STATE UNIVERSITY SYSTEM OF FLORIDA

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

Fall 2022
Proposed Implementation Term

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

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

Biomedical Engineering
Academic Specialty or Field

PhD in Biomedical Engineering
Complete Name of Degree

14.0501
Proposed CIP Code (2020 CIP)

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
Date Approved by the University Board of Trustees

Alexander Cartwright Digitally signed by Alexander Cartwright Date: 2021.11.05 14:36:27 -04'00'
President's Signature **Date**

Board of Trustees Chair'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 Masters 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 (Bioniix) 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) *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 Biiionix 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.

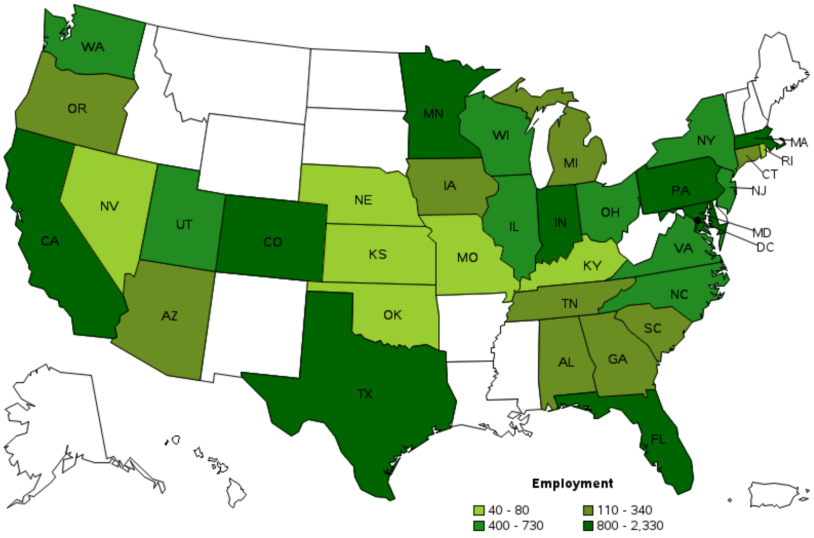
There is a strong demand for individuals with a PhD in BME and there are numerous positions available for well-trained individuals with such advanced training in Academia and industry nationwide. A search on LinkedIn from 7/21/2021 shows 200 current openings for biomedical engineers in Florida alone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

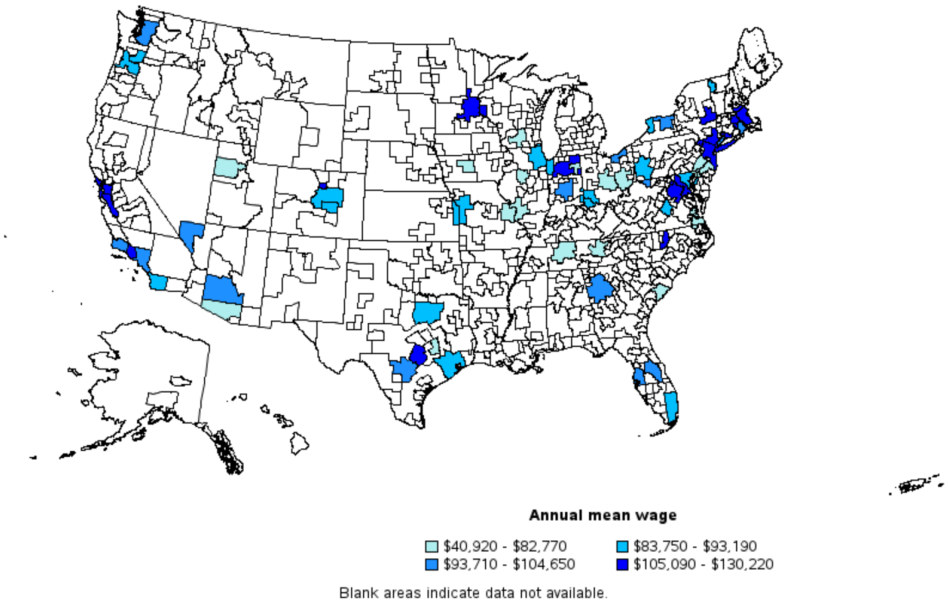
Employment of bioengineers and biomedical engineers, by state, May 2020



Blank areas indicate data not available.

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



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.

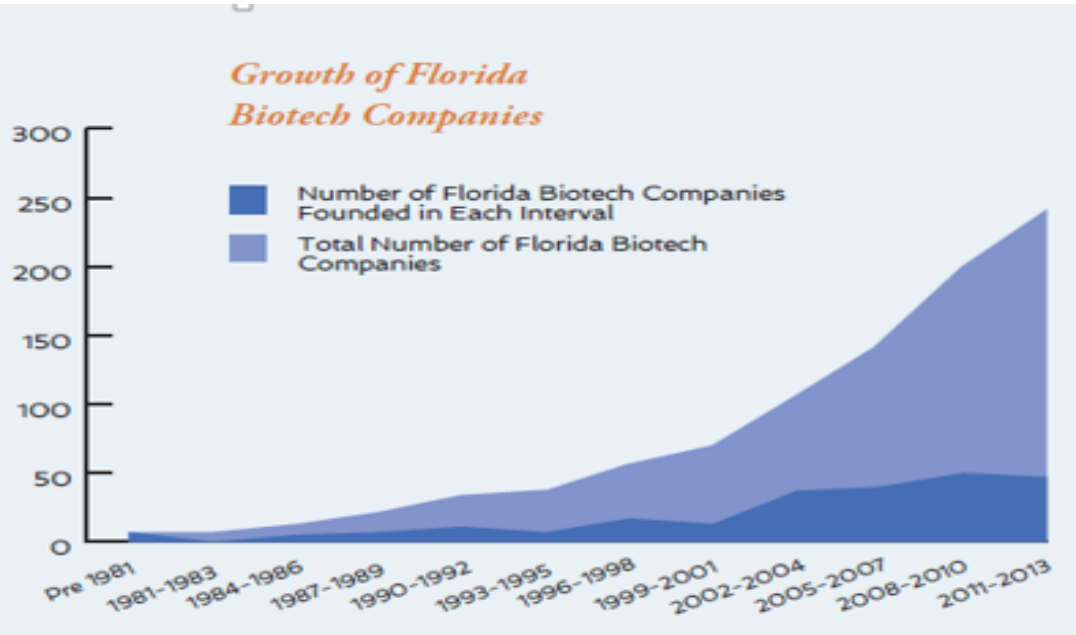
A representative, and by no means exhaustive, list of biomedical companies involved in research and development in Florida that employ biomedical engineers is provided below:

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 ahttp://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. Medtronics 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.biofloridabiodatabase.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 Biionix 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 Biionix 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)	**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. **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.

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.

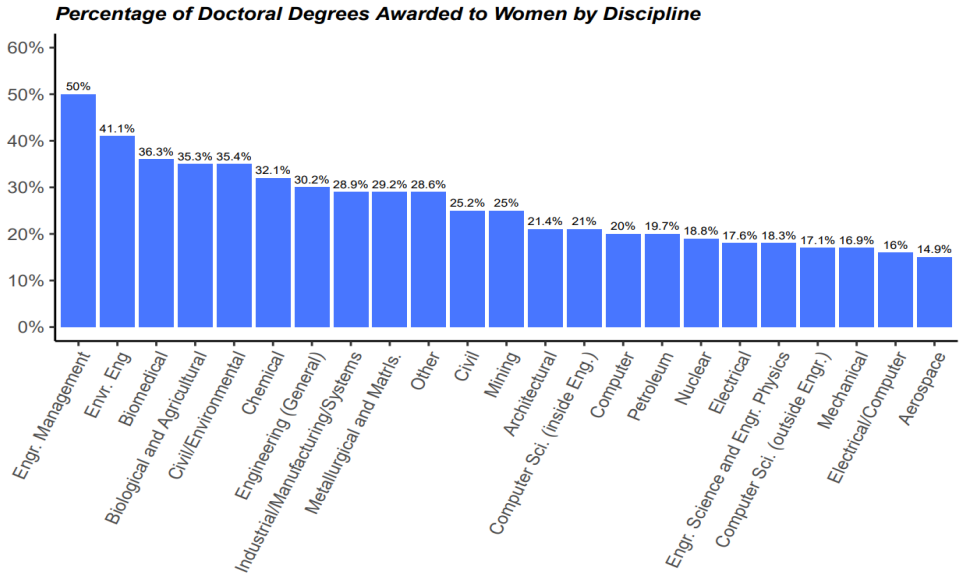
Referring to Table 1B in Appendix A, the projected student headcount (HC) for Year 1 is 11 generating 8.25 Full Time Equivalents (FTE) calculated as 24 credit hours per year for graduate students. We estimate the average FTE per graduate student to be 0.75 as these students will be in various stages 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.

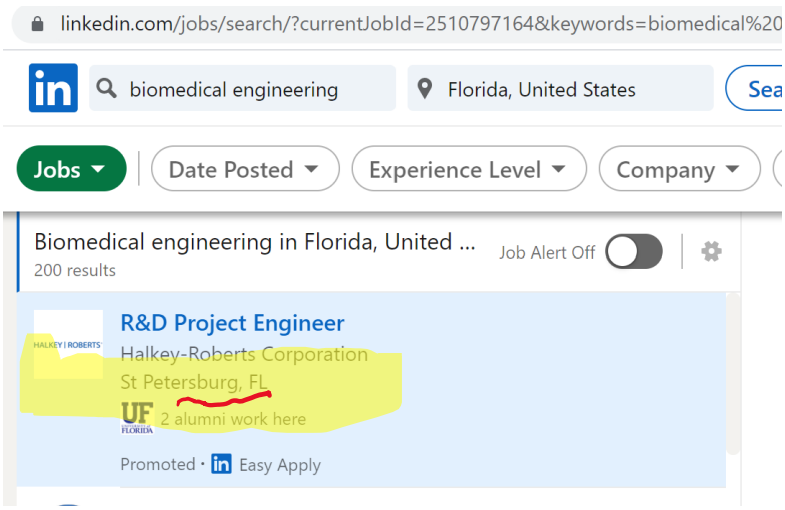
Finally, central Florida's major healthcare systems are potential sources of financial, facilities and human resources support for the proposed PhD program in BME. The healthcare systems (OrlandoHealth, Advent Health, and HCA) will be key in providing clinical facilities for the PhD research. Physicians 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 Dr. DeCampli's support letter.

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 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 DeCampli 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. DeCampli 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. DeCampli 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 increases 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. DeCampli 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 DeCampli (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. DeCampli 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, 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.

Outcome: PhD in BME graduates will have a command of the application of engineering principles to biological and health systems and will receive research and technical training 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 PhD in BME graduates requisite skills enabling them to be immediately productive in the biomedical engineering profession.

Outcome: PhD in BME graduates will have a command of modern biomedical engineering tools, an understanding of relevant physiology and biology, a knowledge of contemporary topics in medical technology, and an 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.

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

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. 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 elctro-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 CI. 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 DeCampli, 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 DeCampli, 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 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 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, Post–doc, 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. * *Biionix 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. * *Biionix 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 bio-sensors. 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 tenured-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).

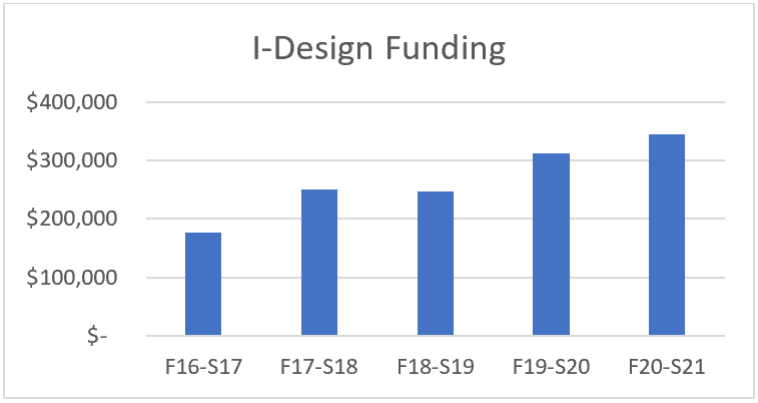
The NIH style 5-page CV's of the twelve BME faculty in MAE are provide in Appendix E. These faculty members are listed in section A of the Faculty Participation section of the PhD in BME program proposal.

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.

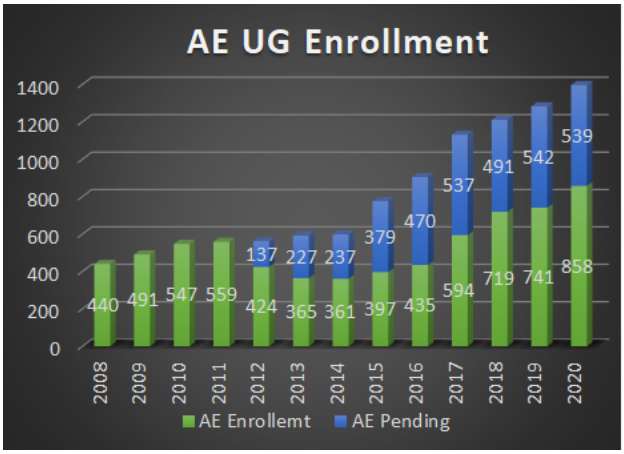
The department offers a BS, MS and PhD in Mechanical Engineering and a BS, MS and PhD in Aerospace Engineering and recently launched the MS in BME in Fall 2017. In Fall 2020, the MAE faculty educated a student body of 4,381 comprised of 3,980 ME and AE undergraduates and 401 MS and PhD students.

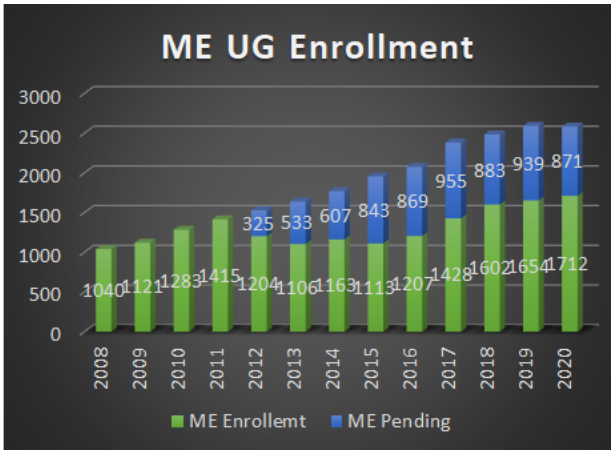
The department has developed an innovative and highly successful heavily subscribed large 2 semester senior design program (over 1,000 students/year) under the guidance and Dr. Mark Steiner and Dr. Kurt Stresau who have secured recurring local industry support (I-Design) for the program that tripled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



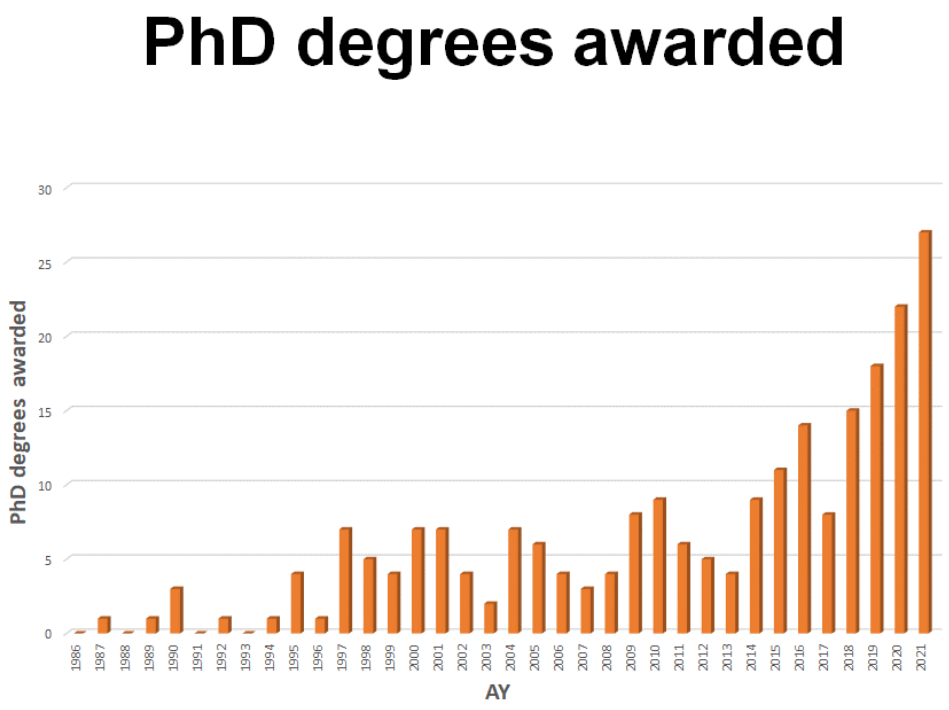


(2) **Graduate student head count (GSHC)** has also steadily increased over the years. Remarkably, the graduate student count has more than doubled from 170 (118 MS and 52 PhD) in AY 2010-2011 to 401 (254 MS and 147 PhD) in Fall 2020. In AY 2019-2020 the MAE faculty graduated 114 graduate students (the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

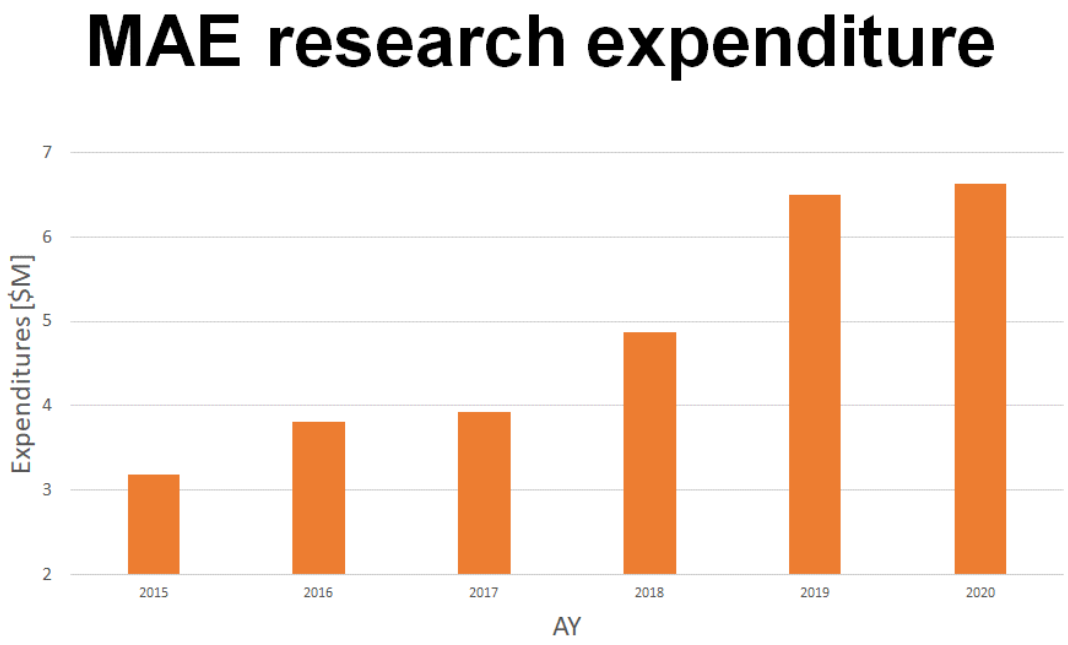
MAE Graduation in 2019-2020

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.



(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.



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 Challaplli*
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 he 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 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**	**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

Database Name	UCF	UF	U Penn	Texas A&M	Purdue
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
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

Database Name	UCF	UF	U Penn	Texas A&M	Purdue
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	Med school 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)	Med school	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 &	x	x	x	x	**x**

methods in medical & 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

Subject Heading	UCF	UF	U Penn	Texas A&M	Purdue
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	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	Selective med school	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 Toxiocology (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/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
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 trade mark 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 Biionix 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 than1200 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 Harvad 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. Ilegbusi. 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; reflectormetry 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 FACS Canto 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 (myoMuscule, 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 a 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 DeCampli, MD, PhD who is Chief of Pediatric Thoracic Surgery and Director or 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 DeCampli.

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 experiencer 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 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.	Professor	Tenured	Fall 2022	9	0.75	0.10	0.08	9	0.75	0.15	0.11
A	Olusegun Ilegbusi, Ph.D.	Professor	Tenured	Fall 2022	9	0.75	0.10	0.08	9	0.75	0.10	0.08
A	Robert Steward, Ph.D.	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.	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.	Associate Professor	Tenured	Fall 2022	9	0.75	0.10	0.08	9	0.75	0.10	0.08
A	Helen Huang, Ph.D.	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.	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.	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.	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.	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.	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.	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
B	New faculty to be hired on a vacant line	Current Education & General Revenue	0.00	0.00

APPENDIX A

Table 2

Anticipated Faculty Participation

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.

	6/25/2021
Signature of Equal Opportunity Officer	**Date**
Frank Allen Digitally signed by Frank Allen Date: 2021.07.28 09:21:44 -04'00'	
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.

-

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.cshlpress.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	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			
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	Purdue
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		
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	Med school 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)	Med school	x	Med school	x	
Wiley Online Library	x				x
WorldCat	x	x	x	x	x

Database Name	UCF	U F	U Penn	Texas A&M	Purdue
Zoological Record	1978-2007	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, pharmaceutics, 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=EAIaIQobChMIx_2pnNTT5QIVGYiGCh0d4AD2EAAYAiAAEgK0UvD_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=EAIaIQobChMIx_2pnNTT5QIVGYiGCh0d4AD2EAAYAiAAEgK0UvD_BwE.

Biomedical Engineering Protocols and Standards

	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**

	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	117 117	86 68	89 182	84 120	130 117
Bioinformatics	623 2,809	604 1,309	216 1,161	552 528	601 114
Biological transport	57 93	58 77	62 107	46 46	68 66
Biomechanics	147	92	183	105	442
Biomedical engineering	1,157 4,168	330 2,040	1,083 15	732 1011	1,248 2,684
Biomedical engineering—Computer simulation	9 12	6 9	11	6	8 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	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

	UCF	UF	UPENN	Texas A&M	Purdue
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	Selective 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 Toxiocology (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
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 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/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		
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 and Letters of Support

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.

BIOFLORIDA
Florida BioDatabase

- **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).

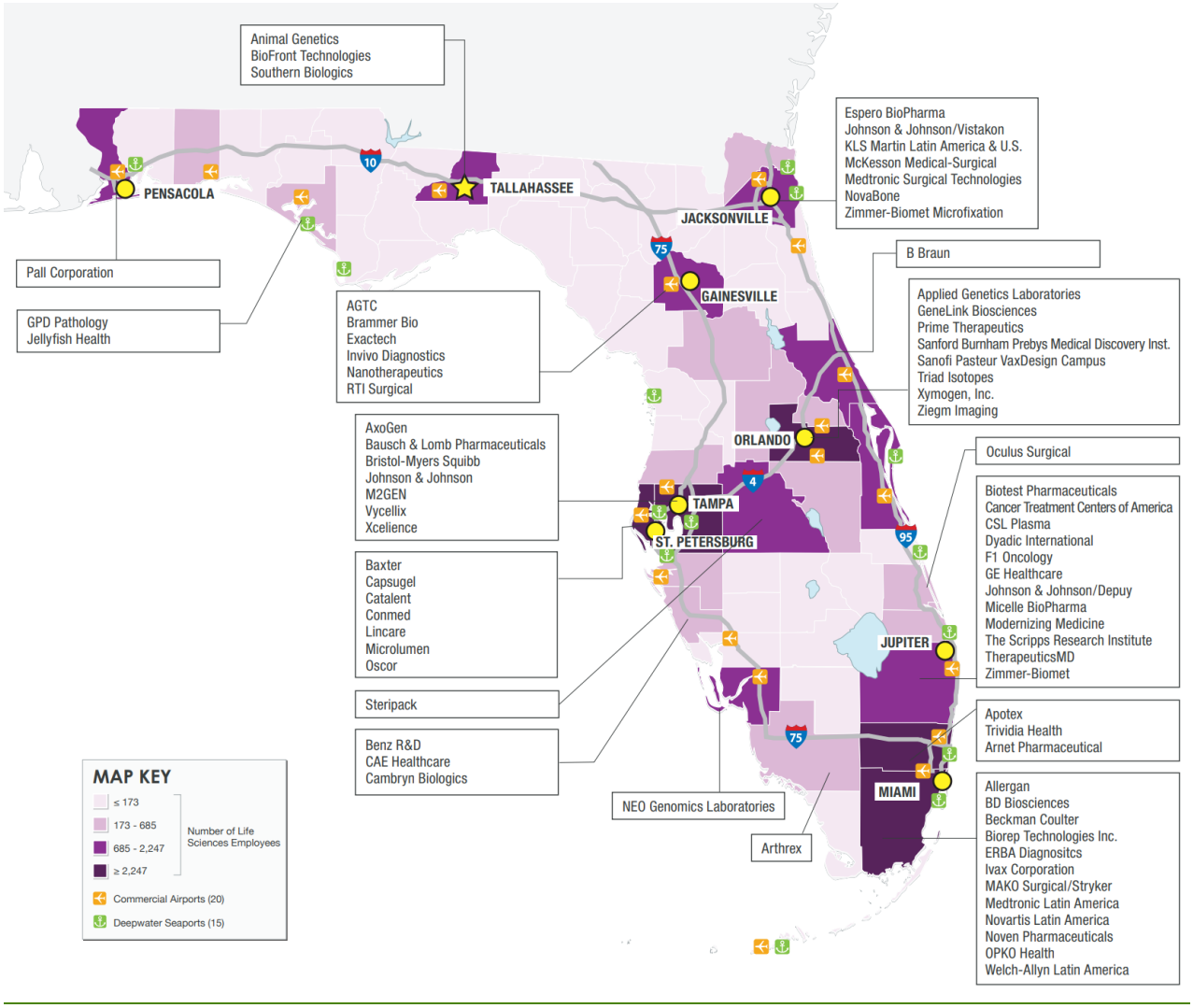
Visit the BioDatabase

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 (enterpriseflorida.com)



5. **National Need for BME from National Bureau of Labor Statistics**
   Bioengineers and Biomedical Engineers (bls.gov)

Occupational Employment and Wage Statistics

OEWS PRINT:

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

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- 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

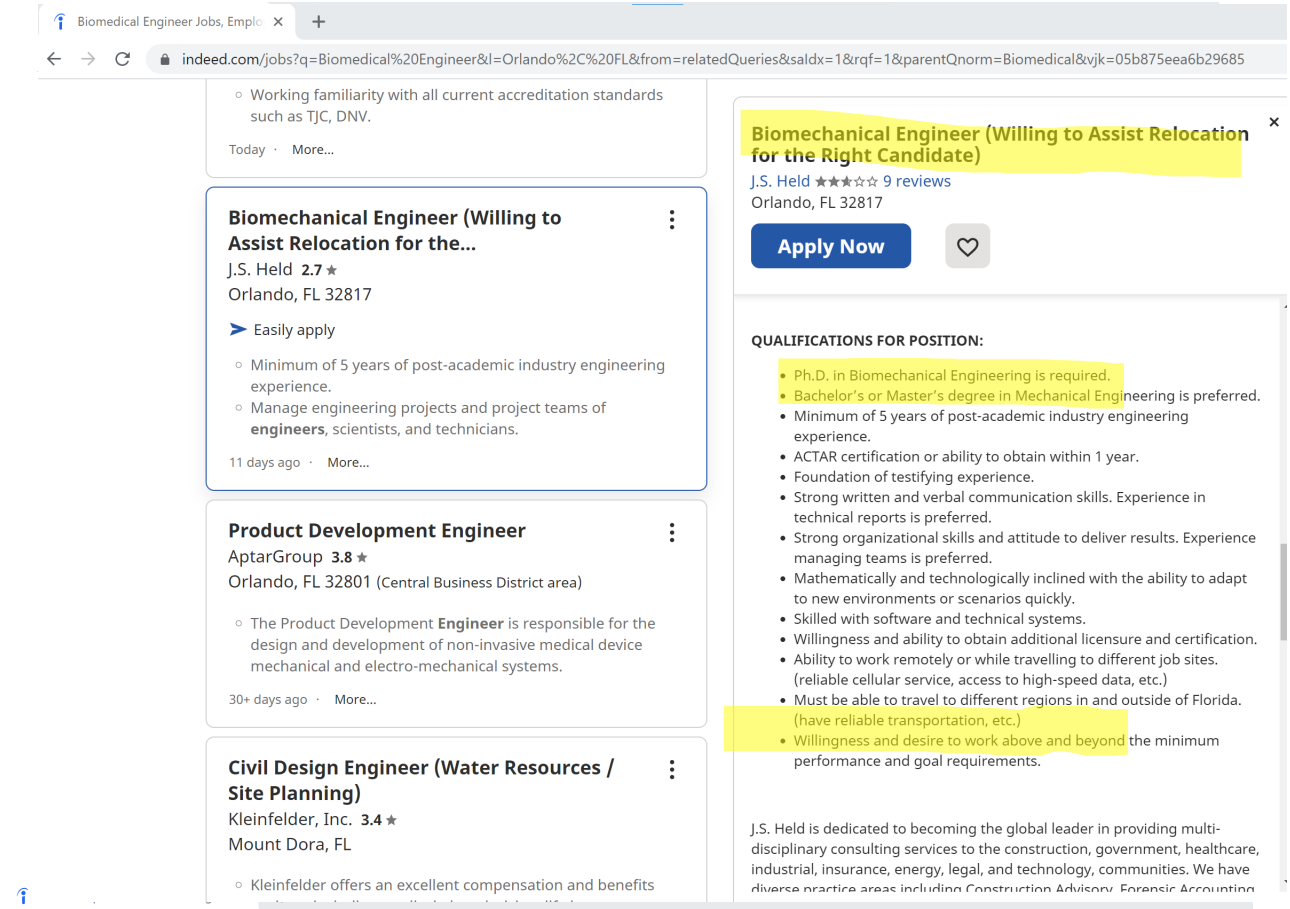
Industries with the highest concentration of employment in Bioengineers and Biomedical Engineers:

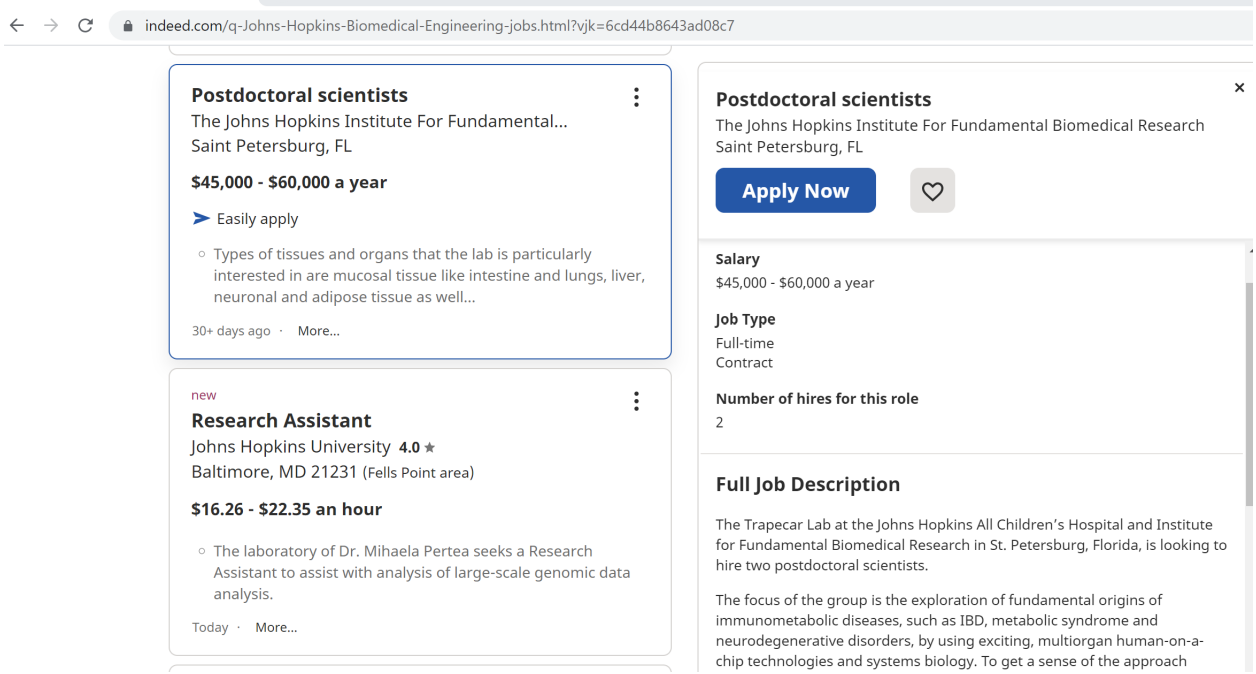
Industry	Employment (1)	Percent of industry employment	Hourly mean wage	Annual mean wage (2)
Medical Equipment and Supplies Manufacturing	3,090	0.99	$ 47.02	$ 97,800
Pharmaceutical and Medicine Manufacturing	2,560	0.86	$ 47.41	$ 98,610
Scientific Research and Development Services	3,090	0.41	$ 50.00	$ 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

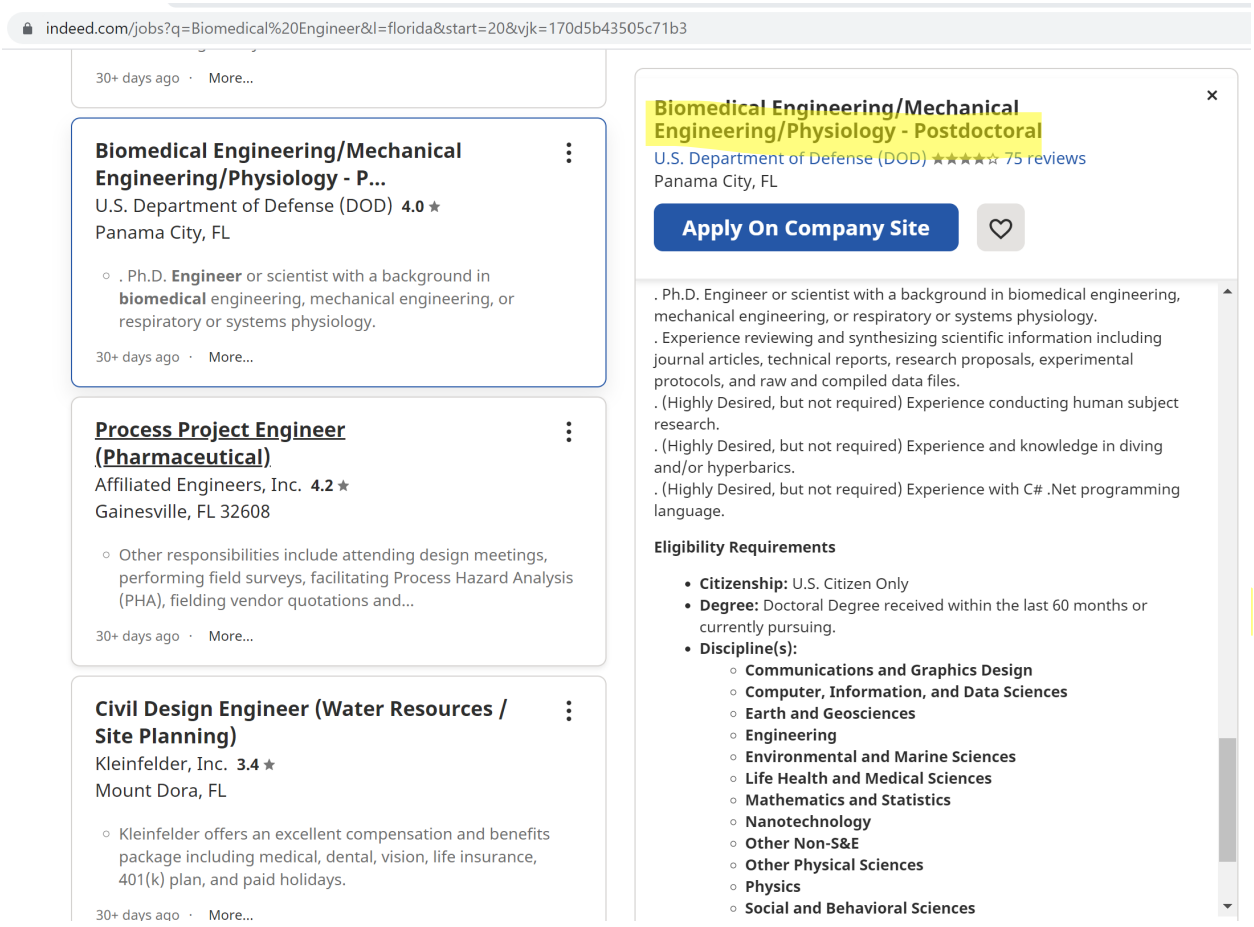
Top paying industries for Bioengineers and Biomedical Engineers:

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







PHD SCIENTIST/BIOENGINEER

SAVED

Procter and Gamble
Mason, OH

Apply on PG Careers | Apply on Monster | Apply on LinkedIn | Apply on Mendeley | Apply on Glassdoor | Apply on Me

Over 1 month ago · Full-time

We are looking for a motivated, goal-oriented candidate to join P&G global Corporate R&D Function Bioscience team as a PhD Scientist/Bioengineer! The scientist will work in close collaboration with multifunctional project teams and lead upstream innovation programs to evaluate efficacy and safety of various P&G products. In addition, the candidate will provide technical expertise in Life science, chemistry and clinical science to support development of new products and initiatives. The candidate will be responsible for:

• 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.

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 -04'00'

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,

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,

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 Biionix 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

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,

michaelg Digitally signed by michaelg Date: 2021.08.20 17:48:31 -04'00'

Michael Georgiopoulos, PhD
ECE Professor and Dean CECS

UCF Institutional letter from Limbitless Solutions President Albert Manero

7/10/2021
To the review board,

I am writing to share my enthusiasm and support for the proposed doctoral program focused on biomedical engineering here at the University of Central Florida. As a three-time graduate of UCF and now a UCF researcher, I have seen firsthand the incredible transformational power of education and research. This value directly impacts the lives of students and extends for our community.

During my graduate research I listened to seminar lectures from UCF faculty and guest speakers from around the country speak to the powerful research work in fundamental, applied, and clinical bio-medical research. When given the opportunity to work on a prosthetics project, I was thrilled for the opportunity. From that work I have helped established Limbitless Solutions at UCF, focused on biomedical engineering hardware development and clinical translation. Through the program we have developed collaborative research with hospital partners nationwide, including Mayo Clinic, Oregon Health and Science University, UCF's Faculty Cluster program, and the Veterans Affairs Medical Center in Orlando.

Many of the students in my laboratory are keenly interested in pursuing advanced degrees in biomedical engineering. UCF has excelled for the past several years, developing excellent students and research through the master's degree program, and now looks to leverage that success for a doctoral program. As Florida continues to grow the thriving biomedical engineering industry and sees significant investments from medical institutions, now is certainly the time to establish this cutting-edge doctoral program. The opportunity to see rapid advances in research, improvements in the standard of care for patients, and to provide the critical professional training for students is incredible.

This doctoral program will be transformational, and I look forward to supporting the program. If you have any further questions, please feel free to contact me.

Albert Manero, PhD
Albert@Limbitless-Solutions.org
President // Limbitless Solutions DSO
University of Central Florida

4217 East Plaza Drive, Orlando, Florida 32816. Main operations located at the University of Central Florida
Office: albert@limbitless-solutions.org | 3DHope.com & Limbitless-Solutions.org

UCF Institutional Letters from the Dean of the College of Medicine Dr. Deborah German and the Deran of the College Nursing Dr. MaryLou Sole

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,

Deborah C. German

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 Biionix 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,

Mary Lou Sole

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

External letters from the Co-Director of the Heart Center at Orlando Health, Dr. William DeCampli and the Director of Research at Advent Health University, Dr. Mohtashem SamSam

William M. DeCampli, M.D., PhD

Chief, Division of Cardiothoracic Surgery
Co-Director
The Heart Center at Arnold Palmer Hospital

ARNOLD PALMER HOSPITAL
For Children
Supported by Arnold Palmer Medical Center Foundation

Professor of Surgery
University of Central Florida
College of Medicine

June 10, 2021

Michael Georgiopoulos, Dean
College of Engineering & Computer Science
The University of Central Florida
Orlando, FL

Dear Professor Georgiopoulos,

I am pleased to write this letter in support of the initiation of the Doctor of Philosophy degree program in Biomedical Engineering to be based in the Mechanical and Aerospace Engineering Department in the College of Engineering & Computer Science (CECS) at the University of Central Florida. I am Co-Director of the Heart Center at Orlando Health/Arnold Palmer Hospital for Children, Professor of Surgery (with Tenure of Title) in the College of Medicine (COM) and member of the Graduate Faculty of the College of Graduate Studies at UCF. I hold the position of adjunct Professor of Surgery at the University of Toronto, where I am also Managing Director of the Data Centre of the Congenital Heart Surgeons' Society.

For more than a decade I have worked with Professor Alain Kassab, Pegasus Professor of Mechanical Engineering, on problems at the interface of engineering and medicine. Our lab is a world leader in applications of computational fluid dynamics to the treatment of both adult and pediatric cardiovascular disease. Focusing on practical and feasible alterations in standard surgical approaches to disorders such as end-stage heart failure and complex single ventricle congenital heart disease, we have developed techniques that may prolong the functionality of the Fontan circulation, reduce the risk of stroke in patients supported with ventricular devices, and provide less invasive operations that may reduce the risk of neurological injury during congenital heart surgery. In 2013 our work evolved into the formation of an informal Biomedical Engineering (BME) Group in the CECS. This resulted in an expanded, multi-disciplinary group of faculty members, some within the CECS and some in other UCF Colleges. A few years later, the UCF Board of Trustees approved the creation of both the Master of Science degree program in BME and the joint MD-MS degree program in conjunction with the COM. As noted in the proposal, over the past several years, the MAE Department has also invested in hiring several BME faculty members through department faculty lines and through university cluster initiatives. The number of such BME faculty members in the MAE Department currently standing at twelve, which is a typical number that forms the core faculty in many BME programs throughout the country. With our continued development of the program and the evident interest level of students, we now wish to initiate the PhD degree program.

While it is clear that the research and education opportunities of PhD in BME program as outlined in the program proposal will add great value for the CECS, for its students, and the UCF research mission, I will emphasize the value that a continued relationship with Orlando Health (and our Heart Center in particular) will have in making this proposed program a success. At the heart of a successful BME degree program is

the access students have to clinics, hospitals, and other healthcare entities. Among the numerous health care systems in the region, Orlando Health probably has the broadest and most robust structures in place for the conduct of collaborative translational and clinical research. This includes a corporate Office of Research, Grants Department, Orlando Health Ventures (the external arm of its strategic innovations initiative), Institutional Review Board and Research Advisory Council. At the service line level, many of the medical staff in cardiology, cardiac surgery, orthopedics, neurosurgery, trauma surgery, radiation therapy and radiology are engaged in research relationships with industry, government, and academia. The Heart Center physicians, for example, are all faculty members of the COM. Three of our most recent faculty additions (Tain-Yen Hsia, Faras Al Mousily, Michael Farias) were recruited from Yale, UF, and Harvard, respectively and are all members of the UCF BME Group. Professor Hsia, a pediatric cardiac surgeon at OH, currently heads the Single Ventricle "Cures" Collaborative sponsored by Additional Ventures (a private foundation) and administrates this through the CECS. Professor Al Mousily is an advanced imaging expert and currently working with a collaborative group on the development of a new heart valve. Dr. Farias works in our BME Group on developing methods for measuring the characteristics of the pulmonary circulation in single ventricle heart disease. Dr. Ray Prather, who received his PhD in the CECS, is now on the full-time biomedical engineering staff at the Heart Center. In addition to my work with Dr. Kassab, I have collaborated with Pegasus Professor Aristide Dogariu (CREOL) on a novel way to continuously measure clotting and coagulation status in critically ill and surgical patients. This work has been NIH supported and has resulted in publication in *Nature Biomedical Engineering*. My Heart Center Co-Director, Professor David Nykanen, is a leading interventional cardiologist who has been supported by many industry grants in trialing innovative devices for treatment of congenital heart disease. The studies and programs mentioned above are supported by industry, government, foundation, and internal grants, all of which can accommodate funding for UCF graduate student participation.

At the core of any degree program is the commitment of accomplished researchers to provide education, training, mentoring and financial support for its graduate students. A large proportion of Orlando Health medical staff members have a formal commitment to one of the many independent graduate medical educational (GME) programs at OH and have established their dedication to graduate education. Many of the medical staff members are volunteer faculty members of the COM. In the Heart Center, the physician staff take pride in engaging in UCF medical student education through teaching sessions in the pre-clinical core modules, the research module ("FIRE") and/or clinical electives we have established for students. We have a streamlined process by which UCF students from any of the Colleges can obtain credentials to engage in observation, study, or research at any of the OH campuses. Indeed, essentially all the studies I have conducted at the Heart Center over the past 13 years have engaged UCF students. In short, the OH medical staff have a history of engaging in graduate training and education and will, in my opinion, enthusiastically embrace a new doctoral degree program in BME at UCF. The opportunity to educate our future biomedical engineers and direct them to the pressing problems in medicine and healthcare will be our honor and privilege.

Sincerely,

William M. DeCampli, M.D., Ph.D, FACC, FACS

June 06, 2021

671 Winyah Drive
Orlando, FL 32803

Letter of Support for the PhD Program in Biomedical Engineering in UCF at the Department of Mechanical and Aerospace Engineering

Dear Dr. Gordon,

I reviewed the summary of your Biomedical Engineering (BME) PhD program. The core courses are appropriate, the setup of the program and the number of the credits are typical for a PhD program.

I am also aware of the fact that this new program will have a close collaboration with the UCF College of Medicine and biomedical researchers, the Orlando regional hospitals, and various medical professionals for basic and translational research and these collaborations have already been established by the Mechanical and Aerospace Engineering Department.

Therefore, I am in full support of BME PhD program at UCF and I think it can be offered as early as fall 2022 due to the already established/developed core courses for this purpose, the availability of infrastructures and the core faculty and facilities as well as the library resources. I think this program will be an asset to the research and education at UCF and Florida, and it will be a magnet for regional, national, and international students.

Sincerely,

Mohtashem Samsam, MD, PhD, SAMSAM
Director of Research of Advent Health University,
Professor, Department of Physical Therapy,
Advent Health University, Orlando, FL,
Phone: 407-303-9183
Cell: 497- 913 5080

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

UF UNIVERSITY of FLORIDA

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,

Christine Schmidt

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

FIU Engineering & Computing
Biomedical Engineering

10555 West Flagler Street, EC 2602
Miami, FL 33174

305-348-3722
Fax: 305-348-6954
Email: rjung@fiu.edu
bme.fiu.edu

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

FAMU-FSU Engineering

Department of Chemical and 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.

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 - CV's of Participating BME Faculty

OMB No. 0925-0001/0002 (Rev. 08/12 Approved Through 8/31/2015)

BIOGRAPHICAL SKETCH

Provide the following information for the Senior/key personnel and other significant contributors.
Follow this format for each person. **DO NOT EXCEED FIVE PAGES.**

NAME: Alain Kassab

eRA COMMONS USER NAME (credential, e.g., agency login): ALAINKASSAB

POSITION TITLE: Professor

EDUCATION/TRAINING *(Begin with baccalaureate or other initial professional education, such as nursing, include postdoctoral training and residency training if applicable. Add/delete rows as necessary.)*

INSTITUTION AND LOCATION	DEGREE *(if applicable)*	Completion Date MM/YYYY	FIELD OF STUDY
University of Florida, Gainesville Florida	B.S.E.S	1982	Engineering Science
University of Florida, Gainesville Florida	M.S.M.E.	1985	Mechanical Engineering
University of Florida, Gainesville Florida	Ph.D.	1989	Mechanical Engineering

A. Personal Statement I am currently engaged as PI in an American Heart Association (AHA) funded study utilizing multi-scale Computational Fluid Dynamics (CFD) modeling to optimize the left ventricular outflow graft implantation with the aim of reducing stroke due to thromboembolic event in the great vessels and an Additional Ventures grant aimed at the design of a self-powered Fontan circulation that utilized the right ventricle to energize venous return to the lungs via an RV-to-Fontan-extracardiac-conduit shunt or an RV-to-left and -right-PA's Y-split shunt, a continuation of a project previously funded by the AHA grants in aid. I was also funded as PI or Co-PI by the AHA in investigations of the hemodynamics of a novel hybrid approach to comprehensive Stage II operation for single ventricle palliation, and multiscale CFD studies of the shunt size and placement in the Hybrid Norwood palliation of single ventricle congenital heart disease. I have over 30 years of experience in research and development in computational heat transfer, computational fluid dynamics, inverse problems, boundary elements, and meshless methods resulting in over 350 scientific publications, including 114 journal papers, 227 refereed international/national archival conference papers, 3 books authored/edited, 9 invited chapters in monographs, and I am Co-editor of 9 Proceedings of international conferences. I am associate editor of 2 journals and member of 3 editorial boards. I have mentored to graduation 18 PhD and 29 MS students. Over the past 10 years, I have been collaborating closely with William DeCampli, MD, PhD at Arnold Palmer Children's hospital in Orlando in a program of research in the general area of CFD applications to cardiovascular modeling with applications to thrombus transport in LVADs and investigation of the Hybrid Norwood circulation and treatment planning for Congenital Heart Disease. I also have experience in biomechanics research as PI on a multi-year collaborative project with Dr. Charles Price at Arnold Palmer Children's Hospital on Finite Element analysis and optimization of the Pavlik Harness treatment of neonates with developmental dysplasia of the hip a project that received grant support from OrlandoHealth and the NSF, as well as support from the International Hip Dysplasia Institute. All these bioengineering projects have led to publications and presentations in the bioengineering and medical literature as well as produced several MS and PhD theses. I have experience in carrying out experiments having been involved in designing and constructing an 8KW solar concentrator facility to pump Neodynium YAG lasers, infrared thermography for inverse problems, and design and instrumentation of a transonic wind tunnel facility for film cooling studies, and development of a pulsatile benchtop flow-loop of the VAD circulation for thrombus studies.

I have been appointed as Director of Biomedical Engineering for the MAE Department at UCF. I am Director of the Bioengineering Minor for the College of Engineering and Computer Science at UCF, co-director of the Medical Engineering Dual Degree program, and principal author of the MS in Biomedical Engineering Master Program. I was co-chair and co-organizer of the 5th International Conference on Engineering Frontiers in

Pediatric and Congenital Heart Disease held at the UCF College of Medicine in June 2016. I will support and supervise all aspects of the PhD in BME as set out in this proposal.

B. Positions and Honors. (in chronological order previous positions and honors)

Positions and Employment

1982-1985 Engineering Science Department, Research Assistant, Solar pumping of Nd YAG lasers.
1983-1989 Mechanical Engineering Research Assistant, inverse heat conduction problems
1989-1991 Visiting Assistant Professor, University of Florida C.A.S.E., Palm Beach Gardens
1991-1995 Assistant Professor, UCF, Mechanical, Materials and Aerospace Engineering Department (MMAE), Joint appointment: Department of Mathematical Sciences.
1996-2001 Associate Professor, UCF, MMAE Department. MMAE Graduate Program Coordinator. Joint appointment: Department of Mathematical Sciences.
2001- Professor, UCF, MMAE Department. Joint Appointment Department of Mathematical Sciences.
1996-2003 MAE Graduate Program Coordinator
2007-2015 MAE Graduate Program Coordinator (1996-2003; 2007-2015).
2015- MAE Bio-medical Engineering Director (2015-present)
2011- Director of CECS Bioengineering Minor(2011-present)
2019- Appointed University of Central Florida Trustee Chair Professor.
2019 - Co-Director of the UCF Medical Engineering Double Degree (MEDD) Program(2019-present)

Other Experience and Professional Memberships

1985- Member of American Society of Mechanical Engineers
1994 Co-chair *9th Intl. Conf. on Boundary Element Technology*
1994-1996 Editorial board *Boundary Element Communications*
1998 Co-chair *of 20th Intl. Conf. on Boundary Elements*
1999 Co-chair *6th Intl. Conf. on Comp. Aided Optimum Design*
2000 Elected Fellow of the American Society of Mechanical Engineers (FASME)
2000-2013 Editorial Board *Engineering Analysis with Boundary Elements*
2000- Associate Editor *Inverse Problems in Science and Engineering*
2001 Co-chair *14th Intl. Conf. on Boundary Element Technology*
2001 Elected Fellow of Wessex Institute of Technology (UK).
2002 Editorial Chair *of SECTAM XXI, 21st Southeast Conference on Theoretical and Applied Mechanics*
2002 Co-Chair *of 27th World Conference on Boundary Elements and Other Mesh Reduction Methods*
2005-2008 Editorial board *of Computers, Materials & Continua*
2011 Chair *International Conference on Inverse Problems in Science and Engineering*
2011 Co-Chair *6th Subrata Chakrabarti International Conference on Fluid Structure Interaction*
2011 Co-Chair *2nd International Conference on Disaster Management and Human Health: Reducing Risk, Improving Outcomes*
2013- Editor *Engineering Analysis with Boundary Elements*
2013- Editorial Board *International Journal of Computational Methods and Experimental Measurements*
2013- Editorial Board *Thermopedia*
2014- Editorial Board *International Journal for Engineering Modelling*
2014- Member of American Heart Association
2015- Co-Chair *of the 5th International Conference on Engineering Frontiers in Pediatric and Congenital Heart Disease*
2015 Principal author of the MS in Biomedical Engineering Program (2015).
2018 Chair of Committee drafting the PhD in Biomedical Engineering Program proposal.
2019 Elected Fellow of the American Institute for Medical and Biological Engineering (FAIMBE)

Honors

1994 UCF, MMAE Dept, Excellence in Graduate Teaching Award (also 1996, 1997, 1999 and 2000)
1994 State University System of Florida Teaching Incentive Program (SUS-TIP) Award
2000 UCF, College of Engineering and Computer Science: 2000 Excellence in Graduate Teaching Award.
2000 UCF, University Excellence in Graduate Teaching Award

2001 University of Central Florida Teaching Incentive Program (UCF-TIP) Award.
2002 UCF, MMAE Department, Excellence in Professional Academic Advising
2002 UCF, College of Engineering and Computer Science: Distinguished Researcher Award,
2002 UCF, MMAE Department, Research Award
2003 University of Central Florida Research Incentive Award (UCF-RIA).
2005 UCF, MMAE Department, Research Award
2006 UCF, College of Eng. & Computer Science, Excellence in Professional Service Award
2006 University of Central Florida Teaching Incentive Program (UCF-TIP) Award
2008 UCF, MMAE, Excellence in Professional Service Award
2014 University of Central Florida Research Incentive Award (UCF-RIA).
2017 University of Central Florida Teaching Incentive Program (UCF-TIP) Award
2017 University of Central Florida Pegasus Professor Award
2019 University of Central Florida Scroll and Quill Society

C. Contributions to Science

1. Over the past 10 years, I have been collaborating closely with William DeCampli, MD, PhD at Arnold Palmer Hospital for Children in a program of research in the general area of CFD applications to cardiovascular modeling with applications to thrombus transport in LVADs, development of the injection jet shunt concept to energize the Fontan circulation, investigation of a novel hybrid comprehensive stage 2 palliation for single ventricle disease, and investigation of the Hybrid Norwood palliative treatment for congenital heart disease. I direct the Computational Mechanics Laboratory at UCF where my graduate students are engaged in carrying out the challenging computational studies in support of our investigations. This research has led to several joint publications, refereed journals papers and conference papers/poster presentations. This work has received support from the American Heart Association (AHA): AHA grant (2011-2013) 11GRNT79400 entitled "Multiscale Modeling of the Neonate Circulation After Hybrid Norwood Palliation" (PI: Kassab PI and CoPI: DeCampli), AHA (2017-2018) 17GRNT33411154 entitled "Hemodynamics of Novel Hybrid Approach to Comprehensive Stage II Operation for Single Ventricle," (PI: DeCampli, CoPI: Alain Kassab), and AHA grant (2015-2016) 5IRG22470015 "Conceptual and Laboratory Development of a Self-Powered FONTAN for Treatment of Congenital Heart Disease." (PI: DeCampli and CoPI: Kassab). Our multiscale studies has elucidated the complex hemodynamics of the Hybrid Norwood shunt flow circulation, the hybrid comprehensive stage II, the development of the IJS concept for the Fontan and has impact on treatment planning for CHD .

a. Hameed, M., Prather, R., Divo, E., Kassab, A., and DeCampli, W.Computational Fluid Dynamics Investigation of the Novel Hybrid Comprehensive Stage II Operation," Journal of Thoracic and Cardiovascular Surgery Open (accepted for publication April 2021).
b. Ni, M., Prather, O., Rodriguez, G., Quinn, R., Divo, E., Fogel, M., **Kassab, A.** and DeCampli, W. " Computational Investigation of a Self-Powered Fontan Circulation", *BMES Journal of Cardiovascular Engineering and Technology*, June 2018, Volume 9, Issue 2, pp 202–216 https://doi.org/10.1007/s13239-018-0342-5.
c. Ceballos, A., Prather, R., Divo, E., **Kassab, A.**, and DeCampli, W., "A Patient-Specific Multi-Scale Model Analysis of the Hemodynamics Following the Hybrid Norwood Procedure for Hypoplastic Left Heart Syndrome: effects of the reverse Blalock-Taussig Shunt*", BMES Journal of Cardiovascular Engineering and Technology*, March 2019, Volume 10, Issue 1, pp 136–154, https://doi.org/10.1007/s13239-018-00396-w.
d. Prather, R., Seligson, J., Ni, M., Divo, E., **Kassab, A.**, and DeCampli, W., "Patient-Specific Multiscale Computational Fluid Dynamics Assessment Of Embolization Rates In The Hybrid Norwood: Effects of Size and Placement of the Reverse Blalock-Taussig Shunt," *Canadian Journal of Physiology and Pharmacology*, 2018, 96(7), pp. 690-700. https://doi.org/10.1139/cjpp-2018-0002.
e. Ceballos, A., Argueta-Morales, I.R., Divo, E., Osorio, R., Caldarone, C., **Kassab, A.J.**, and DeCampli, W.M., "Computational Analysis of Hybrid Norwood Circulation with Distal Aortic Arch Obstruction and Reverse Blalock-Taussig Shunt," *Annals of Thoracic Surgery*, 2012, 94(5), pp. 1540-1546.

2. The computational studies carried out by my group on CFD modeling of LVADs in collaboration with William DeCampli, MD, PhD has been presented at the Surgical Forum program at the American College of Surgeons 96th Annual Clinical Congress reporting a significant (up to 50%) reduction in thrombo-embolism to the brain by proper adjustment of the inflow cannula and has subsequently led to several journal and conference papers. This is a significant finding that has the potential to mitigate the issues of VAD pump thrombosis by surgical

adjustment. I am PI with Dr. DeCampli Co-PI of a 3-year AHA Transformative Grant 18TPA34230091 supporting this work.

a. Prather, R, Divo, E., Kassab, A., and DeCampli, W. ," Computational Fluid Dynamics Study of Cerebral Thromboembolism Risk in Ventricular Assist Device Patients: Effects of Pulsatility and Thrombus Origin," ASME Journal of Biomechanical Engineering, BIO-20-1332, 2021, https://doi.org/10.1115/1.4050819
b. Prather, R, Ni, M., **Kassab, A.J.**, Divo, E.A., Argueta, I.R., and DeCampli, W.M., "Multi-Scale Pulsatile CFD Modeling of Thrombus Transport in a Patient-Specific LVAD Implantation, " *International Journal of Numerical Methods for Heat and Fluid Flow*, 2017, Vol. 27, No. 5, pp. 1022-1039.
c. Nguyen, T., Argueta-Morales, I.R., Guimond, S., Clark, W., Ceballos, A., Osorio, R., Divo, E., **Kassab, A. J.**, and DeCampli, W.M., "Computational analysis of pediatric ventricular assist device implantation to decrease cerebral particulate embolization," *Computer Methods in Biomechanics and Biomedical Engineering*, (online 7-27-2015) http://www.tandfonline.com/doi/full/10.1080/10255842.2015.1062478.
d. Clark, W., Eslahpazir, B.A., Argueta-Morales, I.R., Divo, E.A., **Kassab, A.J.**, and DeCampli, W.M., "Consistency between Bench-top and Computational Modelling of Cerebral Thromboembolism in Ventricular Assist Device Circulation", *Cardiovascular Engineering and Technology, September 2015, Volume 6, Issue 3, pp 242-255.DOI: 10.1007/s13239-015-0230-1.*
e. Argueta-Morales, I.R., Tran, R., Ceballos, A., Osorio, R., Clark, W., Divo, E., **Kassab, A.**, William M. DeCampli, Mathematical modeling of patient-specific ventricular assist device implantation to reduce particulate embolization rate to cerebral vessels, *ASME, Journal of Biomechanical Engineering*, 2014, Vol. 136, No. 7, pp. 071008-1 – 071008.

3. I was PI on a 3 year grant (2012-2015) from the National Science Foundation on Finite Element analysis and optimization of the Pavlik Harness treatment of neonates with developmental dysplasia of the hip a project that has also received support from OrlandoHealth and the International Hip Dysplasia Institute. This is a collaborative project with Charles Price MD who is an orthopedic surgeon at OrlandoHealth, and it has led to numerous publications and presentations as well as MS and PhD theses earned by students from my Lab.

a. Huayamave, V., Lozinski, B., Rose, C., Ali, A., Divo, E. Moslehy, F., **Kassab, A.**, and Price, C., "Biomechanical Evaluation of Femoral Anteversion in Developmental Dysplasia of the Hip and Potential Implications for Closed Reduction," *Journal of Clinical Biomechanics*, 2020, Vol 72, pp. 175-182.
b. Huayamave, V., Rose, C., Serra, S., Jones, B., Divo, E., Moslehy, F., **Kassab, A.J.**, and Price, C.T., "A Patient-Specific Model of the Biomechanics of Hip Reduction for Neonatal Developmental Dysplasia of the Hip: investigation of strategies for low to severe grades of DDH," *Journal of Biomechanics*, 2015, Vol. 48, pp. 2026-2033.doi: 10. 1016/j.jbiomech.2015.03.031.
c. Ardila, O., Divo, E.A., Moslehy, F., Rab, G.T., **Kassab, A.J**., and Price, C.T.,"Mechanics of Hip Dysplasia Reduction in Infants Using the Pavlik Harness: A Physics-Based Computational Model," *Journal of Biomechanics*, 2013, Vol. 46, No. 9, pp. 1501.
d. Huayamave, V., Rose, C., Divo. E., Moslehy, F., **Kassab, A.J.,** and Price, C.T., "Mechanics of Hip Dysplasia Reduction in Infants with Pavlik Harness Using Patient Specific Geometry, Proc. of the 2014 International Congress and Exposition *ASME Paper IMECE 2014- 3660*, November 14-20, Montreal, Canada (3rd place Track3-13: biomedical and biotechnology PhD Paper Competition).

4. For over 25 years I have carried out active research in computational methods in heat transfer and fluid flow, inverse problems, boundary elements, and meshless methods I have been collaborating with Dr. Divo (Embry-Riddle Aeronautical University) for over 20 years in boundary element, meshless methods and inverse problems in and computational heat transfer and fluid flow. I have co-authored two books and numerous papers in boundary elements and meshless methods reporting fundamental contributions to the boundary element method in non-homogeneous media and in inverse problems. Our work has also led to development of the boundary element method for large-scale industrial applications in cooled turbine blades and conjugate heat transfer. We have developed meshless methods for hemodynamics problems and shape optimization of end-to-distal bypass grafts. Additional experience in bioengineering computational modeling includes a research project with MD Anderson modeling lung tumor motion in patients undergoing radiation therapy. My part of the project (funded by the Florida Department of Health King Foundation Grant) used meshless methods for airflow and lung parenchyma deformation modeling. We have also developed extensive applications of radial basis function trained proper orthogonal decomposition (POD) reduced order models with wide applications to heat transfer and fluid flow as well as various inverse problem.

a. Pepper, D., **Kassab, A.**, and Divo, E., An Introduction to the Finite Element, Boundary Element, and Meshless Methods - with applications to heat transfer and fluid flow, ASME Press, New York, 2014.

b. Khoury, A., Golubev, V., **Kassab, A.**, and Divo, E.," Meshless Modeling of Coupled Transdermal Pharamacokinetics with Analytical Validation," *Engineering Analysis with Boundary Elements*, Volume 122, January 2021, Pages 62-74. https://doi.org/10.1016/j.enganabound.2020.10.009.

c. El-Zahab, Divo, E., and **Kassab, A.,** "Minimization of the Wall Shear Stress Gradients in Bypass Grafts Anastomoses using Meshless CFD and Genetic Algorithms Optimization" *Computer Methods in Biomechanics and Biomedical Engineering*, 2010, Vol. 13, No. 1, pp. 35-47.

d. Erhart, K. **Kassab, A.J.** and Divo, E., "An Inverse Localized Meshless Technique for the Determination of Non-Linear Heat Generation Rates in Living Tissues," *International Journal of Heat and Fluid Flow*, 2008, Vol. 18, No.3, pp. 401-414.

D. Research Support. ***List of selected ongoing or completed (during the last five years).***

Ongoing Research Support

Additional Ventures PI: Alain Kassab **5/1/2020-12/31/2022**
Project Title: The Injection-Jet Powered Fontan Circulation: A Novel Bridge and Destination Therapy for the Failing Fontan.
Project Description: Multiscale CFD and benchtop analysis of.
Role: Co-PI Project Status: **ongoing**

American Heart Association PI: Alain Kassab **7/1/2018-7/31/2021**
Project Title: Multiscale Hemodynamics Investigation of a Surgical Manoeuver to Reduce Stroke Risk in Left Ventricular Assist Devices.
Project Description: Multiscale CFD and benchtop analysis of pulsatile hemodynamics and particle transport in an LVAD vascular bed to optimize outflow graft implantation aimed at reducing stroke risk.
Role: PI Project Status: **ongoing**

University of Central Florida PI: Kassab, A.J **05/15/2019 to 12/31/2025**
Project Title: **Trustee Chair Research Award**
Project Description: Unrestricted research award
Role: PI Project Status: ongoing

Completed Research Support

American Heart Association PI: William DeCampli **1/1/2017-12/31/2018**
Project Title: Hemodynamics of Novel Hybrid Approach to Comprehensive Stage II Operation for Single Ventricle.
Project Description: Multiscale CFD and benchtop analysis of hemodynamics of the comprehensive stage II operation for Single Ventricle.
Role: Co-PI Project Status: **completed**

US Army Research Laboratory PI: Brian Goldiez **3/15/2015-3/15/2018**
Project Title: Evaluation and Transition of Emerging Medical Simulation Technologies
Project Description: Tissue testing and constitutive modeling for synthetic materials for medical simulation.
Role: Co-PI Project Status: **completed**

Orlando Regional Health Services PI: Kassab, A.J **11/15/2015 to 07/31/2018**
Project Title: Biomechanics of closed reduction for DDH: investigation of strategies and obstacles to Reduction
Project Description: Study of biomechanics of orthoses used for DDH treatment.
Role: PI Project Status: **completed**

University of Central Florida PI: Kassab, A.J 05**/15/2017 to 12/31/2018**
Project Title: Pegasus Professor
Project Description: Unrestricted research award
Role: PI Project Status: **completed**

American Heart Association PI: William DeCampli **1/1/2015-12/31/2016**
Project Title: Conceptual and Laboratory Development of a Self-Powered FONTAN for Treatment of Congenital Heart Disease.
Project Description: Multiscale CFD analysis of novel procedure to improve the Fontan circulation.
Role: Co-PI Project Status: **completed**

US National Science Foundation PI: Kassab, A.J. **8/1/2012- 7/31/2015**
Project title: Analysis and Optimization of the Pavlik Harness Treatment of Neonates with Hip Dysplasia
Project Description: Development of a biomechanics model of the Pavlik Harness to aid in understanding its role in the mechanism of reduction and to explore alternative methods for high grades of dysplasia.
Role: PI Project Status: **completed**

OrlandoHealth PI: Alain Kassab **6/1/2015-8/31/2015**
Project Title: Bench-top LVAD Summer student support
Project Description: Graduate student Summer support for benchtop LVAD development.

Role: PI Project Status: **completed**

NIH National Heart, Lung and Blood Institute (NHLBI), PI: Kassab, A.J**. 8/31/2014- 8/31/2015**
Project Title: A Multi-Scale CFD-FSI Model of the Hybrid Norwood Palliative Treatment for Hypoplastic Left Heart Syndrome
Project Description: NIH Graduate Fellowship.
Role: PI Project Status: **completed**

BIOGRAPHICAL SKETCH

Provide the following information for the Senior/key personnel and other significant contributors.
Follow this format for each person. **DO NOT EXCEED FIVE PAGES.**

NAME: Luigi E. Perotti

eRA COMMONS USER NAME (credential, e.g., agency login): perotti2

POSITION TITLE: Assistant Professor

EDUCATION/TRAINING *(Begin with baccalaureate or other initial professional education, such as nursing, include postdoctoral training and residency training if applicable. Add/delete rows as necessary.)*

INSTITUTION AND LOCATION	DEGREE *(if applicable)*	Completion Date MM/YYYY	FIELD OF STUDY
Politecnico di Milano, Milan, Italy	B.S./M.S.	04/2004	Civil Engineering (Structural Engineering)
California Institute of Technology, Pasadena, CA	M.S.	06/2006	Mechanical Engineering
California Institute of Technology, Pasadena, CA	Ph.D.	06/2011	Mechanical Engineering (minor in Applied and Comp. Mathematics)
California Institute of Technology, Pasadena, CA	Post-Doc	11/2011	Aerospace Engineering (simulations of arterial blood flow and hypervelocity impacts)
University of California, Los Angeles, CA	Post-Doc	06/2016	Biomechanics (Structural virology, Cardiac Mechanics, Electrophysiology)

A. Personal Statement

Over the past six years, I have been developing new MRI-based models to investigate cardiac mechanics and cardiac kinematics. As part of this training and previous research, I have received an American Heart Association Postdoctoral Fellowship (2014-2016) and an NHLBI K25 Mentored Quantitative Research Career Development Award (2017 – 2020). During this period, I have trained in the Radiological Sciences Department at UCLA, where I applied my computational modeling background to medical imaging data and I learned the basis of MR imaging and how to design, direct, and execute preclinical (swine) studies. As part of the research sponsored by my NHLBI K25 award, I have carried out preclinical (swine) studies involving healthy and infarcted subjects, from the experimental setup, to the approval of the research protocol, to directing and carrying out subject care and MR exams. These studies allowed me to coordinate and lead a large team of investigators across different disciplines, including veterinarians, MR scientists, MR technicians, lab personnel, undergraduate and graduate students. The goal of the study was to apply a new method that I developed to analyze MR images and estimate passive cardiac stiffness during late diastole. This research has allowed me to perfect my computational mechanics models, optimize their coupling with MR data, train in MRI, and learn how to assemble and direct a large investigative team (including about 15 people) to accomplish interdisciplinary research at the boundary between engineering and medicine [e.g., 1,2].

My training in computational mechanics and numerical analysis applied to multidisciplinary and multiphysics problems started during my PhD research, where I developed and utilized advanced numerical tools capable of modeling fluid-structure interaction and complex material response. This continues today [3]. Following my PhD, I pursue my goal to apply my computational and analytical training to problems in biomechanics. Initially, I focused on the analysis and maturation of spherical viruses. Our model provided important insights into the mechanisms underlying the shape changes of the protein capsomers forming the viral shell [4]. Subsequently, I sought the opportunity to join the Cardiac Modeling Group at UCLA to apply computational biomechanics to

studying cardiac function in health and disease. During this research, I deeply appreciated how rigorous computational tools combined with medical data offer irreplaceable understanding of cardiac kinematics [1], mechanics [2], and electrophysiology (see contribution C3 below) and can provide insight into new pharmacological and interventional therapies.

My PhD and first postdoctoral experience trained me in computational mechanics and in applying my numerical simulation skillset to complex problems in biomechanics. My training in the Radiological Sciences department at UCLA during my AHA postdoctoral fellowship and NHLBI K25 award allowed me to lead, plan, and carry out first-hand acute and chronic preclinical (swine) imaging experiments from beginning to end. The combination of these long training in engineering, MRI, and preclinical experiments provided me with direct knowledge of the complex aspects of cardiac MRI, data acquisition, and how to design new computational tools to extract information and mechanistic insights from the acquired imaging data.

The unique blend of skills that I developed are at the frontier between mechanical engineering, bioengineering, and radiological sciences. This skill set positions me as an optimal candidate to carry out and lead the research described in this proposal.

[1] I.A. Verzhbinsky, **L.E. Perotti**, K. Moulin, T.E. Cork, M. Loecher, D.B. Ennis: "Estimating Aggregate Cardiomyocyte Strain Using In Vivo Diffusion and Displacement Encoded MRI". IEEE transactions on medical imaging. Vol 39, Issue 3, pp. 656-667, 2020. PMID: 31398112. PMCID: PMC7325525.

[2] **L.E. Perotti**, A.V. Ponnaluri, S. Krishnamoorthi, D. Balzani, D.B. Ennis, W.S. Klug: "Method for the unique identification of hyperelastic material properties using full field measures. Application to the passive myocardium material response". International Journal for Numerical Methods in Biomedical Engineering. Vol. 33, pp. e2866, 2017. PMCID: PMC5515704.

[3] S. Dharmavaram, **L.E. Perotti**: "A Lagrangian formulation for interacting particles on a deformable medium". Computer Methods in Applied Mechanics and Engineering. pp. 364:112949, 2020. doi: 10.1016/j.cma.2020.112949.

[4] **L.E. Perotti**, K. Zhang, J. Rudnick, R.F. Bruinsma: "Kirigami and the Caspar-Klug construction for viral shells with negative Gauss curvature". Physical Review E. Vol 99, Issue 2, pp. 022413, 2019. PMID: 30934272.

B. Positions and Honors

Positions

2010 - 2011 Postdoctoral Scholar, Dept. of Aerospace Eng., Caltech, Pasadena, CA
2011 - 2014 Postdoctoral Scholar, Mechanical and Aerospace Eng., UCLA, Los Angeles, CA
2013 Instructor for Introductory Finite Element Class, Mechanical and Aerospace Eng., UCLA, Los Angeles, CA
2014 - 2016 Postdoctoral Scholar, Dept. of Radiological Sciences, UCLA, Los Angeles, CA
2014 - 2016 Postdoctoral Scholar, Dept. of Bioengineering (courtesy appointment), UCLA, Los Angeles, CA
2016 - 2018 Associate Project Scientist, Dept. Radiological Sciences, UCLA, Los Angeles, CA
2016 - 2018 Associate Project Scientist, Dept. of Bioengineering (courtesy appointment), UCLA, Los Angeles, CA
2019 - now Assistant Professor, Dept. of Mechanical and Aerospace Eng., Univ. of Central Florida, Orlando, FL

Honors

2005 - 2006 Daniel and Florence Guggenheim Fellowship (California Institute of Technology)
2013 U.S. National Congress on Computational Mechanics Travel Award
2014 - 2016 American Heart Association Postdoctoral Fellowship (14POST19890027)
2017 Best Paper Award at Functional Imaging and Modeling of the Heart International Conference
2017-2020 NHLBI K25 Mentored Quantitative Research Development Award (HL135408)

C. Contributions to Science

1. CARDIAC KINEMATICS – In the last 4 years I have developed new computational methods to compute microstructurally anchored measures of cardiac strains [1A-1C]. Myocardial strains characterize cardiac function, but are typically measured in an arbitrary reference system that depends on the definition of the ventricle long axis and are not linked to the cardiac microstructure, i.e., the preferential direction of aggregate cardiomyocyte. Together with Dr. Ennis, our goal has been to measure directly the shortening and relaxation of aggregate cardiomyocyte as they are mechanistically responsible for the contraction and relaxation of the ventricles. We

were the first group to combine *in vivo* cardiac motion (using DENSE MRI) and cardiac microstructural data (using cDTI) [1D] to compute myofiber strains (E_{ff}) [1A, 1B]. We have also studied new microstructurally anchored measures of cardiac deformation to quantify both the myocardial response in the direction of the cardiomyocytes and the extracellular matrix response [1B]. As a result of our work, we were able not only to compute microstructurally anchored cardiac strains, but also to investigate the effect of cardiac motion on cardiomyocyte orientation during the cardiac cycle [1C]. This mechanistic link between cardiac motion and cardiac microstructure allows us to measure cardiomyocyte shortening and relaxation, and therefore to link cellular function to global cardiac motion.

[1A] I.A. Verzhbinsky, **L.E. Perotti**, K. Moulin, T.E. Cork, M. Loecher, D.B. Ennis: "Estimating Aggregate Cardiomyocyte Strain Using In Vivo Diffusion and Displacement Encoded MRI". IEEE transactions on medical imaging. Vol 39, Issue 3, pp. 656-667, 2020. PMID: 31398112. PMCID: PMC7325525.

[1B] **L.E. Perotti,** P. Magrath P, I.A. Verzhbinsky, E. Aliotta, K. Moulin, D.B. Ennis: "Microstructurally Anchored Cardiac Kinematics by Combining *In Vivo* DENSE MRI and cDTI." Proceedings of International Conference on Functional Imaging and Modeling of the Heart, 2017, pp. 381-391. PMID: 29450409; PMCID: PMC5808941.

[1C] I.A. Verzhbinsky, P. Magrath, E. Aliotta, D.B. Ennis, **L.E. Perotti**: Time resolved displacement-based registration of in vivo cDTI cardiomyocyte orientations. Proceedings of IEEE 15th International Symposium on Biomedical Imaging (ISBI 2018), pp. 474-478. PMID: 30559922; PMCID: PMC6294325.

[1D] T.E. Cork, **L.E. Perotti**, I.A. Verzhbinsky, M. Loecher, D.B. Ennis: "High-Resolution *Ex Vivo* Microstructural MRI After Restoring Ventricular Geometry via 3D Printing". Proceedings of International Conference on Functional Imaging and Modeling of the Heart, 2019, pp.:177-186. PMID: 31432042; PMCID: PMC6701689.

2. CARDIAC MECHANICS – My research on cardiac motion is closely related to my focus on modeling cardiomyocyte electrophysiology (see C3 below) and mechanics to understand ventricular contraction in health and disease. As in my studies on cardiac kinematics, the cardiomyocyte shortening and relaxation remain the mechanistic drivers for ventricular systole and filling. In order to develop subject specific models that can aid diagnosis and therapy planning, my first step has been developing a new computational tool to model the passive response of the myocardium during late filling [2A]. Diastolic function is compromised in numerous cardiac diseases, including heart failure with preserved ejection fraction (HFpEF), the focus of my NHLBI K25 sponsored research. A main goal of my research was to link left ventricular pressure to cardiac motion to compute passive myocardial stiffness, a key biomarker to characterize heart health. One of the main problems with existing models was their inability to compute uniquely the passive myocardium material properties and therefore material properties computed using previous approaches could not be used as biomarkers to understand the onset and progression of cardiac disease. During my NHLBI K25 sponsored research, I have also tested a procedure to acquire left ventricular pressure by catheterizing the left ventricle under MR guidance only [2D], therefore streamlining the process and avoiding the need to perform this procedure using fluoroscopy. Subsequently, I have focused on modeling the active contraction of the cardiomyocyte with a sophisticated model that incorporates the Frank Starling effect [2B], often neglected in other computational approaches. We were also among the first groups to recognize the crucial role of boundary conditions in models of cardiac contraction [2C], while standard approaches often constrain the base of the left ventricle leading to unphysiological cardiac motion. As in the study of cardiac electrophysiology (please see C3 below), our focus has always been on identifying and achieving the validation criteria that our models need to satisfy, as only validated models can have an impact in the clinic.

[2A] **L.E. Perotti**, A.V. Ponnaluri, S. Krishnamoorthi, D. Balzani, D.B. Ennis, W.S. Klug: "Method for the unique identification of hyperelastic material properties using full field measures. Application to the passive myocardium material response". International Journal for Numerical Methods in Biomedical Engineering. Vol. 33, pp. e2866, 2017. PMCID: PMC5515704.

[2B] A.V. Ponnaluri, **L.E. Perotti**, D.B. Ennis, W.S. Klug: "A Viscoactive Constitutive Modeling Framework with Variational Updates for the Myocardium". Computer Methods in Applied Mechanics and Engineering, Vol. 314, pp. 85-101, 2017. PMCID: PMC5450674.

[2C] A.V. Ponnaluri, I.A. Verzhbinsky, J.D. Eldredge, A. Garfinkel, D.B. Ennis, **L.E. Perotti**: "Model of Left Ventricular Contraction: Validation Criteria and Boundary Conditions". Proceedings of International Conference on Functional Imaging and Model of the Heart. Jun 2019, pp. 294-303. PMID: 31231721; PMCID: PMC6588286.

[2D] X. Li, **L.E. Perotti**, J.A. Martinez, S.M. Duarte-Vogel, D.B. Ennis, H.H. Wu: "Real-time 3T MRI-guided cardiovascular catheterization in a porcine model using a glass-fiber epoxy-based guidewire". PLoS One. 2020; Vol. 15, Issue 2, pp. 0229711, 2020. PMID: 32102092; PMCID: PMC7043930.

3. CARDIAC ELECTROPHYSIOLOGY – My research on complex cardiac computational models began with studying the electrophysiology of arrhythmias. After developing, verifying, and validating a rigorous finite element model to study the normal activation of the heart [3A, 3B], I worked to develop a model of congestive heart failure to investigate the roles of different ion channels and microstructural changes in triggering ventricular tachycardia and fibrillation [3C]. Accurate and rigorous finite element models offer the unique capability to separate the mechanisms leading to arrhythmic conditions and to distinguish specific targets for pharmacological therapies. Our work is among the first to rigorously validate computational models for cardiac electrophysiology, placing a strong emphasis on clear criteria ranging from the restitution curve of the cell models, to the cardiac activation sequence, to the computed ECG, and the ability to initiate ventricular fibrillation under different conditions in the healthy [3A] and diseased heart [3C]. The ECG is the most used and accessible diagnostic tool in cardiac clinical practice but, before our work, only a few researchers computed and reported in the literature an ECG. Our work was the first to correctly compute this critical validation criteria without unphysiological fractionations in models representing healthy patients. Only validated and robust computational tools can provide useful insights for clinical applications.

[3A] S. Krishnamoorthi, **L.E. Perotti**, N.P. Borgstrom, O.A. Ajijola, A. Frid, A.V. Ponnaluri, J.N. Weiss, Z. Qu, W.S. Klug, D.B. Ennis, A. Garfinkel: "Simulation Methods and Validation Criteria for Modeling Cardiac Ventricular Electrophysiology". PLOS ONE, Vol. 9, Issue 12, pp. e114494, 2014. PMCID: PMC4262432.

[3B] **L.E. Perotti**, S. Krishnamoorthi, N.P. Borgstrom, D.B. Ennis, W.S. Klug: "Regional segmentation of ventricular models to achieve repolarization dispersion in cardiac EP modeling". International Journal for Numerical Methods in Biomedical Engineering, Vol. 31, Issue 8, pp. e02718, 2015. PMCID: PMC4519348.

[3C] A.V. Ponnaluri, **L.E. Perotti**, M. Liu, Z. Qu, J.N. Weiss, D.B. Ennis, W.S. Klug, and A. Garfinkel: "Electrophysiology of Heart Failure using a Rabbit Model: from the Failing Myocyte to Ventricular Fibrillation". PLOS Computational Biology, Vol. 12, Issue 6, pp. e1004968, 2016. PMCID: PMC4919062.

4. MODELING VIRUS MATURATION AND ASSEMBLY – I have also applied my computational and modeling expertise to other biological systems and, in particular, to the study of viral capsids [4A-4D]. The computational framework and theoretical underpinnings are very closely related to my work in cardiac modeling. Biomechanical models of viral capsids provide unique explanations and predictions of the mechanisms underlying, for example, viral capsid assembly [4A, 4B] and shape changes [4C, 4D]. One of the major novelties in our work is the modeling of protein capsomers conformational pre-stretch or pre-shear [4B]. This mechanism is experimentally observed and, once accurately modeled, provides explanations on why it is used by a class of spherical viruses during maturation. Indeed, capsomer pre-stretch lowers the energy of capsid assembly, provides an organizational principle, and promotes self-correction of assembly errors [4A]. The combination of computational mechanics models and cryo-electron microscopy experimental data led to the discovery of these novel insights into the virus assembly pathway. The application of continuum mechanics theory and computational mechanics framework to largely different systems and scales is proof that these tools offer a versatile and quantitative approach to investigate the mechanisms underlying biological phenomena.

[4A] **L.E. Perotti**, J. Rudnick, R. Bruinsma, W.S. Klug: "Statistical Physics of Viral Capsids with Broken Symmetry". Physical Review Letters, Vol. 115, Issue 5, pp. 058101, 2015. PMID: 26274443.

[4B] **L.E. Perotti**, A. Aggarwal, J. Rudnick, R. Bruinsma, W.S. Klug: "Elasticity Theory of the Maturation of Viral Capsids". Journal of the Mechanics and Physics of Solids, Vol 77, pp. 86-108, 2015.

[4C] **L.E. Perotti**, K. Zhang, J. Rudnick, R.F. Bruinsma: "Kirigami and the Caspar-Klug construction for viral shells with negative Gauss curvature". Physical Review E, Feb;99 (2-1), pp 022413, 2019. PMID: 30934272.

[4D] **L.E. Perotti**, S. Dharmavaram, W.S. Klug, J. Marian, J. Rudnick, R. Bruinsma: "Useful Scars: Physics of the Capsids of Archaeal Viruses". Physical Review E, Vol. 94, Issue 1, pp. 012404, 2016. PMID: 27575161.

5. COMPUTATIONAL MODELING – During my PhD and postdoctoral research at Caltech, I have trained in developing new computational methods to solve complex problems and multi-physics applications. First, I have formulated and verified a new finite element model that avoided a common locking phenomenon in plate analysis [5A]. Locking is a vexing problem in computational mechanics since it leads to an overly stiff model response

and very inaccurate numerical results. Secondly, I contributed to the development of new mesh-free methods [5B], which are an optimal tool for the analyses of bodies undergoing large deformations such as the heart. Lastly, I studied fluid structure interaction (FSI) in pipes and fiber-composite sandwich structures undergoing underwater shock loading [5C] and the effect of hypervelocity impacts on metal plates [5D]. These complex analyses involve the simultaneous solution of fluid and solid mechanics governing equations and require overcoming several challenges including: 1) communications between the fluid and the solid domains; and 2) adaptive domain refinement to follow and accurately model the propagation of shock waves. The proficiency in computational and continuum mechanics achieved during my studies and demonstrated in peer-reviewed publications in well-regarded journals will be instrumental to carrying out the specific aims of this proposal.

[5A] **L.E. Perotti**, A. Bompadre, M. Ortiz: "Automatically inf-sup compliant diamond mixed finite elements for Kirchhoff plates". International Journal for Numerical Methods in Engineering, Vol. 96, Issue 7, pp. 405-424, Nov 2013.

[5B] Bompadre, **L.E. Perotti**, C.J. Cyron, M. Ortiz: "Convergent meshfree approximation schemes of arbitrary order and smoothness". Computer Methods in Applied Mechanics and Engineering, Vols. 221-222, pp. 83-103, 2012.

[5C] **L.E. Perotti**, R. Deiterding, K. Inaba, J. Shepherd, M. Ortiz: "Elastic response of water-filled fiber composite tubes under shock wave loading". International Journal of Solids and Structures, Vol. 50, Issues 3-4, pp. 473-486, 2013.

[5D] B. Li, **L. Perotti**, M. Adams, J. Mihaly, A.J. Rosakis, M. Stalzer, M. Ortiz: "Large scale Optimal Transportation Meshfree (OTM) simulations of hypervelocity impact". Procedia Engineering, Vol. 58, pp. 320-327, 2013.

A complete list of peer-reviewed publications and conference contributions may be found at:
https://www.ncbi.nlm.nih.gov/myncbi/luigi.perotti.1/bibliography/public/

D. Additional Information: Research Support

ONGOING RESEARCH SUPPORT

Departmental support (PI Perotti) **01.02.2019 to 01.01.2022**

Start-up funds to initiate research program

These funds are designed to initiate Dr. Perotti research program at UCF and can be used for research equipment, computers, software licenses, research related travels, and other expenditures related to Dr. Perotti's laboratory and research including support for graduate students and postdoctoral associates.

Role: Principal Investigator

COMPLETED RESEARCH SUPPORT

NIH/NHLBI/K25 (PI Perotti, HL135408) **02.01.2017 to 01.31.2020**

Defining and Measuring Diastolic Myocardial Kinematics and Stiffness

The goal of this study is to develop a continuum mechanics and computational framework to define and identify regional, microstructurally anchored measures of diastolic strain and the local isotropic/anisotropic stiffness of passive myocardium using a swine model. These strain and stiffness measures are defined to maximize diagnostic sensitivity and reproducibility.

Role: Principal Investigator

NIH/NHLBI/R01 (PI Ennis, HL131823) **09.01.2017 to 08.31.2021**

Dr. Perotti support from this project ended on 07/2018

A New Framework for Understanding the Mechanisms of Diastolic Dysfunction

The goal of this project is to develop and combine patient-specific clinical MRI and LV pressure data in a computer model to diagnose changes in diastolic myocardial stiffness in patients with HFpEF.

Role: Co-Investigator

BIOGRAPHICAL SKETCH

Provide the following information for the Senior/key personnel and other significant contributors.
Follow this format for each person. DO NOT EXCEED FIVE PAGES.

NAME: Huang, Helen

eRA COMMONS USER NAME (credential, e.g., agency login): hjhuang

POSITION TITLE: Assistant Professor

EDUCATION/TRAINING *(Begin with baccalaureate or other initial professional education, such as nursing, include postdoctoral training and residency training if applicable. Add/delete rows as necessary.)*

INSTITUTION AND LOCATION	DEGREE (if applicable)	END DATE MM/YYYY	FIELD OF STUDY
Massachusetts Institute of Technology, Cambridge, MA	BS	05/2001	Materials Science and Engineering
University of Michigan, Ann Arbor, MI	MS	05/2004	Biomedical Engineering
University of Michigan, Ann Arbor, MI	PHD	05/2009	Biomedical Engineering
University of Colorado, Boulder, CO	NIH training grant	10/2012	Integrative Physiology of Aging

A. Personal Statement

As one of the biomedical engineering (BME) focused tenure track faculty members in the Mechanical and Aerospace Engineering Department at the University of Central Florida (UCF), I am extremely excited to be part of growing the BME graduate program and helping to increase the UCF BME group's reputation of conducting advanced BME research. Being able to offer a BME PhD is critical to the recruitment of the best PhD students to conduct my research, and my current and former students have expressed the desire and expectation of graduating with a BME PhD. I direct the UCF Biomechanics, Rehabilitation, and Interdisciplinary Neuroscience (BRaIN) Lab. Students in my lab come from multiple disciplines such as biomedical engineering, mechanical engineering, computer engineering, electrical engineering, and biomedical sciences. I have expertise multimodal neuromechanics of human locomotion and motor adaptation and in mobile brain/body imaging. The lab is funded by an NIH R01, "Adaptation of brain and body responses to perturbations during gait in young and older adults" (NIH R01AG054621, role: PI, 09/2017-05/2022), which focuses on understanding how brain processes for balance, stepping, and walking change with age, and an NSF CAREER Award (#1942712, "CAREER: Leveraging electroencephalography (EEG) artifacts for multimodal neuromechanics," role: PI, 08/01/2020-07/31/2025) to develop new EEG methodologies using machine learning. I have taught multiple BME courses (Engineering Biomechanics; Advanced Biomechanics; Bioinstrumentation; and Topics in Biomedical Engineering), which were well-received.

1. Castano CR, Huang HJ. Speed-related but not detrended gait variability increases with more sensitive self-paced treadmill controllers at multiple slopes. PLoS One. 2021;16(5):e0251229. PubMed PMID: 33961654.
2. Shirazi SY, Huang HJ. Differential Theta-Band Signatures of the Anterior Cingulate and Motor Cortices During Seated Locomotor Perturbations. IEEE Trans Neural Syst Rehabil Eng. 2021;29:468-477. PubMed Central PMCID: PMC7989773.
3. Li J, Wang P, Huang HJ. Dry Epidermal Electrodes Can Provide Long-Term High Fidelity Electromyography for Limited Dynamic Lower Limb Movements. Sensors (Basel). 2020 Aug 27;20(17) PubMed Central PMCID: PMC7506900.
4. Shirazi SY, Huang HJ. More Reliable EEG Electrode Digitizing Methods Can Reduce Source Estimation Uncertainty, but Current Methods Already Accurately Identify Brodmann Areas. Front Neurosci. 2019;13:1159. PubMed Central PMCID: PMC6856631.

B. Positions, Scientific Appointments and Honors

Positions and Scientific Appointments

2019 -	Assistant Professor, Disability, Aging, and Technology (DAT) Cluster, University of Central Florida, Orlando, FL
2019 -	Assistant Professor, Bionic Materials, Implants, and Interfaces (Biionix) Cluster, University of Central Florida, Orlando, FL
2015 -	Assistant Professor, Mechanical and Aerospace Engineering, College of Engineering and Computer Science, University of Central Florida, Orlando, FL
2012 - 2015	Assistant Research Scientist, School of Kinesiology, University of Michigan, Ann Arbor, MI
2001 - 2002	Process Engineer, Michelin North America, Sandy Springs, SC

Honors

2021	Research Incentive Award, University of Central Florida
2021	Graduate Faculty Spotlight for Women's History Month, University of Central Florida
2021	Editor's Pick, Frontiers in Neuroscience Brain Imaging Methods
2021	Reach for the Stars Award, University of Central Florida
2020	Luminary Award, University of Central Florida
2020	President's Award (best poster), American Society of Biomechanics
2020	NSF Faculty Early Career Development (CAREER) Award, National Science Foundation
2019	Invited Participant, US National Academy of Engineering (NAE) 2019 China-America Frontiers of Engineering (CAFOE)
2019	Travel Award for Recognition of Faculty Excellence, University of Central Florida
2017	Trainee, Training in Grantsmanship for Rehabilitation Research (TIGRR) Program
2016	Faculty Travel Award, University of Central Florida
2011	Best post-doc poster presentation, Front Range Neuroscience Group Annual Meeting
2011	Scholarship Award, Society for the Neural Control of Movement
2011	Top Ten, Advances in Computational Motor Control Conference
2009 - 2011	Institutional Training Grant (T32) Postdoctoral Fellowship, NIH National Institute on Aging
2006 - 2009	Individual Predoctoral Fellowship (F31), NIH National Institute of Neurological Disorders and Stroke

C. Contribution to Science

1. Electrocortical dynamics of locomotor tasks - Understanding brain dynamics during locomotion can help inform the design of rehabilitation robotic devices and potentially could be used to customize gait rehabilitation therapies for individual patients. I study electrocortical dynamics during locomotor tasks and am developing better methods and sensors for collecting EEG data during dynamic movements. I have found that adding arm effort during rhythmic stepping produced greater spectral fluctuations than legs only stepping. In another study, I found that recumbent stepping uses a different network of brain areas compared to walking and that spectral fluctuations during recumbent stepping and walking both occur at limb transitions, from flexion to extension and swing to stance, respectively. Because EEG signals are highly susceptible to motion artifacts, particularly during walking, that may obscure neural signals, I helped develop a novel method to isolate and measure the movement artifact recorded in the EEG electrodes. I found that isolated motion artifact data have some characteristics like actual EEG data measured from the scalp. Also, Independent Components Analysis (ICA) can separate out most of the artifact-based sources, but not all. This knowledge is critical for accounting for motion artifact in EEG data recorded during walking and has helped to improve the interpretation of EEG results during gait. This work has also led to the development of novel dual-layer electrodes that has been shown to be able to recover high fidelity simulated source signals. I served as the research scientist and helped conceive the experiments, collect and analyze the data, present the findings at conferences, and publish the results.

a. Shirazi SY, Huang HJ. Differential Theta-Band Signatures of the Anterior Cingulate and Motor Cortices During Seated Locomotor Perturbations. IEEE Trans Neural Syst Rehabil Eng. 2021;29:468-477. PubMed Central PMCID: PMC7989773.
b. Kline JE, Huang HJ, Snyder KL, Ferris DP. Cortical Spectral Activity and Connectivity during Active and Viewed Arm and Leg Movement. Front Neurosci. 2016;10:91. PubMed Central PMCID: PMC4785182.
c. Snyder KL, Kline JE, Huang HJ, Ferris DP. Independent Component Analysis of Gait-Related Movement Artifact Recorded using EEG Electrodes during Treadmill Walking. Front Hum Neurosci. 2015;9:639. PubMed Central PMCID: PMC4664645.
d. Kline JE, Huang HJ, Snyder KL, Ferris DP. Isolating gait-related movement artifacts in electroencephalography during human walking. J Neural Eng. 2015 Aug;12(4):046022. PubMed Central PMCID: PMC4946867.

2. Neuromuscular control of a locomotor task - Arm swing is a natural feature in human gait; however, gait rehabilitation robotic devices typically do not incorporate arm swing. I proposed that using the upper limbs during a locomotor task could improve lower limb neuromuscular recruitment and serve as a basis for selfassisted neurorehabilitation. In healthy individuals and individuals with incomplete spinal cord injury, I found that upper limb effort can enhance lower limb neuromuscular recruitment during a locomotor task, but the effects were limited. Other researchers have since published papers showing that including arm swing while using a robotic gait trainer can help recruit and shape lower limb muscle activation in clinical populations, further providing support for my findings. I served as the primary graduate student researcher and helped conceive the experiment, collect and analyze the data, present the findings at conferences, and publish the results.

a. Huang HJ, Ferris DP. Upper and lower limb muscle activation is bidirectionally and ipsilaterally coupled. Med Sci Sports Exerc. 2009 Sep;41(9):1778-89. PubMed Central PMCID: PMC2769567.
b. Huang HJ, Ferris DP. Upper limb effort does not increase maximal voluntary muscle activation in individuals with incomplete spinal cord injury. Clin Neurophysiol. 2009 Sep;120(9):1741-9. PubMed Central PMCID: PMC2763629.
c. Ferris DP, Huang HJ, Kao PC. Moving the arms to activate the legs. Exerc Sport Sci Rev. 2006 Jul;34(3):113-20. PubMed PMID: 16829738.
d. Huang HJ, Ferris DP. Neural coupling between upper and lower limbs during recumbent stepping. J Appl Physiol (1985). 2004 Oct;97(4):1299-308. PubMed PMID: 15180979.

3. Minimization of error and effort during motor adaptation of arm reaching tasks - A prevailing thought in motor control is that preferred movements minimize effort, but there were no studies that measured metabolic cost during arm reaching and over the course of motor adaptation. I demonstrated that expired gas analysis could be used to measure significant differences in metabolic cost in arm reaching and during motor adaptation. I found a reduction in metabolic cost when young and older adults adapted reaching movements to compensate for novel force perturbations and also, interestingly, for a visuomotor rotation, that does not involve any force perturbations. I also found that an intermediate arm reaching speed minimizes metabolic cost and that the preferred reaching speed tracks the metabolically optimal reaching speed across different reach distances. Overall, my findings suggest that minimization of effort and error may be general feature of motor adaptation and motor control. These findings have since been used to develop computational models of decision-making in movement and motor control, which have provided additional insight about motor control. I served as the research associate and helped conceive the experiment, collect and analyze the data, present the findings at conferences, and publish the results.

a. Shadmehr R, Huang HJ, Ahmed AA. A Representation of Effort in Decision-Making and Motor Control. Curr Biol. 2016 Jul 25;26(14):1929-34. PubMed Central PMCID: PMC7912535.
b. Huang HJ, Ahmed AA. Reductions in muscle coactivation and metabolic cost during visuomotor adaptation. J Neurophysiol. 2014 Nov 1;112(9):2264-74. PubMed PMID: 25098963.
c. Huang HJ, Ahmed AA. Older adults learn less, but still reduce metabolic cost, during motor adaptation. J Neurophysiol. 2014 Jan;111(1):135-44. PubMed Central PMCID: PMC3921372.

d. Huang HJ, Kram R, Ahmed AA. Reduction of metabolic cost during motor learning of arm reaching dynamics. J Neurosci. 2012 Feb 8;32(6):2182-90. PubMed Central PMCID: PMC3865509.

4. Development and evaluation of sensors and methodologies for multimodal neuromechanics - To advance the ability to conduct multimodal human movement experiments, sensors are evolving to be thinner and for long-term use. I have shown that a thin dry epidermal electrode can be used to measure long-term EMG signals with high fidelity for limited dynamic lower limb movements but not for walking. I have also shown that thin tunable strain sensors can be used to measure joint movement. Analyzing muscle and brain activity using electromyography (EMG) and electroencephalography (EEG) often rely on signal processing methods, which may lead to divergent results. I found that regardless of the co-contraction index and EMG normalization method used, muscle co-contraction was not employed universally among individuals after stroke. I also found that more reliable methods for digitizing EEG electrode locations reduced the uncertainty of source estimation but less reliable digitization methods did not affect the accuracy of identifying Brodmann areas. I served as a collaborator and PI on these projects, helping to conceive the experiment, analyze and interpret the data, mentor mentees, provide resources, and disseminate findings at science conferences and in publications.

   a. Li J, Wang P, Huang HJ. Dry Epidermal Electrodes Can Provide Long-Term High Fidelity Electromyography for Limited Dynamic Lower Limb Movements. Sensors (Basel). 2020 Aug 27;20(17) PubMed Central PMCID: PMC7506900.
   b. Shirazi SY, Huang HJ. More Reliable EEG Electrode Digitizing Methods Can Reduce Source Estimation Uncertainty, but Current Methods Already Accurately Identify Brodmann Areas. Front Neurosci. 2019;13:1159. PubMed Central PMCID: PMC6856631.
   c. Wang X, Li J, Song H, Huang H, Gou J. Highly Stretchable and Wearable Strain Sensor Based on Printable Carbon Nanotube Layers/Polydimethylsiloxane Composites with Adjustable Sensitivity. ACS Appl Mater Interfaces. 2018 Feb 28;10(8):7371-7380. PubMed PMID: 29432684.
   d. Banks CL, Huang HJ, Little VL, Patten C. Electromyography Exposes Heterogeneity in Muscle Co-Contraction following Stroke. Front Neurol. 2017;8:699. PubMed Central PMCID: PMC5743661.

Complete List of Published Work in My Bibliography:
https://www.ncbi.nlm.nih.gov/myncbi/helen.huang.1/bibliography/public/

BIOGRAPHICAL SKETCH

Provide the following information for the Senior/key personnel and other significant contributors. Follow this format for each person. ***DO NOT EXCEED FIVE PAGES.***

NAME: Olusegun Johnson Ilegbusi

eRA COMMONS USER NAME (credential, e.g., agency login): OJILEGBUSI

POSITION TITLE: Professor

EDUCATION/TRAINING *(Begin with baccalaureate or other initial professional education, such as nursing, include postdoctoral training and residency training if applicable. Add/delete rows as necessary.)*

INSTITUTION AND LOCATION	DEGREE	Completion Date	FIELD OF STUDY
University of Ibadan, Nigeria	B.S.	06/1979	Mechanical Engineering
Imperial College, University of London	Ph.D.	06/1983	Mechanical Engineering
Imperial College, University of London	Post Doctor	08/1984	Computational Fluid Dynamics
Massachusetts Institute of Technology (MIT)	Post Doctor	09/1987	Materials Engineering
Massachusetts Institute of Technology (MIT)	Advanced Studies	12/1987	Management

A. Personal Statement.

My expertise is in the computational modeling of biomedical systems across dimensional scales, with successful leadership of several bio-systems modeling projects and grants. I am the director of the Biomedical Research and Modeling Laboratory at UCF. I will lead the numerical modelling of cellular mechanics component of the present project, relying on techniques already developed and successfully applied in my lab. I was a leading member of the team that developed PHOENICS, the first commercial multi-purpose Computational Fluid Dynamics (CFD) code in the world for simulation of a wide range of engineering and biomedical processes. I played a lead role in collaboration with the Harvard Medical School (Brigham and Women's Hospital) to pioneer the integration of Intravascular Ultrasound Imaging with CFD for flow profiling of human coronary disease on projects funded by the National Science Foundation (NSF), NIH, Johnson and Johnson, and Boston Scientific Company. The integrated system was successfully used by Astra Zeneca for assessment of the efficacy of new drugs for cardiovascular disease, and Boston Scientific for the design of drug-eluting stents. We have extended the biomechanical modeling technique to the respiratory system on a variety of pioneering projects. We pioneered integration of CFD with CT imaging for the first determination of the patient-specific elastic property of human lungs and the simulation of tumor motion in non-small-cell lung cancer. The research led to the invention of patient-specific deformable lung phantom for radiotherapy quality assurance. We have recently applied our approach to microstructural characterization of tissue engineering scaffolds and cellular behavior. The techniques and findings of these previous projects bear direct heritage to the present application.

B. Positions and Honors

Positions and Employment

1983 - 1984 Post-Doctoral Associate, Imperial College, London

1984 – 1985 Lecturer 1 (USA Equivalent: Assistant Professor), University of Ibadan, Nigeria
1985 Visiting Lecturer, Imperial College of Science, Engineering and Medicine, London
1986 – 1990 Research Associate, Materials Engineering, Massachusetts Institute of Technology
1990 – 1992 Principal Research Associate, Massachusetts Institute of Technology
1992 – 1999 Associate Professor, Northeastern University, Boston
1999 – 2000 Visiting Professor, Massachusetts Institute of Technology
2000 – 2002 Professor, Northeastern University, Boston
2002 - Provost Research Excellence Professor, University of Central Florida

Other Experience and Professional Memberships

1988, Consultant and Lecturer, Toshiba Ceramics, Japan.
1988, Consultant and Lecturer, Nippon Steel, Japan.
1989, Consultant, Kawasaki Steel, Japan.
1989, Consultant, Outokumpu Steel, Finland.
1989, Consultant, Hoogovens BFP, The Netherlands.
1994-1996, Consultant, United Nations Development Program (UNDP-TOKTEN).
1995, NASA Faculty Fellowship, NASA GLEN, Cleveland, OH.
1997, 2001, Naval Research Laboratory Faculty Fellowship, Washington DC.
1999-2003, Editorial Boad Member, Journal of Materials Processing and Manufacturing Science.
2001, Visiting Scientist, Hokkaiddo University, Sapporo, Japan.

Honors

1979, Graduated with First Class Honors, University of Ibadan, Nigeria.
1984, Mike Akrill Trophy of the British Heat Transfer Society for Top Graduating Student**.**
1995, 1996, ALCOA Researcher of the Year Merit Awards**,** Aluminum Company of America.
1999-2000, Martin Luther King Jr. Scholar, MIT.
2020 Fellow, American Society of Mechanical Engineering

Patents

1. Magnetic Streamlining and Flow Control in Tundishes, J. Szekely and O.J. Ilegbusi. U.S. Patent No. 4,824,078, April 1989.
2. Active Magnetic Flow Control in Czochralski Growth of Semi-Conductor Crystals, O.J. Ilegbusi and J. Szekely, US 005196085A, March 23, 1993.
3. Optical Probes for Imaging Narrow Vessels or Lumens, J. Rolland, O.J. Ilegbusi,: 20070191682, August 16, 2007.
4. Systems and Methods for Evaluating Vessels, O.J. Ilegbusi and J. Rolland, US 2008/0228086 A1, Sep. 18, 2008.
5. Physical Deformable Lung Phantom with Subject-Specific Elasticity, A. Santhanam and O.J. Ilegbusi, 21225738, 15 Jan, 2015.

C. Contribution to Science

1. Computational Fluid Dynamics

   My early research interest was in the development of novel unified numerical methods for simulation of a wide variety of practical problems. Traditionally, software codes based on computational fluid dynamics (CFD) had been specialized, with different techniques and codes required for different applications. I was a pioneer member of the team that developed PHOENICS, the first commercial multi-purpose CFD code in the world. I published the first report describing the application of that code. My subsequent research then focused on the universality of the technique embodied in PHOENICS through adaptation and application to a wide variety of complex problems including turbulence phenomena, multiphase flows and materials processing.

   a. Ilegbusi, O.J. and Spalding D.B., "A two-fluid model of turbulence and its application to near- wall flows", PCH PhysicoChemical Hydrodynamics, Vol. 9, No. 1/2, (1987), pp.127-160.
   b. Ilegbusi, O.J. and Spalding D.B., "Application of a two-fluid model of turbulence to flows in conduits and free shear layers", PCH PhysicoChemical Hydrodynamics, Vol. 9, No. 1/2, (1987), pp.161-181.
   c. Iguchi, M. and Ilegbusi, O.J., *Multiphase Flow Phenomena in Materials Processes: Gas-Liquid Systems*, Springer, New York, 2010.
   d. Iguchi, M. and Ilegbusi, O.J., *Basic Transport Phenomena in Materials Processing*, Springer Tokyo, 2014

2. Modeling of Blood flow in Coronary arteries

Having fully established and validated universal application of CFD technique as described above, my research then focused on extending it biomedical systems which traditionally had not been widely simulated. Our primary initial focus was in utilizing CFD to understand the focal nature of athlescerosis. I started by modeling blood flow phenomena in generic coronary arteries, with emphasis on the effect of artery geometry and blood rheology on hemodynamic stress distribution. The success of this effort led to collaboration with Harvard Medical School (Massachusetts General Hospital, Boston) on the simulation of blood interaction with optical fluid in laser angioplasty. We also extended the study to investigate light propagation in laser angioplasty.

a. Ilegbusi, O.J., Nosovitsky, V., "A model of blood interaction with optical-fluid guide for laser angioplasty," Annals of Biomedical Engineering, Vol. 25, (1997), pp. 653-664. PMID: 9236978
b. Nosovitsky, V., Ilegbusi, O.J., Jiang, J.J., Stone, P.H., Feldman, C.L., "Effects of curvature and stenosis-like narrowing on wall shear stress in a coronary artery model with phasic flow," Computers in Biomedical Research, Vol. 30, (1997), pp. 61-82. PMID: 9134307
c. Ilegbusi, O.J., Nosovitsky, V., DiMarzio, C., "Light guiding effect in a two-fluid model of laser angioplasty," IEEE Transactions of Biomedical Engineering, Vol. 44:7 (1997), pp. 61-82. PMID 9210819
d. Ilegbusi, O.J., Z. Hu, Nesto R , Waxman S , Cyganski D , Kilian J , Stone PH , Feldman CL. "Determination of Blood Flow and Endothelial Shear Stress in Human Coronary Artery in Vivo," The Journal of Invasive Cardiology, 11:11 (1999), pp. 667-674. PMID: 10745459

3. Flow Profiling of Coronary Disease

The next phase of my research involved extension of our established CFD technique to real human artery. Specifically, in collaboration with researchers from Harvard Medical School (Brigham and Women's Hospital, Boston) I integrated CFD with intravascular ultrasound imaging to reconstruct for the first time in the world, the 3D geometry of the human artery and simultaneously model blood flow in the artery. We thus developed the first in-vivo flow profiling of coronary artery disease in man, an approach that had never been undertaken. Our objective was to use the integrated technique to understand the genesis and progression of human coronary artery disease. We proceeded to use the method to assist in assessing drug efficacy (Astra Zenecca) and stent efficiency (Boston Scientific). We subsequenty extended the model to quantify for the first time, the relationship between the arterial structural dynamics and blood flow characteristics on incipient plaque rupture and the role they play in thrombus formation and myocardial infaction. Specifically, we established the first flow-structure intercation parameter that correlates with medical finding of potential vulnerable plaque to rupture.

a. Feldman, C.L., Ilegbusi, O.J., Hu, Z., Stone, P.H.. *Determination of in vivo velocity and endothelial shear stress patterns with phasic flow in human coronary arteries: a methodology to predict progression of coronary atherosclerosis.* Am Heart J 2002;143:931-939. PMID: 12075241
b. Ilegbusi, O.J., Hu, Z., Nesto, R., Waxman, S., Cyganski, D., Kilian, J., Stone, P.H., Feldman, C.L.. *Determination of blood flow and endothelial shear stress in human coronary artery in vivo*. J Invas Cardiol 1999; 11: 667-74. PMID: 10745459
c. Stone, P.H., Coskun, A.U., Kinlay, S., Clark, M.E., Sonka, M., Wahle, A., Ilegbusi, O.J., Popma, J.J., Orav, J., Kuntz, R.E., Feldman, C.L. *Effect of endothelial shear stress on the progression of coronary artery disease, vascular remodeling and in-stent restenosis in man as a function of endothelial shear stress; an in-vivo 6 month followup study.* Circulation. 2003;108:438-444.
d. Ilegbusi, O.J., Velaski-Teuma, E. "A fluid-structure interaction index of coronary plaque rupture," ISBMS 2010, Springer-Verlag, Berlin, 2010, 98-107.

4. Biomechanical Modeling of Lung Dynamics and Lung Cancer

Targeted radiotherapy relies on accurate representation of breath-induced tumor motion. Our respiratory research has focused on techniques to quantify lung motion through integration of computational fluid

dynamics (CFD) and imaging techniques. The first step in the study is the processing of images (4D CT Scan dataset and MRI) in order to reconstruct the true three-dimensional lung geometry. In order to utlize the reconstructed geometry for CFD simulation, it is crucial to determine the biomechanical property (specifically, elasticity) of human lung which did not exist. Lung parenchyma is heterogeneous with non-linear

elastic property. Thus we pioneered an inverse technique to integrate imaging with modeling to determine the exact spatial distribution of the elastic property of the lung with and without tumor. We then validated the approach by comparing breath-induced deformation predicted by the technique with values obtained at monitored landmarks by clinical experts. In an ongoing research we have started extending the validated approach to the upper airway to simulate the swallowing and coughing phenomena in patients with head and neck cancer. This ongoing research dovetails into the current proposal.

a. Santhanam, A., Min, A., Y., Papp, N., Bhargava, A. Erhart, K. Long, X., Neelakkantan, H., Mitchell, R., Ruddy, B.H., Divo, E., Kassab, A., Ilegbusi, O.J., Rolland, J., Meeks, S., Kupelian, P. Visualization of 3D volumetric lung dynamics for real-time lung radiotherapy. Studies in Health Technology and Informatics (2011), 163: 567-573. PMID: 21335858
b. Ilegbusi, O.J., Li, Z., Min, Y., Meeks, S., Kupelian, P., Santhanam, A. 2012. CFD modeling of airflow inside lungs using heterogenous anisotropic lung tissue elastic properties. Studies in Health Technology and Informatics, 173, 205-211.
c. Ilegbusi O.J., Z. Li, B. Noferest, Y. Min, S. Meeks, P. Kupelian, Santhanam, A.P. (2012). "Modeling Airflow Using Subject Specific 4DCT Based Deformable Volumetric Lung Models," *International Journal of Biomedical Imaging*.1-10. PMID: 23365554. PMCID: PMC3539421
d. Ilegbusi O.J., Seyfi B., Neylon J, and Santhanam A.P. (2015). "Analytic intermodal consistent modeling of volumetric human lung dynamics," *J. Biomechanical Engineering,* Vol. 137, 101005-1. PMID: 26292034

5. Tissue and Cellular Mechanics integrating Imaging

We have developed a method to integrate imaging with Computational Fluid Dynamics (CFD) for biomechanical modeling across dimensional scales ranging from tissues to organs. The algorithm couples CFD with image segmentation for microstructural characterization of scaffolds for bone tissue engineering applications. The method enables control of the scaffold pore structure which largely determines the bone mechanical properties as well as cell growth, proliferation, mobility, and nutrient delivery to the cells. The modeling results which include distributions of pore size, pore elongation and pore orientation were successfully validated with the experimental data. On the macrolevel, our approach has also been used to successfully model upper airway functionality including the effect of cancer of the tongue base on swallow, and cough dysfunction in patients with neurological diseases.

a. Ilegbusi O.J., N. Kuruppumullage, E. Silverman, V. Lewis, Lehman, J., & Ruddy, B. H. Mathematical modelling of tongue deformation during swallow in patients with head and neck cancer. Mathematical and Computer Modelling of Dynamical Systems, 22(6), 569-583, 2016.
b. Hoffman Ruddy, B., Nadun Kuruppumullage, D., Carnaby, G., Crary, M., Lehman, J., O.J. Ilegbusi. Computational Modelling of Cough Function and Airway Penetrant Behavior in Patients with Disorders of Laryngeal Function. Laryngoscope Investigative Otolaryngology, 2(1), 23-29, 2017.
c. Rouhollahi, O. Ilegbusi , S. Florczyk, K. Xu, H. Foroosh, Effect of Mold Geometry on Pore Size in Freeze-Cast Chitosan-Alginate Scaffolds for Tissue Engineering, Annals of Biomedical Engineering (2019) https://doi.org/10.1007/s10439-019-02381-3.
d. Rouhollahi, A., O. Ilegbusi , H. Foroosh, Segmentation and Pore Structure Estimation in SEM Images of Tissue Engineering Scaffolds Using Genetic Algorithm, Annals of Biomedical Engineering (2020) https://doi.org/10.1007/s10439-020-02638-2

Complete List of Published Work in MyBibliography:
http://www.ncbi.nlm.nih.gov/myncbi/browse/collection/49566486/?sort=date&direction=ascending

BIOGRAPHICAL SKETCH

Provide the following information for the Senior/key personnel and other significant contributors.
Follow this format for each person. **DO NOT EXCEED FIVE PAGES.**

NAME: Pal, Sudeshna

eRA COMMONS USER NAME (credential, e.g., agency login): PSUDESHNA

POSITION TITLE: Lecturer

EDUCATION/TRAINING *(Begin with baccalaureate or other initial professional education, such as nursing, include postdoctoral training and residency training if applicable. Add/delete rows as necessary.)*

INSTITUTION AND LOCATION	DEGREE *(if applicable)*	Completion Date MM/YYYY	FIELD OF STUDY
University of Calcutta, Kolkata, India	B.Sc.	1998	Chemistry
Jadavpur University, Kolkata, India	B.Tech.	2002	Biochemical Engineering
Jadavpur University, Kolkata, India	M.Tech.	2004	Biochemical Engineering
Michigan State University, East Lansing, MI	Ph.D.	2009	Biosystems Engineering, Biomedical Sensors
University of Rochester, Rochester, NY	Postdoc	2011	Biomedical Sensors & Biophotonics
University of Central Florida, Orlando, FL	Postdoc	2013	Biomechanics, Bio-inspired Systems & Controls

A. Personal Statement

My teaching and research interests are in the fields of system dynamics and control and biomedical engineering (BME). I have a diverse research background in Bioengineering with experience and expertise in sensors, biomedical diagnostic devices, bio-inspired systems and control, motion mechanics and analysis, and assistive and rehabilitative devices. Throughout my academic career, I have collaborated with multi-disciplinary teams of researchers', all of which have culminated in multiple journal and conference publications, book chapters and three patents. At the University of Central Florida (UCF), I teach undergraduate and graduate courses that include core Mechanical & Aerospace Engineering (MAE) courses and BME courses in the areas of Dynamics, Vibrations, Controls, Biomechanics and Rehabilitation Engineering. I have served as a senior design faculty advisor for over 50 senior design teams. I am actively involved in implementing novel pedagogical approaches such as blended learning, experiential learning and problem-based learning in teaching the undergraduate MAE curriculum at UCF. I have developed multiple undergraduate and graduate courses in the subfields of BME such as "Engineering Biomechanics", "Advanced Biomechanics", "Introduction to Rehabilitation Engineering", "Biodesign Summer Immersion" and "Topics in Biomedical Engineering" during my academic career at UCF. I co-direct the undergraduate teaching program entitled "Biodesign Program in Rehabilitation Engineering" at UCF, which is a collaborative project between the College of Engineering and the College of Medicine, the College of Health and Public Affairs and Orlando Veteran Affairs Hospital.

An ongoing project that I would like to highlight is:

R25HD096933 03/2018 – 02/2023
Role- PI
A Biodesign Program in Rehabilitation Engineering

B. Positions, Scientific Appointments, and Honors

Positions and Employment

7/02-7/04 Research Scholar, Department of Food & Biochemical Engineering, Jadavpur University Kolkata, India.

1/05-5/09 Graduate Research Assistant, Department of Biosystems & Agricultural Engineering, Michigan State University, East Lansing, MI.

5/09-7/11 Postdoctoral Research Associate, Department of Electrical & Computer Engineering, University of Rochester, Rochester, NY.

1/12-8/13 Postdoctoral Associate, Department of Mechanical & Aerospace Engineering, University of Central Florida, Orlando, FL.

9/13-12/14 Visiting Lecturer, Department of Mechanical & Aerospace Engineering, University of Central Florida, Orlando, FL.

1/15-1/17 Research Assistant Professor, Department of Mechanical & Aerospace Engineering, University of Central Florida, Orlando, FL.

2/17- present Lecturer, Department of Mechanical & Aerospace Engineering, University of Central Florida, Orlando, FL.

Membership in Professional Societies

2009-2016 Institute of Electrical and Electronics Engineers (IEEE)

2009-2016 Optical Society of America (OSA)

2018-2020 Sigma Xi Honor Society

2019- American Society of Engineering Education

Honors

2004 Gold Medal Recipient, First place in Masters, Department of Food & Biochemical Engineering, Jadavpur University, Kolkata, India.

2007 Agricultural Engineering Endowment Fellowship, Department of Biosystems & Agricultural Engineering, Michigan State University, East Lansing, MI.

2008 Distinguished Outstanding Graduate Award in Biosystems Engineering, College of Engineering, Michigan State University, East Lansing, MI.

2008 Fitch H. Beach Outstanding Graduate Award, College of Engineering, Michigan State University East Lansing, MI.

2020 Excellence in Undergraduate Teaching Award, College of Engineering and Computer Science, Orlando, FL.

Other Professional Experience

Reviewer: Biosensors & Bioelectronics; Sensors; IEEE Transactions on Nanotechnology; ACS Nano Journal; Crystals, European Physical Journal, Journal of Mechanisms & Robotics.

Session Chair: Invited Session on “Bio-Inspired Systems”, ASME Dynamic Systems and Control Conference, San Antonio, TX, 2014.

C. Contributions to Science

Early detection and identification of diseases caused by pathogenic microorganisms is crucial for extending effective treatment and cure of these diseases to patients. A significant portion of my research career has focused on the design and development of novel diagnostic biomedical devices as rapid screening tools for disease causing pathogens.

1. Biomedical sensors research - My doctoral research at Michigan State University involved design, development and implementation of novel magnetic polymer nanostructure based bio-sensing devices for rapid detection of pathogens. In this research, we demonstrated for the first time that magnetic nanoparticles could be embedded within conductive polymer matrices to generate a class of novel magnetic nanostructures with strong magnetic, electrical and electrochemical properties all of which could be exploited in diverse transduction modes in sensing platforms. We exploited these novel nanostructures for detection of *Bacillus anthracis* spores in a lateral flow device and demonstrated that the sensing

platform could roughly detect a few hundred spores through electrical resistance changes across silver electrodes. We additionally exploited the electrochemical properties of these novel multi-functional nanostructures and further extended their applicability in the detection of genomic sequences. The electrochemical sensing device could detect a few nanograms of the *Bacillus anthracis* pag A gene sequence on activated carbon electrodes from the redox signals of the magnetic nanostructures in a 60 min detection time. The strong magnetic properties of these nanostructures were shown to be appropriate for magnetic pre-concentration of specific targets form complex matrices with a maximum capture rate of 97% for bacterial samples. Listed below are selected significant publications and patents resulting from this research.

a. **Pal, S.**, Setterington, E. B., Alocilja, E. C., "Electrically active magnetic nanoparticles for concentrating and detecting *Bacillus anthracis* spores in a direct-charge transfer biosensor", *IEEE Sensors Journal*, v8, n 6, 2008, pp: 647-654.
b. **Pal, S.**, and Alocilja, E. C**., "**Electrically-active magnetic nanoparticles as novel concentrator and electrochemical redox transducer in *Bacillus anthracis* DNA detection", *Biosensors & Bioelectronics,* v26, 2010, pp: 1624-1630.
c. United States Patent No: 8936946, Patent Title: "*Biologically enhanced electrically-active magnetic nanoparticles for concentration, separation, and detection applications*", Inventors: Evangelyn C. Alocilja, Sudeshna Pal, and Emma B. Setterington.
d. United States Patent No. 8287810, Patent Title: "*Electrically-active ferromagnetic particle conductimetric biosensor test kit*", Inventors: Evangelyn C. Alocilja, Sudeshna Pal, and Emma B. Setterington.

2. Biophotonics research - My post-doctoral research at the University of Rochester focused on design, development and implementation of engineered photonic band gap (PBG) devices as optical biosensing platforms for pathogen detection. Optical nanocavities created in PBG devices by breaking their spatial translational symmetry allows strong trapping of electric field energy at the resonant mode frequency thus rendering these devices with very high sensitivity to environmental changes. In this research, we demonstrated for the first time, that by creating optical nanocavities adjacent to photonic crystal optical waveguides and by placing such cavity coupled waveguide structures in series, the PBG devices allowed multiplexing capability on a single sensor platform. The PBG devices were realized on silicon-on-insulator structures though nano-fabrication techniques (electron-beam-lithography and reactive-ion-etching) and demonstrated excellent sensitivity to small proteins and model viral pathogens. The PBG sensor platforms could detect protein molecules in femtogram levels and a few human papilloma virus like particles from resonance red-shifts. Due to the large free spectral range of the nanocavity coupled PBG waveguide design (as compared to other resonator structures), its ultra-small dimension and ultra-low sample volume requirement, the design was appropriate for high throughput applications since arrays of PBG structures could be conveniently fabricated on a single chip. Listed below are the selected significant publications resulting from this research.
    a. **Pal, S**., Yadav, Lifson, M., A.R, Miller, B., and Fauchet, P.M., "Selective Virus Detection in Complex Sample Matrices with Photonic Crystal Optical Cavities", *Biosensors & Bioelectronics*, v44, 2013, 229-234.
    b. **Pal, S**., Miller, B., and Fauchet, P.M., "1-D and 2-D photonic crystals as optical methods for amplifying biomolecular recognition", *Analytical Chemistry **(Feature Article)***, v84, 2012, 8900-8908.
    c. **Pal, S**., Guillermain, E., Sriram, R., Miller, B., and Fauchet, P.M., "Silicon photonic crystal nanocavity-coupled waveguides for error-corrected optical biosensing", *Biosensors & Bioelectronics,* v26, 2011, 4024-4031.

3. Bio-inspired systems and controls research – In this research at UCF, I have focused on eliciting the fundamental principles of motor control in aerial species such as bats and insects from flight biomechanics. Specifically, I have worked on the following aspects: identified strategies used by aerial species in accomplishing complex maneuvers such as negotiating tight turns during flight, prey pursuit and capture and more; analyzed the flight biomechanics of bats in prey capture using rigid body models; and correlated sensory mechanisms in the aerial species with flight performance. I have also collaborated with faculty at UCF in bio-inspired robotics research, where I have contributed in the dynamic analysis of circular shaped

robots that mimic cellular locomotion. The following publications resulted from the above research. Some other manuscripts in the area of bio-inspired systems are also in the preparation stage.

a. **Pal, S**., "A Review of Target Pursuit Strategies in Aerial Species'', in *ASME- Dynamic Systems & Controls Conference, San Antonio TX, 2014, DSCC2014-6219 pp. V001T05A004* (Peer Reviewed).
b. **Pal, S**., "Dynamics of Aerial Target Pursuit", *European Physical Journal Special Topics,* v224, 2015, pp 3295-3309.
c. Steffan, E., **Pal, S.,** and Das, T**.**, "Bio-inspired Locomotion of Circular Robots with Diametrically Translating Legs", *ASME Journal of Mechanisms & Robotics,* v-12(1), 2020, pp 11005-11019.

Complete List of Published Work in MyBibliography:

https://www.ncbi.nlm.nih.gov/myncbi/1nwV2U6bxWf5A/bibliography/public/

BIOGRAPHICAL SKETCH

Provide the following information for the Senior/key personnel and other significant contributors.
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NAME: Park, Joon-Hyuk

eRA COMMONS USER NAME (credential, e.g., agency login): joonhpark

POSITION TITLE: Assistant Professor

EDUCATION/TRAINING *(Begin with baccalaureate or other initial professional education, such as nursing, include postdoctoral training and residency training if applicable. Add/delete rows as necessary.)*

INSTITUTION AND LOCATION	DEGREE *(if applicable)*	Completion Date MM/YYYY	FIELD OF STUDY
Konkuk University, Seoul, Kyonggi-do, South Korea	B.S.	02/2007	Mechanical and Aerospace Engineering
Konkuk University, Seoul, Kyonggi-do, South Korea	M.S.	02/2009	Mechanical and Aerospace Engineering
Columbia University, New York, NY, United States	M.Phil.	10/2014	Mechanical Engineering
Columbia University, New York, NY, United States	Ph.D.	10/2016	Mechanical Engineering

A. Personal Statement

I am an Assistant Professor of Mechanical and Aerospace Engineering, and my research is focused on wearable devices for motor training, rehabilitation and assistive applications. This includes wearable robots for enabling, assisting or augmenting human physical performance and wearable sensors for monitoring and assessing human biomechanical, physiological and psychological states. I have a broad background in mechatronics and robotics, particularly in the areas that involve interactions with a human user. As a member of Disability, Aging and Technology Cluster at UCF, my goal is to enhance utility, accessibility and intelligence of wearable assistive technologies through integration of research, education and outreach. To achieve this goal, I apply the principles of human biomechanics in sensing, actuation, and control of wearable devices. I then develop tools and techniques that well-incorporate those principles, eventually test and validate the approaches through human experiments. I also look to study human movement biomechanics (kinematics, kinetics, muscle activity) in various settings using wearable sensors, with the aim of developing models and metrics for i) assessment of and discrimination between different human behaviors and states in real-world environments, ii) patient monitoring, data mining and diagnosis/prognosis purposes, and iii) effective and adaptive assistive strategies leveraging new sensors, materials and control methods. A DARPA funded project (W911QX-12-C-0042; June 2012 – May 2015) to research load carriage assistive robot laid the groundwork for my research direction on wearables and assistive robots. I collaborated with doctors and clinicians to identify unmet needs in rehabilitation engineering and physical therapy, developed an NSF-funded research proposal (IIS-1527087, Sep 2015 – Aug 2019) to create a robotic device for spine deformity characterization and treatment, and interacted with minority and clinical populations on several human subject studies. During my three years at the Army Research Lab (Aberdeen, MD) as a National Academy of Science Research Associate, I've experienced many cutting-edge wearable technologies brought into the Army. As a result of these previous experiences, I have the expertise, leadership, training and motivation necessary to successfully carry out the proposed research project.

B. Positions, Scientific Appointments, and Honors

2019 – present	Assistant Professor, University of Central Florida, Orlando, FL, United States
2018 – present	Technical Committee, IIE Transactions on Occupational Ergonomics and Human Factors
2018 – present	Member, American Society for Testing and Materials (ASTM) International – Committee F48 on Exoskeletons and Exosuits (Subcommittee F48.01 on Design and Manufacturing)
2016 – present	Member, Institute of Electrical and Electronics Engineers (IEEE)
2016 – present	Member, American Society of Mechanical Engineers (ASME)
2016 – 2019	Research Associate, US Army Research Laboratory, Human Research and Engineering Directorate, Aberdeen, MD, United States

C. Contributions to Science

Upper body wearable robots for load carriage application: My research on the design of wearable robots has been targeted for upper body augmentation and rehabilitation, and the incorporation of cable-driven systems and parallel mechanisms. Walking with a heavy load carried over the shoulders is a common daily task across many occupations (e.g., construction workers, soldiers, and firefighters). The heavy torso-borne load not only increases the metabolic cost of walking but also increases the risk of upper-body injuries. The main research question addressed in this work was: Is it possible to reduce the metabolic cost of load carriage by minimizing the dynamic loads exerted on the human body while distributing the load between trunk and hips to reduce the risk of back injuries? Answering this question led to the development of a novel torso exoskeleton, the Second Spine, which provides alternative load pathways to transfer the load from the shoulders to the hips, and the Motorized Second Spine, which compensates for the vertical excursions of a torso-borne load and the resulting dynamic forces exerted on the human body during human (bipedal) locomotion. These functions were then utilized in the Wearable upper-Body Suit (WEBS), the first prototype of a cable-driven powered torso exoskeleton for load carriage application. This device was evaluated on twelve healthy subjects, demonstrating a load distribution capability and an average of 8.6% of metabolic savings while walking with a 25% body-weight backpack.

a. **J. Park**, X. Jin, S. Agrawal, “Compensating inertia forces during human load-carrying using a motorized second spine,” Proceeding of ASME International Design Engineering Technical Conferences (IDETC), Volume 5B: 38th Mechanisms and Robotics Conference, DETC2014-34853, 2014.
b. **J. Park**, X. Jin, S. Agrawal, “Second Spine: Upper Body Assistive Device for Human Load Carriage,” ASME. J. Mechanisms Robotics. 7(1), 011012, pp. 1-11, 2015
c. **J. Park**, P. Stegall, S. Agrawal, “Reducing Dynamic Loads from a Backpack during Load Carriage using an Upper Body Assistive Device,” ASME. J. Mechanisms Robotics. 8(5), 051017, pp. 1-8, 2016.
d. **J. Park**, P. Stegall, H. Zhang, S. Agrawal, “Walking with a backpack using load distribution and dynamic load compensation reduces metabolic cost and adaptations to loads,” IEEE Transactions on Neural Systems and Rehabilitation Engineering, 25(9), pp. 1419-1430, 2017.

Robotic spine exoskeleton for correction of spine deformity: Trunk support is needed for treatment and rehabilitation of people with various neuromuscular disorders, motor deficits, muscle weakness, or spinal diseases/injuries. Torso braces are widely used in practice for this purpose; however, they are mostly rigid, passive, and sensor-less which impose many practical and clinical limitations. We challenged the current practice by addressing this research question: How can we dynamically sense and modulate trunk support in different levels of the torso to improve clinical outcomes of bracing? This led to the development of a novel Robotic Spine Exoskeleton (RoSE), comprising of two Stewart platforms connected in series that allow for sensing and controlling the three-dimensional forces (or positions) applied to the human torso. The device was used to characterize, for the first time, the three-dimensional stiffness of the human torso which has implications on the clinical outcomes of bracing for spinal deformity treatment.

a. **J. Park**, P. Stegall, S. Agrawal, "Dynamic brace for correction of abnormal postures of the human spine," IEEE International Conference on Robotics and Automation (ICRA), Seattle, WA, pp. 5922-5927, 2015.

b. **J. Park**, P. Stegall, D. Roye Jr., S. Agrawal, “Robotic Spine Exoskeleton (RoSE): Characterizing the Three-dimensional Stiffness of the Human Torso in Treatment of Spine Deformity,” IEEE Transactions on Neural Systems and Rehabilitation Engineering, 26(5), pp. 1026-1035, 2018.

Methodologies for real-world human movement biomechanics assessment: Wearable sensors have paved a way to study human movement biomechanics in unconstrained environments, allowing researchers to collect real-world data in outdoor or residential areas. In my previous research, several types of wearable sensors were utilized – wearable motion capture sensors (e.g., inertial measurement units (IMU)), portable wireless surface electromyography (EMG), in-shoe pressure insoles, metabolic measurement mask, heart/breath rate monitor – to research physical activity, task performance and physiological state of Soldiers in the field. Data process and analysis techniques for human movement biomechanics data using wearable sensors, such as joint/segment kinematics, muscle activity, foot plantar pressure, metabolic cost, were developed and validated by gold-standard lab equipment.

a. H. Crowell, **J. Park**, C. Haynes, J. Neugebauer, A. Boynton, “Design, evaluation, and research challenges relevant to exoskeletons and exosuits for military load carriage: a 26-year perspective from the U.S. Army Research Laboratory,” IIE Transactions on Occupational Ergonomics and Human Factors, 7:3-4, pp.199-212, 2019.
b. H. Crowell, G. Kanagaki, M. O'Donovan, C. Haynes, **J. Park**, J. Neugebauer, E. Hennessy, A. Boynton, B. Mitchell, A. Tweedell, H. Girolamo, “Methodologies for evaluating the effects of physical augmentation technologies on Soldier performance,” ARL-TR-8444, DTIC AD1057611, US Army Research lab, Aberdeen Proving Ground, United States, pp. 1-78, 2018.
c. Boynton, **J. Park**, J. Neugebauer, “Biomechanical, physiologic, and mobility performance changes during prolonged load carriage,” Journal of Science and Medicine in Sport, 20S, S172-S174, 2017.

BIOGRAPHICAL SKETCH

Provide the following information for the Senior/key personnel and other significant contributors.
Follow this format for each person. DO NOT EXCEED FIVE PAGES.

NAME: Qiushi Fu

eRA COMMONS USER NAME (credential, e.g., agency login): QIUSHIFU

POSITION TITLE:

Assistant Professor, Department of Mechanical and Aerospace Engineering, University of Central Florida

EDUCATION/TRAINING

INSTITUTION AND LOCATION	DEGREE *(if applicable)*	Completion Date MM/YYYY	FIELD OF STUDY
Tsinghua University, Beijing, China	B.S	07/2006	Control Engineering
SUNY at Buffalo, Buffalo, NY	M.S.	07/2008	Mechanical Engineering
Arizona State University, Tempe, AZ	Ph.D.	07/2013	Biomedical Engineering
Arizona State University, Tempe, AZ	Post-doc	09/2015	Biomedical Engineering

A. Personal Statement

I have a broad background in neurophysiology, biomechanics, and robotics. My past and current research focuses on understanding the neural control of dexterous hand and arm movements. Specifically, I have expertise in the following areas: 1) motion analysis of human hand movements to quantify hand-object interactions; 2) novel experiment design using virtual reality and haptics technologies; 3) computational modeling of neurophysiological signals for understanding sensorimotor control mechanisms; and 4) quantitative assessment of limb prosthetics, as well as assistive and rehabilitation devices. My expertise can significantly contribute to the research and education objectives of the proposed Biomedical Engineering PhD program at University of Central Florida.

B. Positions and Honors

Professional Experience:

2006-2007 Teaching Asst., Mechanical Engineering Dept., SUNY at Buffalo, Buffalo, NY
2007-2008 Research Asst., Mechanical Engineering Dept., SUNY at Buffalo, Buffalo, NY
2008-2009 Teaching Asst., Kinesiology Dept., Arizona State Univ. (ASU), Tempe, AZ
2009-2013 Research Asst., Sch. Biol. & Health Systems Eng., ASU, Tempe, AZ
2013-2015 Post Doctoral Associate, Sch. Biol. & Health Systems Eng., ASU, Tempe, AZ
2015-2017 Research Assistant Professor, School of Biol. & Health Systems Eng., ASU., Tempe, AZ
2017-present Assistant Professor, Dept. of Mech. & Aero. Eng., Univ of Central Florida, Orlando, FL

Other Experience and Professional Memberships

2009- Member, Society for Neuroscience
2010- Member, Institute of Electrical and Electronic Engineers
2012 Member, Society for Neural Control of Movement
2013- Member, American Physiology Society

Honors and Awards:

2010 ASU Graduate and Professional Student Association Travel Grant
2011 ASU Biomedical Engineering Department Travel Grant
2013 Chinese government award for outstanding self-financed students abroad

C. Contribution to Science

I. **Characterization of learning and generalization of dexterous manipulation**. This project focused on how dexterous manipulations are learned, stored, retrieved, and generalized to different task contexts. We found that once a manipulation task has been learned, changes at the "effector level" (i.e., hand orientation or grip type) could be compensated for, but changes occurring at the "task level" (i.e., object orientation) cause poor motor learning generalization. This was revealed by using objects that can afford different manipulative actions while providing visual geometric cues. We demonstrated that, while visuomotor transformations based on the object's visual geometric cues about the object's mass distribution were effective on the very first manipulation, subsequent learning of a different manipulation with the same object could interfere with the ability to use such visual cues again. This novel finding strongly suggested the existence of parallel sensorimotor processes underlying planning and learning of dexterous manipulation. Overall, these results have laid the foundation for using neuroimaging techniques to understand how the brain controls the hand to interact with objects and tools.

   a. Fu Q, Santello M (2012) Context-dependent learning interferes with visuomotor transformations for manipulation planning. Journal of Neuroscience 32(43):15086-92. doi: 10.1523/JNEUROSCI.2468-12.2012. PMID: 23100429; PMCID: PMC6704838.
   b. Fu Q, Choi JY, Gordon AM, Jesunathadas M, Santello M (2014) Learned manipulation at unconstrained contacts does not transfer across hands. PLOS One: e0108222. doi: 10.1371/journal.pone.0108222. PMID: 25233091; PMCID: PMC4169447.
   c. Fu Q, Santello M (2015) Learning skilled manipulation: parallel processes underlie retention and interference. Journal of Neurophysiology 113(1):144-55. doi: 10.1152/jn.00348.2014. PMID: 25274349.

II. **Discovery and characterization of digit force-to-position modulation of dexterous manipulation.** This project examined the mechanisms underlying learning and control of object manipulation by quantifying how digit position and force are coordinated in response to trial-to-trial variability in digit placement. I designed physical grip devices and haptic simulation in virtual environment that allow subjects to choose digit positions while allowing the experimenter to concurrently measure digit forces in response to digit position modulation. Through the use of these unconstrained manipulation and torque production tasks, my work revealed, for the first time in the motor neuroscience literature, that the central nervous system (CNS) plans and controls local variables (i.e., digit forces and positions) in a coordinated fashion on every manipulation to consistently accomplish high-level task goals. These results were interpreted as a hierarchical control framework that is capable of decomposing task-level representations into motor commands to control individual end-effectors. These novel experimental protocols are now being incorporated with brain imaging and brain stimulation approaches to reveal the neural mechanisms underlying the novel framework.

   a. Fu Q, Zhang W, Santello M (2010) Anticipatory planning and control of grasp positions and forces for dexterous two-digit manipulation. *Journal of Neuroscience* 30(27): 9117-26. doi: 10.1523/JNEUROSCI.4159-09.2010. PMID: 20610745; PMCID: PMC2917583.
   b. Fu Q, Hasan Z, Santello M (2011) Transfer of learned manipulation following changes in degrees of freedom. Journal of Neuroscience 31(38):13527-34. doi: 10.1523/JNEUROSCI.1143-11.2011. PMID: 21940448; PMCID: PMC6623297.
   c. Fu Q, Santello M (2014) Coordination between digit forces and positions: interactions between anticipatory and feedback control. Journal of Neurophysiology 111(7):1519-1528. doi: 10.1152/jn.00754.2013. PMID: 24401711.

III. **Development of motion tracking framework for natural hand-object interactions**. I developed a kinematic tracking framework that could quantify the interaction between the human hand and the environment. This framework has been used to study how humans modulate reaching and grasping kinematics in response to object orientation uncertainty. It was found that subjects tended to maximize the chance of initial contact by adjusting the reach approaching angle. This finding has the potential to be used for controlling robotic hands in unstructured environments, because uncertainty caused by unstructured environments is a challenge to real-world robotic applications due to inaccuracy of sensing. I also developed a motion capture framework integrated in immersive virtual reality to evaluate compensatory movement in upper-limb prostheses users.

a. Fu Q, Santello M (2011) Towards a complete description of grasping kinematics: a framework for quantifying human grasping and manipulation. Proceedings of IEEE Engineering in Biology and Medicine Conference, Boston, MA, USA. doi: 10.1109/IEMBS.2011.6092033. PMID: 22256257.
b. Fu Q, Ushani A, Jentoft LP, Howe RD, Santello M (2013) Human reach-to-grasp compensation with object pose uncertainty. Proc. IEEE Eng. Med. Biol. Soc. Osaka, Japan. doi: 10.1109/EMBC.2013.6611142. PMID: 24111329.
c. Odette K, Fu Q (2019) A physics-based virtual reality environment to quantify functional performance of upper-limb prostheses. Proc. IEEE Eng. Med. Biol. Soc., Berlin, Germany. doi: 10.1109/EMBC.2019.8857850

IV. **Bio-inspired novel myoelectric control and training protocols for hand prosthesis**. I designed and implemented a hybrid gain myoelectric controller for the SoftHand-Pro, a prosthetic hand built on the concept of mechanical synergies. This controller can switch control parameters based on grasping context detected through real-time estimation of grasp forces, which allows accurate control of grasping force to transport objects with different physical properties. Additionally, I developed contralateral haptic integration training to improve user's ability to transfer haptic information between native hand and close-loop prosthetic systems. Lastly, I have investigated the inter-subject variability in muscle control capability in different populations to guide personalized myoelectric control.
a. Fu Q, Santello M (2018) Myoelectric control of a soft synergy-inspired prosthetic hand: improving hand-object interactions. Frontiers in Neurorobotics 11. doi: 10.3389/fnbot.2017.00071. PMID: 29375360; PMCID: PMC5767584.
b. Fu Q, Shao F, Santello M (2019) Inter-limb Transfer of Grasp force perception with closed-loop hand prosthesis. Transactions on Neural Systems and Rehabilitation Engineering 27(5):927-936. doi: 10.1109/TNSRE.2019.2911893. PMID: 31021799.
c. McClanahan, A., Moench, M., & Fu, Q. (2020). Dimensionality analysis of forearm muscle activation for myoelectric control in transradial amputees. PLoS ONE, 15, 1–19. doi: 10.1371/journal.pone.0242921

Other Published Work in MyBibliography:
https://www.ncbi.nlm.nih.gov/myncbi/qiushi.fu.1/bibliography/public/

D. Research Support

Ongoing

Effect of force-based motor repetition on the control and learning of dexterous manipulation.
04/01/20-03/31/23 **PI**
Funding Agency: National Institutes of Health
1R15AG067792-01
Overall goals: This project aims to understand how different structures and types of simple hand exercise generalize to more complex manipulation tasks in both young and old adults.

RF: Understanding Brain Dynamics of motor control.
08/01/19-07/30/22 **PI**
Funding Agency: University of Central Florida Research Foundation
Overall goals: This project aims to quantify the event related cortical dynamics changes in response to external stimuli related to grasping, especially action affordances. The ultimate goal is to develop brain machine interfaces to control artificial manipulators.

Completed

ER1: Understanding forearm muscle coordination in children for pediatric hand-wrist prostheses: a preliminary study.
01/08/20-01/07/21 **PI**
Funding Agency: University of Central Florida
Overall goals: This project aims to quantify the forearm myoelectric control capability of children as they grow.

Simultaneous and proportional myoelectric control of upper-limb prosthetics: a preliminary study on the design of movement synergy.
05/01/18-04/30/19 **PI**
Funding Agency: VPR Advancement of Early Career Researchers
Overall goals: As a preliminary study, this project aims to develop and validate a virtual reality environment that simulate object grasping and manipulation in real-time with accurate physics.

Sensorimotor control of grasping and manipulation through a soft-synergy prosthetic hand and peripheral neural interface system
02/01/17-07/31/18 **Co-PI** (PI: Dr. Marco Santello)
Funding Agency: Defense Advanced Research Projects Agency, Department of Defense
W911NF-17-1-0049
Overall goals: To improve the myoelectric control algorithm and training procedures for a soft-synergy-based prosthetic hand, and to integrate the hand with a peripheral neural interface for delivering sensory feedback.

BIOGRAPHICAL SKETCH

Provide the following information for the Senior/key personnel and other significant contributors.
Follow this format for each person. **DO NOT EXCEED FIVE PAGES.**

NAME: Song, Sang-Eun

eRA COMMONS USER NAME (credential, e.g., agency login): SSONG17

POSITION TITLE: Associate Professor of Mechanical and Aerospace Engineering

EDUCATION/TRAINING *(Begin with baccalaureate or other initial professional education, such as nursing, include postdoctoral training and residency training if applicable. Add/delete rows as necessary.)*

INSTITUTION AND LOCATION	DEGREE *(if applicable)*	Completion Date MM/YYYY	FIELD OF STUDY
University of Ulsan (ROTC), South Korea	B.S.	03/1995	Mechanical Engineering
University of Liverpool, U.K.	M.Sc.	12/2000	Mechanical Systems Engineering
Imperial College London, U.K.	Ph.D., DIC	12/2005	Mechanical Engineering (Medical Robotics)
University of British Columbia, Canada	Postdoc	09/2006	Medical Robotics

A. Personal Statement

I am a medical robotics expert specialized in delivering engineering technologies to operating rooms. I have been leading many robotic intervention projects from proof-of-concept to human study as a multidisciplinary team leader as well as a hands-on engineer/scientist. My unique interdisciplinary knowledge and experience between engineering and medicine has been a key for solving many practical issues of medical interventions.

I am a Tenure-Track Associate Professor in Department of Mechanical and Aerospace Engineering and Director for Interventional Robotics Laboratory at the University of Central Florida (UCF). My interests focus on robotic interventions, telemedicine, biomedical devices, and soft robotic systems in healthcare and their clinical implementation. I have been developing and clinically implementing medical interventions at world-leading universities and research hospitals over 18 years.

I developed my first surgical robot, a bone-mounted spine surgery robot at Imperial College London, UK (~2005). In 2006, I moved to Institute for Computer Assisted Orthopedic Surgery (ICAOS) at Western Pennsylvania Hospital, Pittsburgh to develop a bone-mount robot for minimally invasive knee surgery (1) (NIH R01AR052700). At Johns Hopkins University (2008~2010), I developed an MRI-compatible robotic intervention for targeted prostate intervention in collaboration with Brigham and Women's hospital (BWH) (NIH R01CA111288). I also worked on implementing another robotic prostate intervention in clinical trials at NIH Clinical Center and carried out an MRI artifact study (3) for MRI-guided intervention (R01EB002963).

As I gained significant knowledge in MRI-guided interventions, I moved to National Center for Image Guided Therapy (NCIGT) at BWH, Harvard Medical School. At BWH (2010~2014), I continued to enhance MRI-guided interventions and developed a robotic needle guidance system for MRI-guided targeted prostate biopsy (3). The robotic intervention was utilized in 45 patient trials resulting in higher cancer detection rate than conventional procedures. The success led to productization of the robotic intervention (NIH R41CA192446).

After being an Instructor in Radiology for 4 years, I moved back to an engineering school (Harvard School of Engineering and Science, 2014~2015) to expand my knowledge in soft robotics (4) before coming to UCF in 2015. Since, I continue advance MRI-guided interventions, revive earlier focus of orthopedic robots, explore tele-palpation, and innovate many other medical interventions in collaboration with local hospitals.

1. **Song SE**, Mor A, Jaramaz B. HyBAR: hybrid bone-attached robot for joint arthroplasty. Int J Med Robot. 2009 Jun;5(2): 223-231. DOI: 10.1007/s11548-011-0598-9. PMCID: PMC3672054.
2. **Song SE**, Cho N, Iordachita, I, Guion P, Fichtinger G, Kaushal A, Camphausen K, Whitcomb L. Biopsy needle artifact localization in MRI-guided robotic transrectal prostate intervention. IEEE Trans Biomed Eng. 2012 July;59(7): 1902–1911. PMCID: PMC3675798.
3. **Song SE**, Tokuda J, Tuncali K, Tempany C, Zhang E, Hata N. Development and Preliminary Evaluation of a Motorized Needle Guide Template for MRI-guided Targeted Prostate Biopsy. IEEE Trans Biomed Eng. 2013 Nov;60(11):3019-3027. PMCID: PMC3778164 (Featured on IEEE TBME).
4. Roche ET, Horvath MA, Wamala I, Alazmani A, **Song SE**, Whyte W, Machaidze Z, Payne CJ, Weaver JC, Fishbein G, Kuebler J, Vasilyev NV, Mooney DJ, Pigula FA, & Walsh CJ. Soft robotic sleeve supports heart function. Sci Transl Med. 2017;9(373). PMID: 28100834.

B. Positions, Scientific Appointments, and Honors

Positions and Scientific Appointments

2016 -	Joint Appointment, Department of Electrical and Computer Engineering, University of Central Florida, Orlando, FL
2015 -	Associate Professor, Department of Mechanical and Aerospace Engineering, Director for Interventional Robotics Laboratory, University of Central Florida, Orlando, FL
2014 - 2015	Research Fellow, Boston Children's Hospital, Boston, MA
2014 - 2015	Research Associate, Harvard John A. Paulson School of Engineering and Applied Sciences, Harvard University, Cambridge, MA
2010 - 2014	Instructor in Radiology, Brigham & Women's Hospital, Harvard Medical School, Boston, MA
2008 - 2010	Associate Research Scientist, NSF Engineering Research Center for Computer- Integrated Surgical Systems and Technology, Johns Hopkins University, Baltimore, MD
2006 - 2008	Research Scientist, Institute for Computer Assisted Orthopaedic Surgery (ICAOS), Western Pennsylvania Hospital (Carnegie Mellon University affiliated), Pittsburgh, PA.
1995 - 1997	Lieutenant, Republic of Korea Army, South Korea

Other Experience and Professional Memberships

2020 - 2021	Orlando Central Florida Chapter President, Korea-American Scientists and Engineers Association (KSEA)
2019 - 2021	Member, Program Committee, International Society for Computer Assisted Orthopaedic Surgery (CAOS International) Annual Meeting
2018 - 2021	Member, Chapter Faculty Advisor, National Biomedical Engineering Society (BMES) at University of Central Florida
2018 - 2019	Member, Program Committee, International Symposium on Medical Robotics (ISMR)
2018	Conference Chair, Florida Conference on Recent Advances in Robotics (FCRAR) 2018
2017 - 2021	Member, Korea Technology Advisory Group, Korea Institute for Advancement of Technology
2017 - 2019	Associate Editor, IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)
2017 - 2018	Panelist: Innovational Research Incentives Scheme (Veni) Grant, Applied and Engineering Sciences (TTW), Netherlands Organisation for Scientific Research (NWO)
2017 - 2018	Member, Special Operations Medical Association (SOMA)
2016	Panelist: National Science Foundation (NSF) National Robotics Initiative (NRI)
2015 - 2021	Member, Korea-American Scientists and Engineers Association (KSEA)
2011 - 2021	Member, American Society of Mechanical Engineers (ASME)
2010 - 2019	Member, Institute of Electrical and Electronics Engineers (IEEE)

C. Contributions to Science

1. The major scientific contribution is on novel mechanism design/development and clinical implementation of robotic interventions. In particular, unique design and on-site implementation of MRI-guided interventions for targeted prostate biopsy and focal therapy are the main contributions. MRI-safe robotic intervention development involves many technical challenges such as patient safety, robot functionality, and image degradation. Following papers report the challenges and solutions, and its clinical implementation.
    a. Krieger A, **Song SE**, Cho N, Iordachita I, Guion P, Fichtinger G, Whitcomb L. Development and Evaluation of an Actuated MRI-Compatible Robotic System for MRI-Guided Prostate Intervention. IEEE ASME Trans Mechatron. 2012 Sep 12; 18(1): 273–284. PMC3544166.
    b. **Song SE**, Hata N, Iordachita I, Fichtinger G, Tempany C, Tokuda J. A workspace-orientated needle-guiding robot for 3T MRI-guided transperineal prostate intervention: evaluation of in-bore workspace and MRI compatibility. Int J Med Robot. 2013 Mar;9(1):67-74. PMC3674858.
    c. Tilak G, Tuncali K, **Song SE**, Tokuda J, Olubiyi O, Fennessy F, Fedorov A, Penzkofer T, Tempany C, & Hata N. 3T MR-guided in-bore transperineal prostate biopsy: A comparison of robotic and manual needle-guidance templates. J Magn Reson Imaging. 2015;42(1):63-71. PMC4376663.
    d. Penzkofer T, Tuncali K, Fedorov A, **Song SE**, Tokuda J, Fennessy FM, Vangel MG, Kibel AS, Mulkern RV, Wells WM, Hata N, & Tempany CM. Transperineal in-bore 3-T MR imaging-guided prostate biopsy: a prospective clinical observational study. Radiology. 2015;274(1):170-180. PMC4334270.
2. Expertise and hands-on experiences in MRI guided prostate interventions have contributed to other image guided intervention developments such in liver cancer therapy, gynecological radio therapy, and also continuum robotic applications for brain surgery.
    a. **Song SE**, Hata N, Iordachita I, Fichtinger G, Tempany C, & Tokuda J. A workspace-orientated needle-guiding robot for 3T MRI-guided transperineal prostate intervention: evaluation of in-bore workspace and MRI compatibility. Int J Med Robot. 2013;9(1):67-74. PMC3674858.
    b. Yoshimitsu K, Kato T, **Song SE**, Hata N. A novel four-wire-driven robotic catheter for radio-frequency ablation treatment of atrial fibrillation. Int J Comput Assist Radiol Surg. 2014 Sep;9(5):867-74. Epub 2014 Feb 8. PMC4209906.
    c. Kato T, Okumura I, **Song SE**, Golby AJ, & Hata N. Tendon-Driven Continuum Robot for Endoscopic Surgery: Preclinical Development and Validation of a Tension Propagation Model. IEEE ASME Trans Mechatron. 2015;20(5):2252-2263. PMC4569018.
    d. Hata N, **Song SE**, Olubiyi O, Arimitsu Y, Fujimoto K, Kato T, Tuncali K, Tani S, & Tokuda J. Body-mounted robotic instrument guide for image-guided cryotherapy of renal cancer. Medical Physics. 2016;43(2):843-853.
3. Recent research activities include needle-and-guide dynamics analysis and optimization for image guided interventions, **body mounted robots for orthopedic surgery** and orthognathic surgery, and tactile display using granular jamming for advanced telemedicine.
    a. Biswas P, Sikander S, Kulkarni P, **Song SE**, A Method and Mechanism for Harvesting Intact Autograft for Osteochondral Transplantation. In: Frontiers in Biomedical Devices, BIOMED - 2019 Design of Medical Devices Conference, DMD 2019. ; 2019. doi:10.1115/DMD2019-3260
    b. Kulkarni P, Sikander S, Biswas P, Frawley S, **Song SE**. Review of Robotic Needle Guide Systems for Percutaneous Intervention. Annals of Biomedical Engineering. 2019. doi:10.1007/s10439-019-02319-9
    c. Sikander S, Biswas P, Kulkarni P, Bradley A, **Song SE**. Prototyping and Initial Feasibility Study of Palpation Display Apparatus Using Granular Jamming. 2019 IEEE Healthcare Innovations and Point-of-Care Technologies (HI-POCT); 2019. doi:10.1109/HI-POCT45284.2019.8962883
    d. **Song S-E**. Chapter 34. Robotic Interventions. Handbook of Medical Image Computing and Computer Assisted Intervention. Ed. Zhou S, Ed. Rueckert D, Ed. Fichtinger G. New York: Elsevier, 2019. 841-860. doi:10.1016/C2017-0-04608-6.

Complete List of Published Work in MyBibliography

https://www.ncbi.nlm.nih.gov/myncbi/browse/collection/43805795/?sort=date&direction=descending

Research Related Patents

a. **Song SE**, Sikander S, Biswas P. Head Mounted Robotic System and Method. 63/122,464, Provisional Patent filed on Dec 7, 2020.

b. **Song SE**, Sikander S. Tactile display apparatus for palpation simulation and telemedicine and methods of use. 62/817,853, Provisional Patent filed on March 13, 2019.

c. **Song SE,** Biswas P. A Nondestructive Autograft Extracting Device for Autologous Osteochondral Transplantation. Publication: US-2020-0046373-A1, 02/13/2020

d. **Song SE**, Burt J. Robotic Guide for Medical Device. PCT/US2015/642953, Filed 2017-07-06, Publication: 2019-01-10.

D. Additional Information: Research Support and/or Scholastic Performance

Ongoing Research Support

NSF FW-HTF-P Song (PI) 11/01/20-10/31/21

Future Healthcare Technologies and Multidisciplinary Workforce Readiness

This is a planning project to prepare a Future of Work at the Human-Technology Frontier (FW-HTF) project.

Role: Principal Investigator

NIH NIBIB R15 Song (PI) 08/01/20-07/31/23

Compact registration-free robotic tool guide for image guided percutaneous interventions

This project is to develop a registration-free needle guide procedure that can simplify and shorten the procedure by utilizing MRI scanner's well-defined space and robotic table control.

Role: Principal Investigator

UCF Research Foundation Gap Award Song (PI) 06/51/19-06/04/20

Nondestructive Autograft Extracting Device for Autologous Osteochondral Transplantation

This project is to develop a robotic device that can extract an intact donor cartilage-bone for transplantation.

Role: Principal Investigator

Completed Research Support

Florida Space Grant Consortium Training Grant Song (PI) 09/01/19-08/31/20

Biomedical Engineering Society Space Medicine Initiative

This project is to provide hands-on biomedical innovation opportunities for cross-disciplinary students.

Role: Principal Investigator

TechFit Digital Surgery LLC Song (PI) 08/26/19-12/20/19

Concept Design of Orthognathic Surgery Alignment Robot

This project is to design a skull-mounted robotic tool that can hold and precisely locate maxilla and/or mandible.

Role: Principal Investigator

Central Florida Health Research Song (PI) 03/01/17-08/31/18

Enabling one-stop definitive prostate cancer diagnosis using a registration-free MRI-guided targeted biopsy

The project is to develop an easy-to-use needle guide tool to enable a one-stop MRI-guided prostate biopsy.

Role: Principal Investigator

Florida Department of Health Bagci (PI) 03/09/17-03/31/18

Utilization of in utero diffusion tensor magnetic resonance imaging to evaluate neurological disorders caused by Zika virus

The project is to develop an imaging method to evaluate neurological disorders caused by Zika virus.

Role: Co-investigator

Lockheed Martin Missiles and Fire Control Kassab (PI) 07/05/17-01/31/18

Warfighter Exoskeleton Evaluation and Augmentation

The project is to design, prototype and evaluate hip and thigh harnessing mechanism for multiple Exoskeletal robotic systems.

Role: Co-investigator

VentureWell Song (PI) 04/01/17-12/31/17

N95 Respirator redesign

The project is to improve N95 respiratory mask design to enhance its function.

Role: Principal Investigator

Lockheed Martin Missiles and Fire Control Kassab (PI) 09/01/17-12/31/17

Aerospace & Defense Fundamental Research Project

The project is to identify and design a wearable tactile display to enhance spatial recognition and cooperative positioning.

Role: Co-investigator

NSF I-Corps Song (PI) 05/20/16-04/01/17

Improved N95 Respirator

The project is to develop a surgical or laboratory mask with improved air sealing.

Role: Principal Investigator

BIOGRAPHICAL SKETCH

Provide the following information for the Senior/key personnel and other significant contributors.
Follow this format for each person. **DO NOT EXCEED FIVE PAGES.**

NAME: **Robert Steward Jr.**

eRA COMMONS USER NAME (credential, e.g., agency login): **RSTEWARD**

POSITION TITLE: **Assistant Professor**

EDUCATION/TRAINING *(Begin with baccalaureate or other initial professional education, such as nursing, include postdoctoral training and residency training if applicable. Add/delete rows as necessary.)*

INSTITUTION AND LOCATION	DEGREE *(if applicable)*	Completion Date MM/YYYY	FIELD OF STUDY
Clark Atlanta University, Atlanta, GA	**BS**	**2007**	**Mech. Engineering**
Carnegie Mellon University, Pittsburgh, PA	**PhD**	**2011**	**Mech. Engineering**
T.H. Chan School Harvard School of Public Health, Boston, MA	**Postdoc**	**2014**	**Cell Mechanics**

A. Personal Statement

My research and training experiences to date have primarily focused on utilizing engineering and biophysical principals to study mammalian cell behavior. To this end, I have developed novel technologies to mechanically stimulate mammalian cells by fluid shear stress and/or stretch. In addition, I also have experience characterizing the mechanical phenotype of cells in response to mechanical and biochemical sitmulation. I have analyzed their structural and morphological responses and developed computational models as well. I have also investigated the effects of cell-generated mechanical forces on cell behavior. Furthermore, my research involves investigating the phenomena of mechanical force-induced biochemical and genetic expression, termed mechanotransduction. Results derived from my works have implications into multiple health fields including cardiovascular disease, tissue engineering, and the neurosciences. My current research expertise has been interdisciplinary in nature as reflected in the mechanical engineering, cell biology, and biophysics papers and conferences I have been able to publish and present, respectively.

B. Positions and Honors

Positions
2015 - Assistant Professor, Department of Mechanical and Aerospace Engineering, UCF

Honors
Ford Foundation Fellowship Program, Honorable Mention, 2008
National Science Foundation Graduate Research Fellowship, 2008 - 2011
Sloan Foundation Fellowship, 2008-2011
Biophysical Society Minority Biophysicist Travel Award, 2009, 2010
Ruth L. Kirschstein NRSA Training Grant, 2011 - 2014

C. Contributions to Science

1. Probing the influence of gap junctions on endothelial biomechanics. – The ability to resolve cell-derived biomechanical forces, specifically tractions (cell-substrate forces) and cell-cell adhesion forces (cell-cell forces) has been around for quite some time. However, in regards to cell-cell adhesion forces, while tight junctions and adherens junctions were believed to be the primaryily responsible for cell-cell adhesion force generation work done by my lab demonstrated the role the gap junction Cx43 plays in endothelial biomechanics. Two publications have been yielded from this work thus far.

S. Beverung, J. Wu, and R. Steward Jr., " Lab-on-a-Chip for Cardiovascular Physiology and Pathology", Micromachnies, 2020.

Md. Mydul Islam and R. Steward Jr., " Perturbing Endothelial Biomechanics via Connexin 43 Structural Disruption", Journal of Visualized Experiments, 2019.

Md. Mydul Islam and R. Steward Jr., " Probing Endothelial Cell Mechanics through Connexin 43 disruption", Experimental Mechanics, 2018.

2. Intercellular forces guide endothelial cell reorientation – mammalian cells are well known to reorient under fluid flow, but the role of underlying cell-cell adhesion forces remained unclear. Using a novel method, monolayer stress microscopy I showed cell-cell adhesion forces to decrease under fluid flow and guide endothelial cell alignment. These findings are important as they link cell-cell adhesion forces to cell alignment, which has been shown to be atheroprotective.

R. Steward, D. Tambe, C. C. Hardin, R. Krishnan, J. J. Fredberg, "Fluid Shear, intercellular stress, and endothelial cell alignment", *American Journal of Physiology-Cell Physiology*, 2015, 308(8): C657-C664.

3. Developed dual force mechanical stimulation technique - Developed novel method to mechanically stimulate mammalian cells in vitro by fluid shear stress and stretch separately and simultaneously. Most studies in cell mechanics generally investigate one mode of mechanical stimulation. However, many mammalian cells, such as endothelial cells, for example experience multiple forces. Outcomes yielded from my work include a mathematical model explaining cellular reorientation in response to coupled modes of mechanical stimulation.

R. Steward, C. Tan, C.M. Cheng, P. R. LeDuc, " Cellular Force Signal Integration through Vector Logic Gates", Journal of Biomechanics, 2015, 48(4):613-20.

R. Steward, C.M. Cheng, D.L. Wang, P.R. LeDuc, Probing Cell Structure Responses Through a Shear and Stretching Mechanical Stimulation Technique Cell Biochem Biophys, 56(2-3):115-24, 2010.

4. Mechanotransduction through syndecan-4 - I was part of the group that proposed the transmembrane protein syndecen-4 to be a mechanosensitve protein. When dealing with transmembrane proteins most in the field look at integrins however syndecan-4 has been demonstrated to be present during many mechanics-related processes including cell migration. Therefore cells with and without syndecan-4 were stretched and cells without syndecan-4 were found to have perturbed responses to mechanical stimulation.

Bellin, R.M., Kubicek, J.D., Frigault, M.J., Kamien, A.J., Steward, R., Barnes, H.M., DiGiacomo, M.B., Duncan, L.J., Edgerly, C.K., Morse, E.M., Park, C.Y., Fredberg, J.J., Cheng, C.M., & LeDuc, P.R. Defining the Role of Syndecan-4 in Mechanotransduction using Surface-Modification Approaches Proceedings of the National Academy of Sciences, 106(52), 22102-22107, 2009.

5. Structural reorganization of ECM under mechanical force – Many structural responses are looked at as a function of the cytoskeleton, but how the question of how the cell remodels its external environment under mechanical force remained unanswered. I showed the cell to 1) create a more fibrous extracellular matrix under both fluid flow and stretch and 2) localize ecm fibrils to the cell periphery when reorienting.

R. Steward, C.M. Cheng, J. D. Ye, R. M. Bellin, P. R. LeDuc, "Mechanical Stretch and Shear Flow Induced Reorganization and Recruitment of Fibronectin in Fibroblasts," *Scientific Reports (Nature Publishing Group)*, 1(147), 1-12, 2012.

A full list of my published work may be found in the following url:
http://www.ncbi.nlm.nih.gov/pubmed/?term=robert+steward+jr

D. Additional Information: Research Support and/or Scholastic Performance

Current Research Support

NSF2045750 PI: Robert Steward 3/1/21 – 2/28/26
National Science Foundation
CAREER: Elucidation of the Physical Principles the Govern Endothelial Structure and Function

K25HL132098 PI: Robert Steward 9/1/2016 – 5/31/2022
National Heart, Lung, and Blood Institute (NHLBI)
Endothelial Cell Mechanical Dysfunction in Early Stage Atherosclerosis

BIOGRAPHICAL SKETCH

Provide the following information for the Senior/key personnel and other significant contributors.
Follow this format for each person. **DO NOT EXCEED FIVE PAGES.**

NAME: Wen Shen

eRA COMMONS USER NAME (credential, e.g., agency login): WENDYSHEN

POSITION TITLE: Assistant Professor

EDUCATION/TRAINING *(Begin with baccalaureate or other initial professional education, such as nursing, include postdoctoral training and residency training if applicable. Add/delete rows as necessary.)*

INSTITUTION AND LOCATION	DEGREE *(if applicable)*	Completion Date MM/YYYY	FIELD OF STUDY
Shanghai Jiao Tong Univeristy, Shanghai, Shanghai	B. S.	06/05	Materials Science and Engineering
Shanghai Jiao Tong Univeristy, Shanghai, Shanghai	B. S.	06/05	Biological Engineering
Auburn University, Auburn, AL	M.S.	05/10	Statistics
Auburn University, Auburn, AL	Ph. D.	05/11	Materials Engineering
Georgia Institute of Technology, Atlanta, GA	Post-doc	05/11-06/14	Electrical and Computer Engineering
University of Pennsylvania, Philadelphia, PA	Post-doc	07/14-06/16	Electrical and System Engineering

A. Personal Statement

I have a broad background in biomaterials and bioelectronics, with specific expertise in micro/nanofabrication of biomaterials and micro/nanoelectronics based on biomaterials. I developed a series of novel micro/nanofabrication techniques for flexible bioelectronics and drug delivery systems based on various biomaterials, including natural materials, biodegradable materials and synthetic biomaterials. The extracellular matric (ECM)-based neural interface I developed was featured in *Microsystem and Nanoengineering*. Moreover, I identified the key geometric and mechanical factors affecting the strains at the interfaces of implanted bioelectronics and surrounding tissues. In addition, I have extensive experience on biosensors based on functional materials and phage-based immunoassays on biosensors. My research on wireless phase-based biosensors was published in well-recognized journals on biosensors such as *Biosensors and Bioelectronics*, *Sensors and Actuators B: Chemical*, and *Journal of The Electrochemical Society*. Furthermore, I created and developed a pulse method for the determination of the resonance frequency of a biosensor made from magnetoelastic materials, which significantly increased sampling rate and signal to noise ratio for the resonant frequency measurement. This pulse detection method was published in *Applied Physics Letters*. The pulse detection method I developed along with my study of the phage-based immunoassay on the magnetoelastic biosensors enabled real-time detection of pathogens directly on food produce.

1. Y. Zhang, D. Castro, Y. Han, Y. Wu, H. Guo, Y. Xue, X. Wang, Y. Xie, D. Ostojich, R. Sun, B. Wang, Z. Xie, D. Peng, S. Qu, W. Shen, T. Hang, A. Banks, Y. Huang, J. Radulovic, P. Gutruf, M. Bruchas, and J. Rogers, “Wireless Injectable Microsystem for Untethered, Programmable Pharmacological and Optogenetic Manipulations of Neural Function in the Brain,” *PNAS*, 116 (43), 21427-21437, 2019.
2. W. Shen, S. Das, F. Vitale, A. Richardson, A. Ananthakrishnan, L.A. Struzyna, D.P. Brown, N. Song, M. Ramkumar, T. Lucas, D.K. Cullen, B. Litt, and M.G. Allen, "Microfabricated Intracortical Extracellular Matrix-Microelectrodes for Improving Neural Interfaces", *Microsystems & Nanoengineering*, 4 (1) 30, 2018 (*Featured Article and Cover Image*).
3. F. Vitale, W. Shen, N. Driscoll, J. Burrell, A.G. Richardson, O. Adewole, B. Murphy, A. Ananthakrishnan, T. Wang, T.H. Lucas, D.K. Cullen, M.G. Allen, and B. Litt, "Biomimetic Extracellular Matrix Coatings Improve

the Chronic Biocompatibility of Microfabricated Subdural Microelectrode Arrays", *PLoS One*, 13(11):e0206137, 2018.

4. W. Shen, L. Karumbaiah, X. Liu, T. Saxena, S. Chen, R. Patkar, R.V. Bellamkonda, and M. Allen, "Extracellular Matrix-Based Intracortical Microelectrodes: Toward A Microfabricated Neural Interface Based On Natural Materials," *Microsystems & Nanoengineering,* vol. 1, p. 15010, 2015.

B. Positions and Honors

Positions and Employment

2016-2017	Senior Research Engineer, Singh Center for Nanotechnology, University of Pennsylvania, Philadelphia, PA
2018-2020	Assistant Professor, Department of Mechanical and Aerospace Engineering & Institute for Predictive Performance Methodologies, University of Texas at Arlington, Arlington, TX
2020-present	Assistant Professor, Department of Mechanical and Aerospace Engineering & Nanoscience Technology Center, University of Central Florida, Orlando, FL

Memberships

Institute of Electrical and Electronics Engineers (2013-), American Society of Mechanical Engineers (2018-), The electrochemical Society (2019-)

Selected Honors

2010	The Outstanding International Graduate Student, Collage of Engineering, Auburn University, Auburn, AL
2010	The Outstanding Graduate Student, Department of Materials Engineering, Auburn University, Auburn, AL

Reviewer for Manuscripts

Journal of Micromechanics and Microengineering, Journal of Physics D: Applied Physics, *Smart Materials and Structures*, *Biosensors & Bioelectronics, Sensors & Actuators: B. Chemical, Analytica Chimica Acta, Biotechnology and Bioengineering*, *Sensors, Biosensors, International Journal of Molecular Sciences, Chemosensors*

C. Contributions to Science

1. My research focuses on the development of methods for enabling biomimetic micro-electro-mechanical systems (MEMS) to address the biological, chemical and mechanical properties of physiological interfaces. I developed a set of unique microfabrication techniques which enabled biomimetic microelectronics composed primarily of extracellular matrix (ECM) proteins. These techniques preserved fibrous structures of ECM proteins and resulted in remarkably improved biocompatibility compared with conventional devices made from synthetic materials. These techniques have been successfully used to make neural interface devices which exhibit same dimensions, comparable electrical functionalities, and superior biocompatibilities compared with current state-of-art devices made from synthetic materials.
    a. W. Shen, S. Das, F. Vitale, A. Richardson, A. Ananthakrishnan, L.A. Struzyna, D.P. Brown, N. Song, M. Ramkumar, T. Lucas, D.K. Cullen, B. Litt, and M.G. Allen, "Microfabricated Intracortical Extracellular Matrix-Microelectrodes for Improving Neural Interfaces", *Microsystems & Nanoengineering*, 4 (1) 30, 2018 (*Featured Article and Cover Image*).
    b. F. Vitale, W. Shen, N. Driscoll, J. Burrell, A.G. Richardson, O. Adewole, B. Murphy, A. Ananthakrishnan, T. Wang, T.H. Lucas, D.K. Cullen, M.G. Allen, and B. Litt, "Biomimetic Extracellular Matrix Coatings Improve the Chronic Biocompatibility of Microfabricated Subdural Microelectrode Arrays", *PLoS One*, 13(11):e0206137, 2018.
    c. W. Shen, L. Karumbaiah, X. Liu, T. Saxena, S. Chen, R. Patkar, R.V. Bellamkonda, and M. Allen, "Extracellular Matrix-Based Intracortical Microelectrodes: Toward A Microfabricated Neural Interface Based On Natural Materials," *Microsystems & Nanoengineering,* vol. 1, p. 15010, 2015.

2. I developed various micro/nanofabrication techniques and MEMS/NEMS design methods for wearable electronics. The MEMS/NEMS techniques I developed enabled a wearable flexible biosensor with

nanoscale electrodes, fully biodegradable wireless pressure sensors, and a drug delivery system that can be integrated within flexible substrate.

a. Y. Zhang, D. Castro, Y. Han, Y. Wu, H. Guo, Y. Xue, X. Wang, Y. Xie, D. Ostojich, R. Sun, B. Wang, Z. Xie, D. Peng, S. Qu, W. Shen, T. Hang, A. Banks, Y. Huang, J. Radulovic, P. Gutruf, M. Bruchas, and J. Rogers, "Wireless Injectable Microsystem for Untethered, Programmable Pharmacological and Optogenetic Manipulations of Neural Function in the Brain," *PNAS*, 116 (43), 21427-21437, 2019.
b. N. Song, P. Xie, W. Shen, M. Javanmard, and M.G. Allen, "Microwell-Array on A Flexible Needle: A Transcutaneous Insertable Impedance Sensor for Label-Free Cytokine Detection", *2018 IEEE Micro Electro Mech. Syst.*, 2018, pp. 392–395.
c. M. Luo, W. Shen, Y. Wang, and M.G. Allen, "*In Vitro* Degradation of Biodegradable Metal Zn and Zn/Fe-Couples and their Application as Conductors in Biodegradable Sensors," *Transducers*, 2015, pp. 1370-1373.
d. M. Luo, W. Shen, and M. G. Allen, "Microfabricated PLGA/PVA-Based Completely Biodegradable Passive RF Pressure Sensors," *Transducers*, 2015, pp. 101-104.

3. My early publications addressed the fact that the pathogen detections are often time-consuming and labor intensive. I created and developed a pulse method for wireless interrogation with a micro-biosensor made from magnetoelastic materials. Compared with traditional interrogation method for large-scale (millimeter or centimeter scale) magnetoelastic biosensors, this pulse method not only significantly increased sampling rate and signal to noise ratio for the resonant frequency measurement, but also eliminated the use of bias magnetic field, resulting in a major reduction of system errors for frequency measurement of magnetoelastic biosensors. Furthermore, I developed a theoretical model which explained the effect of external magnetic field on the resonance of the magnetoelastic biosensors. In addition, I investigated phage-based immunoassays on magnetoelastic biosensors and identified the optimum sensor surface properties to obtain high binding efficiency and high detection sensitivity. The pulse detection method I developed along with my study of the magnetoelastic biosensor allowed real-time detection of pathogens directly on food produce.
    a. W. Shen, S. Li, M.-K. Park, Z. Zhang, Z. Cheng, V. A. Petrenko, and B.A. Chin, "Blocking Agent Optimization for Nonspecific Binding on Phage Based Magnetoelastic Biosensors," *Journal of The Electrochemical Society,* vol. 159, pp. B818-B823, 2012.
    b. W. Shen, L.C. Mathison, V.A. Petrenko, and B. A. Chin, "A Pulse System for Spectrum Analysis of Magnetoelastic Biosensors," *Applied Physics Letters,* vol. 96, pp. 163502-163502-3, 2010.
    c. W. Shen, Z. Zhang, S. Horikawa, A. Zhang, J. Teng, L.C. Mathison, and B.A. Chin, "Time domain characterization of magnetoelastic sensors: A pulse method for resonance frequency determination," *Review of Scientific Instruments,* vol. 81, pp. 084702-084702-6, 2010.
    d. W. Shen, R.S. Lakshmanan, L.C. Mathison, V.A. Petrenko, and B.A. Chin, "Phage Coated Magnetoelastic Micro-Biosensors for Real-Time Detection of *Bacillus Anthracis* Spores," *Sensors and Actuators B: Chemical,* vol. 137, pp. 501-506, 2009.

A complete list of published work in my bibliography can be found here:
https://www.ncbi.nlm.nih.gov/myncbi/wen.shen.3/bibliography/public/

D. Additional Information: Research Support and/or Scholastic Performance

Completed awards within the past 3 years:

United State Department of Agriculture (USDA) 2018-38422-28564 (PI: Taboada)
09/01/2018-05/31/2020
ALFA-IoT: Alliance for smart agriculture in the internet of things era
The goal of this project is to prepare graduate and undergraduate students for data-based careers in agriculture-related fields.
Role: Co-Investigator
Overlap: None

The University of Texas System Rising STARs (PI: Shen)

01/01/2018-05/31/2020
Development of functional materials-based microelectronics
This UT System Rising STARs award supports the equipment purchase associated with functional materials-based microelectronics developed by Dr. Shen's group.
Role: Principal Investigator
Overlap: None

BIOGRAPHICAL SKETCH

Provide the following information for the Senior/key personnel and other significant contributors.
Follow this format for each person. **DO NOT EXCEED FIVE PAGES.**

NAME: Hwan Choi

eRA COMMONS USER NAME (credential, e.g., agency login): HWACHOI

POSITION TITLE: Assistant Professor, University of Central Florida

EDUCATION/TRAINING *(Begin with baccalaureate or other initial professional education, such as nursing, include postdoctoral training and residency training if applicable. Add/delete rows as necessary.)*

INSTITUTION AND LOCATION	DEGREE *(if applicable)*	Completion Date MM/YYYY	FIELD OF STUDY
Korea University	B.S.	03/2004	Control Eng.
Korea University	M.S.	03/2006	Biomechanics
University of Washington, Seattle, WA	Ph.D.	12/2016	Mechanical Eng.
University of Michigan, Ann Arbor, MI	Postdoc	04/2018	Kinesiology

A. Personal Statement

I have a broad background in biomechanics, engineering, and physiology, with specific training and expertise in the study of human locomotion as well as prosthetic and orthotic devices. I completed my master's degree at Korea University, focusing on modeling transfemoral amputees with different surgical methods and evaluating the outcome of these surgeries. I then completed my PhD in Mechanical Engineering at the University of Washington in Seattle, where I focused on the effects of ankle foot orthosis stiffness on walking and musculotendon function for children with cerebral palsy and adults with stroke. Prior to joining the faculty at the University of Central Florida, I worked as a postdoctoral research fellow at the University of Michigan in Ann Arbor. There, I worked on finding optimal ankle power for power prosthesis which can minimize metabolic cost for individuals with transtibial amputation.
My research interests have revolved around identifying the interplay between assistive devices and the human musculoskeletal system in order to develop optimal assistive devices. My research group's new research areas are: 1) the analyses of how different exoskeletal designs and controls impact the musculoskeletal systems of individuals with neurological impairments and amputation and 2) developing an energy efficient and real-time variable tunable exoskeletal device that can dynamically interact with the user to provide improvements to function and serve as a rehabilitation modality. Recently, we designed research modules which can change stiffness in an ankle foot orthosis and an ankle prosthesis. We will integrate nanomembrane sensors from Dr. Yeo and implement a machine learning algorithm from Dr. Lei to conduct an finite element analyses to find optimal dimension of the ankle foot orthosis and correlate with experimental data.

B. Positions and Honors

Positions and Employment

2004-2006 Graduate Research Assistant, Biosystem Control Lab, Korea University, South Korea
2005 Appointed Researcher, Korea Orthopedics and Rehabilitation Engineering Research Center, South Korea
2006-2009 Assistant Manager, Vehicle System Validation Engineer, Renault-Samsung Motors, Renault-Nissan Alliance, South Korea
2011-2016 Graduate Research Assistant, Steele Lab, University of Washington, Seattle, WA
2017-2018 Postdoctoral Research Fellow, Rehabilitation and Biomedical Engineering Lab, Robotics and Motion Lab, University of Michigan, Ann Arbor, MI

2018-pres Assistant Professor, Mechanical and Aerospace Engineering Department, University of Central Florida, Orlando, FL

Honors

2012 Recipient of Louis and Katherine Marsh Memorial Fellowship
2016 Recipient of Gait and Clinics Movement Analysis Society Student Travel Award
2016 Recipient of Gazert Child Welfare Fellowship

C. Contributions to Science

1. My early publications identified the characteristics of muscle from in-vivo muscle experiments in canine to improve Hill-type muscle model. These muscle characteristics were used in a musculoskeletal model to identify more accurate muscle function during dynamic tasks. As another application of musculoskeletal modeling, I also investigated which surgical methods for transfemoral amputees provide better joint kinetics and kinematics. These publications brought forward important evidence suggesting that surgical treatments which can preserve a larger residual muscle will provide better performance in joint kinetics and range of motion. I served as the primary investigator or co-investigator in all of these studies.

    1. Hong, J.H. and Choi, H. (2006) "Flexion, extension, abduction, and adduction exercise analyses of transfemoral amputee depending on variation of the surgical method." Journal of Mechanical Science and Technology, 6:2928-2932.
    2. Bae, T.S., Choi, H., Kim, S.K. and Moon, M.S. (2007) "Effects of Prosthetics Mass Distribution on Musculoskeletal System during Amputee Gait." Journal of Korean Society for Precision Engineering, 24(8): 130-137.
    3. Min, S.G., Choi, H., Lee, S.H. and Hong, J.H. (2007) "Dynamic analysis of canine tibialis cranialis-ankle joint musculoskeletal structure and experimental validation." Journal of Korean Society for Precision Engineering, 24(12): 20-28.

2. Understanding muscle characteristics and musculoskeletal modeling led me to investigate the effect of ankle foot orthosis on neurologically impaired individuals' musculoskeletal function during walking. I developed a method for fabricating adjustable stiffness ankle foot orthoses using 3D printing technology and methods for monitoring muscle and tendon length using ultrasound, musculoskeletal modeling, and a motion capture system. These studies have found that an appropriate ankle foot orthosis stiffness has the potential to improve pathologic walking and provide muscle stretching exercise on a step-by-step basis. I served as the primary investigator for a majority of these studies.

    1. Choi, H., Bjornson, K., Fatone, S. and Steele K.M. (2015) "Using musculoskeletal modeling to evaluate the effect of ankle foot orthosis tuning on musculotendon dynamics: a case study." Disability and Rehabilitation Assistive Technology, 2:1-6. 25640240
    2. Choi, H., Wren, T. and Steele, K.M. (2017) "Gastrocnemius operating length with ankle foot orthoses in cerebral palsy." Prosthetics and Orthotics International, 41(3): 274-285. 27613590
    3. Choi, H., Peters, K., MacConnell, M., Katie, L., Eckert, E. and Steele, K.M. (2017) "Impact of ankle foot orthosis stiffness on Achilles and gastrocnemius function during unimpaired gait." Journal of Biomechanics. 64: 145-152. 29037441

3. Adjusting active tuning parameters can be another solution for improving walking function for people with disabilities. Transtibial amputees spend greater energy compared with unimpaired individuals walking with passive ankle prostheses because they provide insufficient ankle power. Thus, I investigated to find an optimal power level of powered ankle prosthesis that can minimize metabolic cost. The key finding of this study is providing a greater ankle power than what occurs in an unimpaired individuals' biological ankle can reduce metabolic cost. Applying excessive ankle power led to recruitment of other compensatory musculature leading to increasing metabolic cost. However, the active prostheses are not widely used because they are expensive, bulky, and heavy. Thus, I am also developing bio-inspired, lightweight, and affordable passive prosthetic modules that enables to maximize energy efficiencies. I served as the primary investigator for all of these studies.

1. Ingraham, K.*, Choi, H.*, Gardinier, E., C.D. Remy and Gates, D, (2018) “Choosing appropriate prosthetic ankle work to reduce the metabolic cost of individuals with transtibial amputation.” Scientific Reports 2018; 15303, DOI:10.1038/s41598-018-33569-7 (*These authors contributed equally to this work.) 30333504
2. Alex, A., Rios Carbonell, G., Jung, S.M., Hong, J.W., Choi, H., and Chi, H.L. (2020) Design and Optimization of Variable Stiffness Ankle Foot Orthoses via Finite Element Analysis. Bio Med Sci 56(1): 89-84 In Publish. 978-1-939527-03-0
3. Rios Carbonell G, Dranetz JM, Choi H, A Lower Limb Prosthetic Augment for Optimal Energy Recycling, Biomimetic to Gastrocnemius and Achilles Tendon Function. 8th IEEE RAS/EMBS BioRob; 477-482, DOI: 10.1109/BioRob49111.2020.9224443

D. Additional Information: Research Support and/or Scholastic Performance

Ongoing Research Support

None

Previous Research Support

1069472 Choi (PI) 07/01/19 – 06/30/20
Korea University
Development of Rehabilitation Integrated Real Time Control Ankle Foot Orthosis Algorithm
The goal of this project is to collaborate with Korea University to develop adjustable stiffness ankle foot orthosis research platform which can tune the stiffness while the participants in dynamic tasks and develop musculoskeletal model which represents interparticipant variabilities.
Role: PI

1069239 Choi (PI) 06/30/19 - 12/31/20
University of Central Research Foundation
Ankle Prosthetic Adjustable Timing Module
The goal of this project is to fabricate the adjustable timing module for ankle prosthetics which can determine optimal push-off timing for individuals with lower limb amputation.
Role: PI

BIOGRAPHICAL SKETCH

Provide the following information for the Senior/key personnel and other significant contributors.
Follow this format for each person. **DO NOT EXCEED FIVE PAGES.**

NAME: Hansen A. Mansy, PhD

eRA COMMONS USER NAME (credential, e.g., agency login): hhmansy

POSITION TITLE: Associate Professor

EDUCATION/TRAINING *(Begin with baccalaureate or other initial professional education, such as nursing, include postdoctoral training and residency training if applicable. Add/delete rows as necessary.)*

INSTITUTION AND LOCATION	DEGREE *(if applicable)*	Completion Date MM/YYYY	FIELD OF STUDY
Cairo University, Egypt	BS, MS	5/1981,8/1985	Mechanical Engineering
Illinois Institute of Technology, Chicago, IL	PhD	5/1990	Mechanical & Aerospace Engineering
Illinois Institute of Technology, Chicago, IL	Post Doc fellow	12/1993	Flow induced vibrations
Rush Medical College, Chicago, IL	Post Doc fellow	12/1996	Bio-vibro-acoustics
Project Management Institute, Newtown Square, PA	PMP certification	2010, 2013, 2016, 2019	Project management

A. Personal Statement

Dr. Mansy specializes in the use of computerized analysis of body sounds for medical diagnosis for more than 25 years and currently directs the Biomedical Acoustics Research Lab at University of Central Florida. He has a proven track record of executing and collaborating on projects in his area of expertise. He has been PI or Co-PI who was responsible for: designing and executing animal and human experiments in consultation with key personnel, developing contact sensors and equipment optimized for body sound acquisition, and developing algorithms and software for advanced digital signal processing involving time frequency distribution, adaptive filtering, noise removal and machine learning. He has been teaching bio-acoustics, instrumentation, statistical analysis, digital data acquisition and processing, and electromechanical systems design, analysis and testing for over 25 years. My collaboration with the other faculty on several research projects directly contributes to the strength of the program.

B. Positions and Honors

Positions and Employment

1986-1990	Graduate Research Assistant, Illinois Institute of Technology, Chicago, IL
1990-1994	Research Scientist, Illinois Institute of Technology, Chicago, IL
1997-2002	Adjunct Associate Professor in Mechanical Engineering, Illinois Institute of Technology, Chicago, IL
	Adjunct Associate Professor in Bioengineering, University of Illinois at Chicago, Chicago, IL
1995-2003	Senior Research Scientist, and Associate Director, Biomedical Acoustics Research Group, Rush University Medical Center, Chicago, IL

1997-Present	Senior Scientist, Biomedical Acoustics Research Company, Orlando, FL
2003-2013	Assistant/Associate Professor, and Co-Director, Biomedical Acoustics Research Group, Rush University Medical Center, Chicago, IL
2013-Present	Associate Professor, Mechanical and Aerospace Engineering Dept - Bioengineering Track, University of Central Florida, Orlando, FL

Other Experience and Professional Memberships

Membership

Acoustical Society of America (ASA)

American Society of Mechanical Engineers (ASME)

American Physical Society (APS)

Institute of Electrical and Electronics Engineers (IEEE)

Engineering in Medicine and Biology Society (EMBS)

Review Activities

a. Research proposals

Air Force office of Scientific Research

Department of Defense

Israel science foundation

Michigan Tri-Corridor Technology Grants /American Association for the Advancement of Science

National Institutes of Health

National Science Foundation

b. Journals

Annals of Biomedical Engineering

European Journal of Mechanics B / Fluids

IEEE Transactions on Biomedical Engineering

Journal of Clinical Anesthesia

Journal of Engineering in Medicine

Journal of Fluids Engineering

Journal of Materials Research

Journal of the Acoustic Society of America

Latin American Applied Research

Medical and Biological Engineering and Computing

Medical Engineering and Physics

New England Journal of Medicine

c. Text Books

McGraw Hill Mechanics Series

John Wiley & Sons, Science Series

d. Patents

Grossman and Flight, Attorneys at Law, Chicago, IL

Honors

2002 Certificate of Teaching Excellence, Armor College of Engineering, Illinois Institute of Technology.

C. Contributions to Science

1) Developing new low-cost and radiation-free patient monitoring methods. This translational research investigated the feasibility of new techniques for monitoring certain conditions using body sounds and vibrations in the audible and sub-audible frequency ranges. Optimized low-complexity digital signal processing algorithms were developed for feature extraction and noise removal. Animal and human studies were performed and suggested the feasibility of this approach for certain pulmonary, cardiac, vascular, neurological and gastrointestinal conditions.

1. Kostick N, Manwaring K, Dhar R, Sandler R, **Mansy HA**. The "Brain Stethoscope": A Non-Invasive Method for Detecting Elevated Intracranial Pressure. Cureus 13(3): e13865. 2021
2. Palnitkar H, Henry BM, Dai Z, Peng Y, **Mansy HA**, Sandler RH, Royston, TJ. Sound transmission in human thorax through airway insonification: an experimental and computational study with diagnostic applications. Medical & Biological Engineering & Computing, 58(10), 2239-2258, 2020
3. Taebi A, Solar BE, Bomar AJ, Sandler RH, **Mansy HA**. Recent advances in seismocardiography, Vibration 2, 64–86; doi:10.3390/vibration2010005, 2019
4. O'Connor CJ, **Mansy HA**, Balk RA, Tauman KJ, Sandler RH. Identification of endotracheal tube malpositions using computerized analysis of breath sounds. Anesthesia and Analgesia 101: 735-9, 2005.
5. **Mansy HA**, Hoxie SJ, Patel NH, Sandler RH. Computerized analysis of auscultory sounds associated with vascular patency of hemodialysis access. Med Biol Eng Comput 43: 56-62, 2005.

2) Investigating important physical mechanisms of airflow and sound propagation in the chest: Computational analysis of flow and frequency-dependent wave propagation in the lung parenchyma, airways and surrounding tissue revealed new insights into transmission mechanisms and optimal modelling approaches. Computer simulations were validated using experiments. The proposed work directly builds on these scientific advances.

1. Gamage P, Khalili F, Azad MK, **Mansy HA**. Modeling inspiratory flow in a porcine lung airway. ASME J of Biomech Eng 140.6: 061003, 2018
2. Dai Z, Peng Y, **Mansy HA**, Sandler RH, Royston TR, A Model of lung parenchyma stress relaxation using fractional viscoelasticity, Medical engineering & physics 37.8, 752-758, 2015.
3. Dai Z, Peng Y, **Mansy HA**, Sandler RH, Royston TR, Experimental and computational studies of sound transmission in a branching airway network embedded in a compliant viscoelastic medium, Journal of Sound and Vibration 339, 215-29, 2015.
4. Dai Z, Peng Y, Henry B, **Mansy HA**, Sandler RH, Royston TJ. A Comprehensive Computational Model of Sound transmission through the Porcine Lung. J. Acous. Soc. Am. 136 (3), 1419 - 29 (2014b). doi: 10.1121/1.4890647, 2014

3) Studying flow induced oscillations that lead to improved flow control in wakes: My early research focused on studying flow induced oscillations in wakes behind moving objects and how waves can be decomposed into symmetric an non-symmetric waves as well as how nonlinear wave interactions may produce harmonic and sub harmonic waves. This work guided efforts to perform controlled alteration of flow structures in the wakes, which in turn can alter forces the flow exerts on objects. In addition, evidence of creation of three dimensional coherent structures in two-dimensional flows was revealed using advanced flow diagnostics.

1. Williams DR, **Mansy HA**, and Fotouh A. Three-dimensional subharmonic waves during transition in the near-wake region of a cylinder. Physics of Fluids A 8:1476-85, 1996.

2. **Mansy HA**, Yang P, and Williams DR. Quantitative measurements of three-dimensional structures in the wake of a circular cylinder. J Fluid Mechanics 270:277-96, 1994.
3. Williams DR, **Mansy HA,** and Amato C. The response and symmetry properties of a cylinder wake subjected to localized surface excitation. J Fluid Mechanics 234:71-96, 1992.
4. **Mansy HA** and Williams DR. Symmetry of interacting modes in a cylinder wake. Physics of Fluids 3:2047-49, 1991.

4) New fluidic devices with no moving parts that are suitable for use as spirometers: This early work investigated mechanisms of self-generated oscillations in fluidic devices. A new fluidic oscillator was invented and was capable of handling a wide range of flow rates that cover both the laminar and turbulent regimes. The device showed extended linear behavior while consuming a fraction of the energy needed by previous oscillators. Both experimental and numerical analysis of vortical structures and their instability were key in enhancing the performance of the device.

1. Williams DR, Meade K, Wilson N, and **Mansy HA**. Spirometer. US Patent 7094208, 2006.
2. **Mansy HA** and Williams DR. Flow meter based on the trapped vortex pair fluidic oscillator. Rev. Scientific. Instruments 60:935-38, 1989.

D. Additional Information: Research Support and/or Scholastic Performance

Ongoing Research Support

NIH/Biomedical Acoustics Research Company Mansy (subcontract PI) 08/01/2017-12/31/2021

A Device for Monitoring Heart Failure Patients

A study to develop an acoustic device for monitoring heart failure patients.

Role: subcontract PI

Biomedical Acoustics Research Company Mansy (PI) 12/15/2015-12/14/2022

Bedside monitoring of endotracheal tube

A study to develop a method for monitoring the location of endotracheal tubes.

Role: PI

Florida High Tech Corridor Council Mansy (PI) 12/15/2015-12/14/2022

Bedside monitoring of endotracheal tube

A study to develop a method for monitoring the location of endotracheal tubes.

Role: PI

Completed Research Support

R01 EB012142 Mansy **(**UCF Subcontract PI**)** 1/1/2012-8/1/2015
NIH/NIBIB
The Audible Human Project
A study to develop an acoustic model of the human torso