, Vice Provost
CC: John Weishampel, Associate Dean, Graduate Studies
RE: Ph.D. Biomedical Engineering Proposal

Thank you for the follow up to our proposal for the Ph.D. in Biomedical Engineering. We have outlined the questions with a response under each.

- **Pursuant to Section VIII.A. of the proposal, please provide expected student learning outcomes associated with the proposed program.**
 - This is included in the narrative under section VIII.A. We realized the section was very compacted, so we have bulleted each of the student learning outcomes individually below.
 - There are three objectives and outcomes set out for the proposed Ph.D. in BME program.
 - Objective I: Career Preparation
 - The objective is to prepare graduates for successful employment as biomedical engineers, for further graduate study in engineering or science, and for medical school. Career opportunities include research, design, analysis, and testing and product development in the biomedical and rehabilitation industries, in clinical engineering, and in biomedical engineering. Also included is clinical practice as a physician.
 - Student Learning Outcomes:
 - Ph.D. in BME graduates will have a command of the application of engineering principles to biological and health systems.
 - Students will be able to conduct research in one or more of the following areas: Robotics/surgical intervention/biomedical devices, Biofluids, Biomechanics, Biomaterials, Rehabilitation/prosthetics/orthotics, bioacoustics, biosensing, medical imaging, instrumentation, bioelectronics, and electrophysiology.
 - Objective II: Skills
 - The objective is to engender in Ph.D. in BME graduates requisite skills enabling them to be immediately productive in the biomedical engineering profession.
 - Student Learning Outcome: Ph.D. in BME graduates will have
 - a command of modern biomedical engineering tools,
 - an understanding of relevant physiology and biology,
 - knowledge of contemporary topics in medical technology,
 - the ability to engage in advanced biomedical engineering industry and research enterprises including elements of research, analysis, design, and experimentation.
 - Objective III. Professionalism
 - The objective is to produce graduates who understand and are committed to fulfilling professional and public responsibilities.



- Student Learning Outcome: Ph.D. in BME graduates will:
 - have an appreciation of their special responsibility as biomedical engineers to promote safe, reliable, and effective medical technology.
 - have a strong commitment to ethical conduct.
 - understand how the rapid progress in medical technology imposes an obligation to engage in lifelong learning.
 - communicate effectively orally and in writing at an advanced engineering level with elements of research, analysis, design, and experimentation.

- Section VIII.B. of the proposal states that competitive scores on the Graduate Record Examination in the verbal, quantitative, and writing portions should be presented at the time of application. Please clarify the minimum score required for admission into the proposed program.
 - Since the program is competitive and each applicant is assessed holistically with the GRE being one of many factors used in the process, a minimum score is not set. However, based on the other Ph.D. programs in the College of Engineering and Computer Science, the average GRE score for admission is 310.


- Appendix A-Table 2 indicates the contract status for Dr. Sudeshna Pal as “non-tenure.” Please clarify if the contract is a multi-year contract or an annual contract.
 - Dr. Pal is an associate lecturer on an annual renewable contract. Dr. Pal has held this position since 2017.

- Please provide letters of support from local industry partners to support the demand for graduates at the doctoral level.
 - Letters of support from both internal and external stakeholders were all combined in one section in the proposal. Under a separate submission in the BOG portal, we combined and resubmitted just the letters from the following industry partners:
 - Limbitless
 - Orlando Health
 - AdventHealth
 - If the BOG is requesting additional letters of support from industry partners, please let us know.

April 13, 2022

MEMORANDUM

TO: Dr. Michael D. Johnson
Provost and Vice President for Academic Affairs
University of Central Florida

FROM: Dr. Christy England 
Vice Chancellor for Academic and Student Affairs

SUBJECT: Ph.D. in Biomedical Engineering, CIP 14.0501

The initial review of the Ph.D. in Biomedical Engineering has been completed. The following clarifications and revisions are required. Please note that a substantive delay in responding to these issues and/or failure to address the issues in the initial response adequately may result in a delay in the implementation of this program.

- Pursuant to Section VIII.A. of the proposal, please provide expected student learning outcomes associated with the proposed program.
- Section VIII.B. of the proposal states that competitive scores on the Graduate Record Examination in the verbal, quantitative, and writing portions should be presented at the time of application. Please clarify the minimum score required for admission into the proposed program.
- Appendix A-Table 2 indicates the contract status for Dr. Sudeshna Pal as “non-tenure.” Please clarify if the contract is a multi-year contract or an annual contract.
- Please provide letters of support from local industry partners to support the demand for graduates at the doctoral level.

Please submit your response to this memo no later than **May 4, 2022**. Should you have any questions, please contact Dr. Disraelly Cruz at (850) 245-9681 or Disraelly.Cruz@flbog.edu.

CE/bkg

c: Dr. Timothy Letzring
Dr. Disraelly Cruz
Mrs. Brittanian K. Gamble