Attachment 3

NEW UNDERGRADUATE BIOMEDICAL ENGINEERING DEGREE PROGRAM IN THE KANSAS STATE UNIVERSITY COLLEGE OF ENGINEERING

Proposed Effective Date: Fall 2017

This narrative summarizes a proposed undergraduate Biomedical Engineering (BME) degree program to be offered by the Kansas State University (KSU) College of Engineering (COE). The motivation for this effort is three-fold: to capture growing interest from prospective students that wish to pursue biomedical engineering, to bolster the biomedical teaching/research synergy that already exists within the KSU COE, and to look ahead toward opportunities for employment of KSU engineering graduates in the growing Midwest biomedical industry.

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I. Program Need and Student Characteristics

Biomedical engineering (BME) is one of the most sought-after degrees noted by prospective students who meet with the Kansas State University (KSU) College of Engineering (COE) recruitment team, and it is important for K-State to be able to offer that degree to these highly capable students. The well-known Animal Health Corridor that stretches from Missouri to central Kansas is now being supplemented with a growing number of biomedical companies that specialize in technologies for both human and animal medicine, partially spurred by support from the Kansas Bioscience Authority. These companies will provide healthcare employment opportunities for BME graduates that augment offerings from Cerner, Garmin, Medtronic, RBC Medical Innovations, The Stowers Institute, Biomedical Devices of Kansas, Cardiovascular Imaging Technologies, and other Midwest biomedical institutions. The following sections address the alignment between these opportunities and the proposed BME degree program in more detail.

A. Centrality to Mission

Biomedical engineering is one of the fastest growing degree areas supported by U.S. universities. Approval of the proposed B.S. degree program will enable the KSU COE to offer such a program in a state and region where demand for the degree and its graduates continues to rapidly increase. Biomedical engineering is very broad and multidisciplinary in nature, and providing such a program at Kansas State University is well founded: the degree would be offered by the state's most comprehensive college of engineering and by a university that is strong in both human and animal sciences, incorporating a world-renowned College of Veterinary Medicine. The land-grant mission of Kansas State University and the mission of the College of Engineering resonate thematically with such a BME program, offering world-class faculty and facilities to the citizens of Kansas. Within ten years, we firmly believe that the BME program will be a top program in the KSU College of Engineering.

B. Student Demand

The KSU College of Engineering Office of Recruitment notes that biomedical engineering has, in recent years, been the most requested degree program by prospective students and their families. A study was conducted by Hanover Research to determine the student demand for such a BME program as well as the demand for the resulting graduates. Both B.S. and M.S. degrees in biomedical engineering were analyzed in this study.

Nationally, bachelor's and master's degree completions demonstrate strong growth from 2011 to 2015, as depicted in Table 1 below. For regional degree completions, the study found a lack of undergraduate and graduate programs in biomedical engineering in the Plains Region (Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, and South Dakota), so Hanover expanded its analysis to include the IPEDS-defined Great Lakes region (Illinois, Indiana, Michigan, Ohio, and Wisconsin). Table 2 reports the number of B.S. and M.S. programs in biomedical engineering for each of these states. When compared to national trends, regional degree completions, as noted in Table 3, experienced slightly slower growth – regional

bachelor's degree completions grew at an annualized rate of 9.1 percent (compared to 10.1 percent nationally).

Table 1. National completions of bachelor's and master's degrees in Biomedical Engineering, 2011-2015.

Degree	2011	2012	2013	2014	2015	Compound Annual Growth Rate
B.S. in Biomedical Engineering	4,184	4,625	5,101	5,735	6,137	10.1%
M.S. in Biomedical Engineering	1,532	1,873	1,958	1,946	2,246	10.0%

Table 2. Number of Biomedical Engineering programs by state, 2011-2015.

State	No. Institutions Reporting Bachelor's Programs	No. Institutions Reporting Master's Programs
Iowa	1	1
Kansas	1	1
Minnesota	1	1
Nebraska	1	--
South Dakota	--	1
Illinois	4	5
Indiana	4	3
Michigan	6	3
Ohio	7	9
Wisconsin	3	3
Missouri	3	2
Total	**31**	**29**

Note: North Dakota did not report any bachelor's or master's degrees in biomedical engineering awarded from 2011-2015.
Source: IPEDS

Table 3. Regional completions of bachelor's and master's degrees in Biomedical Engineering, 2011-2015.

Degree	2011	2012	2013	2014	2015	Compound Annual Growth Rate
B.S. in Biomedical Engineering	1,025	1,075	1,163	1,353	1,452	9.1%
M.S. in Biomedical Engineering	375	443	404	386	481	6.4%

Wichita State University started the only other undergraduate biomedical engineering program in Kansas, accommodating an enrollment of 60 students during the first year (2011) – a number which has increased to 193 students in the fall of 2016. In 2015, the WSU BME program awarded 20 B.S. degrees. In addition, the WSU program has indicated that approximately 70% of their undergraduate students originate from within 30 miles of Wichita. Most KSU engineering students originate from the Kansas City metropolitan area and are joined by many other students from all Kansas counties consistent with the engineering and agriculture missions of this land-grant university. Given the growing demand from Kansas students for biomedical engineering degree options, a need exists for another program in the state and region. It is prudent for KSU, the state's most comprehensive engineering college, to offer such a BME program. We predict that a minimum of 30 students will join the program in the first year, and by the second year we expect over 80 students to be enrolled, reaching a total enrollment number of 200+ students by the 5th year of the program without substantial impact on the enrollment numbers at other institutions in the state.

C. Demand for Graduates

According to the Bureau of Labor Statistics, the job outlook for biomedical engineers is projected to grow nationally by over 20% from 2014 to 2024. Biomedical companies in the Midwest will represent a significant portion of that growth, including those considered part of the Midwest Animal Health Corridor. In the analysis study by Hanover using BLS data, the regional employment projections are subdivided into two groups, since three states (Iowa, Kansas, and Ohio) had not yet updated their projections (the period of 2012 to 2022 is used for them). The study predicts a growth of 13.2% in biomedical employment during this period. All of the other states in the Hanover region (Minnesota, Missouri, Nebraska, North Dakota, South Dakota, Illinois, Indiana, and Wisconsin) have updated their 2014-to-2024 projections, and they show a 30.6% growth for this period. We also expect that the National Bio and Agro-defense Facility (NBAF) will provide unique opportunities for KSU BME students locally in Manhattan.

While a significant fraction of BME graduates will seek employment in industry upon degree completion, others will pursue pre-medical degrees or continue on to biomedical engineering graduate school. BLS data indicate that 28.8% of biomedical engineering professionals that are age 25 and older have received a post-graduate degree. Post-graduate work is an important path for graduates of this program.

D. Locational and Comparative Advantages

It is proposed that the B.S. BME program be housed in the KSU Department of Electrical and Computer Engineering (ECE). For over 40 years, the KSU ECE department has supported a Regents-approved Bioengineering Option within Electrical Engineering, and the department offers a collection of biomedical courses. A number of ECE faculty have extensive biomedical engineering backgrounds, having taught biomedical courses and served as investigators on numerous biomedical research grants. For example, the *ECE 571 – Introduction to Biomedical Engineering* course has served over 200 students from 6 departments within the KSU College of Engineering since 2009. Both the ECE 571 course and the *ECE 772/773 – Biomedical*

Instrumentation course have been listed in the KSU undergraduate catalog for 30 years. Other ECE course offerings address thermal therapy/ablation, neural interfacing, biomedical modeling/computation, and independent biomedical design. The ECE department has also been the sponsoring department for the KSU Student Chapter of the IEEE Engineering in Medicine and Biology Society (EMBS), which was founded in Fall 2005 and continues to the present. At the same time, KSU ECE faculty were also instrumental in starting the Kansas City section of the IEEE EMBS, which is also still active.

This course work is complemented by a substantive research portfolio. For example, the four ECE faculty that form the faculty core for this proposal, as listed in Table 4 in Section III, maintain active research laboratories that have supported more than 70 funded efforts for which these individuals have served as investigators since 2000. These efforts have garnered more than $17M from numerous funding sources, and most of that work was/is biomedical in nature. The diversity of ECE's biomedical teaching and research partners on the KSU campus is significant and includes faculty in at least 22 departments within 7 KSU colleges. Hence, ECE is the logical home for this new program.

The University also has strong complementary programs in biology, chemistry, kinesiology, human nutrition, gerontology, and other areas of science that will strengthen this BME program. As part of its central mission as a land grant institution, Kansas State University is bound by a mandate to prepare students for successful employment or advanced studies through a variety of degree programs. Given the projected growth of the biomedical engineering field, it is important for K-State to provide a commensurate degree program to all Kansas students. The University's veterinary medical school and agricultural programs, in addition to the Johnson Cancer Research Center, also provide key elements of the framework that will support this BME undergraduate program. The KSU Biosecurity Research Institute and the National Bio and Agro-defense Facility (NBAF) will also provide unique opportunities for KSU BME faculty and students.

A related B.S. program in Biological Systems Engineering is located in the Department of Biological and Agricultural Engineering (BAE) at K-State. This program places a major emphasis on biological systems that incorporate microbes, plants, and animals. Three engineering degree options are supported through this department: biological, machinery, and environmental. Of the three options, the biological focus would be the closest in theme to a BME degree, and it emphasizes bioremediation, biomaterials, bio-based energy, bioinstrumentation, and biomaterial processing, which are almost exclusively plant-based. Thus there is a significant thematic difference between this degree option and the proposed BME degree.

The only similar program in the Kansas Regents system is the existing undergraduate BME program at Wichita State University. Their 133-credit-hour program is a traditional program with faculty emphases in the areas of sensing, biomechanics, and biomaterials, as evidenced by their published online listings of undergraduate research design projects. The two initial areas of emphasis for the KSU BME degree (biomedical sensors and devices; biomedical computation) exhibit minimal overlap with the WSU program, focusing on skill development toward the design of hardware- and software-based medical devices and systems, including requisite skills in biosignal and image processing in both the time and frequency domains. These courses have foundations in existing courses and research programs managed by KSU engineering faculty.

As noted above, the proposed BME program at KSU offers two initial areas of emphasis that relate thematically to "bioelectronics" or "bioinstrumentation." Hanover identified 10 institutions in the Plains and Great Lakes regions offering a bachelor's degree program in biomedical engineering with a bioelectronics or bioinstrumentation concentration. The programs that are physically closest to Kansas are those at the University of Minnesota - Twin Cities and the Rose-Hulman Institute of Technology in Indiana. Three biomedical B.S degree programs exist in Missouri, and one resides in Oklahoma, but they all have very little overlap with this proposed program, especially from a biomedical devices and computation viewpoint.

E. Student Characteristics

The main pool of students that will enter this program are anticipated to be individuals who (a) might otherwise not consider engineering as their main discipline, (b) seek a pre-medicine degree with an engineering emphasis, and/or (c) may attend an out-of-state university in order to enroll in a biomedical engineering program that matches their degree interests. Students that migrate toward this program will be those with a strong interest in the life sciences whose talents also drive them to seek a fundamental base in math and physics. These individuals will see this exciting and promising degree program as a stepping stone to a career with the potential for significant societal impact. While some student migration between the BME degree program and existing KSU engineering degree programs will undoubtedly occur, this rebalancing is anticipated to be minor relative to existing enrollment numbers, but with the added benefit of providing a much better degree match for the affected students.

Admission criteria will mirror the admission criteria for the KSU College of Engineering. Consistent with enrollment demographics in other BME programs across the U.S., an extremely diverse student population is expected with significant enrollment from women and underrepresented groups. National and regional BME programs run near gender parity.

As with all KSU engineering programs, opportunities for student interactions are significant. Besides the obvious interactions that occur in the classroom and laboratory environments, over 50 different student organizations and competition teams exist in the KSU COE. This includes the KSU Student Chapter of the IEEE Engineering in Medicine and Biology Society (EMBS), which has been active in the ECE department and College of Engineering for over 10 years.

II. Curriculum

A. Overview: Core Courses and Areas of Emphasis

The proposed Biomedical Engineering (BME) curriculum (133 credit hours) incorporates core courses (106 credit hours) coupled with technical electives (27 credit hours), where the latter comprise an area of emphasis. Every student in the program will take the core courses, but their technical electives will vary depending on their chosen area of emphasis. In other words, multiple areas of emphasis are supported in this curriculum, where each area of emphasis is adopted by a subset of the students in the program. The modularity realized via this approach will improve the viability and adaptability of the curriculum over time: existing emphasis areas can be modified, and new emphasis areas can be created, depending on market need, student interest, and faculty expertise, without the need to revisit the whole curriculum.

A.1 Core Courses

The core courses in the proposed curriculum address subject matter that the proposing KSU faculty consider to be an essential part of a BME curriculum, regardless of the area of emphasis chosen by the student. These courses were identified based on a (1) a broad survey of existing biomedical engineering curricula offered by division I engineering programs in the U.S., (2) an assessment of core courses offered by the various KSU engineering departments (to maintain a level of cross-department consistency), and (3) the biomedical research and teaching experiences of the proposing faculty. The four cores are illustrated in Figure 1 and described in more detail in the following paragraphs:

1. **Math & Science Core (52 credit hours)** – This core consists of math, science, and chemistry courses typical of an ABET-accredited KSU engineering program. Additional courses in organic chemistry, biology, and human anatomy/physiology have been added to strengthen the backgrounds of these students in preparation for their other upcoming BME courses. Note that the 8-hour 'human body' experience, not often taken by engineering majors, is required for all BME students. These core courses also overlap significantly with the courses required for a KSU pre-medicine degree, which should entice pre-medicine students to consider engineering as an undergraduate degree option.

2. **Biomedical Engineering Core (37 credit hours)** – These core courses, consistent with model programs across the U.S., address a range of subjects relevant to the "biomedical engineering" discipline. This discipline is extremely broad, incorporating areas of study such as [1]
    - instrumentation, sensors, and measurement,
    - biosignal processing,
    - robotics in surgery,
    - BioMEMS,

[1] "Designing a Career in Biomedical Engineering," IEEE Engineering in Medicine and Biology Society, © 2015, http://www.embs.org/docs/careerguide.pdf.

- imaging and image processing,
- radiology,
- medical and health informatics,
- bioinformatics (incl. genomics),
- proteomics,
- information technology,
- telemedicine,
- biomechanics,
- micro and nanotechnology,
- biomaterials,
- biotechnology,
- drug delivery,
- biofuels,
- tissue engineering,
- cellular and molecular biomechanics, and
- genetic engineering and synthetic biology.

It is impossible to offer a single curriculum that prepares students for all of these application areas. The Biomedical Engineering Core therefore incorporates essential cross-cutting subject matter as a means to strengthen each student's undergraduate knowledge base in as many areas as are sensible:

- **Biomedical engineering** (BME 001, 200) – Application areas and career opportunities in biomedical engineering, including interactions with faculty that perform biomedical research.
- **Biomaterials** (BME 430) – Interactions between materials and biological systems, techniques to assess biomaterial characteristics, and the role of biomaterial selection during the design of medical devices.
- **Biomechanics** (BME 451) – The mechanics of biological tissues and systems at the macroscopic scale. This course addresses the structure and mechanics of biological tissue based on the principles of statics and dynamics, with an emphasis on bone, muscle, and connective tissue.
- **Biomedical signals and instrumentation** (ECE 512, ECE 540, and ECE 772/3) – Signals that describe physiological processes, means to process those data, and the instrumentation to acquire those signals from human and animal subjects.
- **Medical imaging** (ECE 772/3 and BME 674) – Medical imaging modalities as an extension of biomedical instrumentation. Methods for image data acquisition, processing, and display form the core for these courses, which also address industry standards for image storage and transmission.
- **Biomedical systems** (BME 575) – The creation and use of biomedical "systems of systems" as applied in various health care delivery scenarios, including hospitals, home care settings, and environments that employ personalized wearable systems. The material focuses on technical areas typically associated with the field of "clinical engineering," emphasizing the use of design standards that promote system interoperability and reconfiguration.

These courses adhere to the following numbering system, which will flexibly support the addition of core courses and technical electives in the years to come:

BME #0# - Generalized, cross-cutting, socio-political, and ethics material
BME #1# - Administrative and business material (currently unused, but suitable for hospital management, care delivery, and medical patents/economics)
BME #2# - Anatomy and physiology material (currently unused)
BME #3# - Tissue compatibility and the creation/modeling of biological material
BME #4# - Biochemical sensing and cellular engineering (currently unused)
BME #5# - Thermal, mechanical, and fluidic subject matter
BME #6# - Computational analyses, simulation/modeling, and bioinformatics standards/software (currently unused)
BME #7# - Instruments, sensors/devices, optics, and general physical systems
BME #8# - Application-based material (currently unused but suitable for telemedicine, home care, military, assistive, and wearable scenarios)
BME #9# - Independent study, design, and discretionary material

The Biomedical Engineering Core also emphasizes **software skills** with the realization that the ability to create and use software is essential in the current healthcare enterprise, where electronic medical records are now standard, and an increasing number of medical devices are being monitored by, and controlled with, smartphones. Software development skills are addressed in CIS 200, ECE 512, ECE 540, ECE 772/3, and the BME 490/491 and 590/591 design experiences, in addition to any technical electives taken as a part of a student's area of emphasis. This focus on programming abilities helps to address the breadth versus depth problems faced by some BME programs, where finding jobs for BME graduates can be a challenge because the graduates do not have a large-enough skill base in any one area to be attractive to employers. In the proposed BME program, the software skill base will be significant and underscore any other skills developed in the areas of, e.g., device creation, modeling, system-level design, etc.

Finally, the proposed Biomedical Engineering Core also incorporates **two two-semester design sequences**, which the proposers believe is an essential step toward producing graduates that have the ability to think through complex physiology-related challenges. While this approach is atypical in general engineering curricula, it is widely adopted in biomedical programs because of the breadth of topics that are addressed.

3. **Communication Core** (8 credit hours) – The communication core consists of a set of oral and written communication courses taken by students in all departments within the KSU College of Engineering.

4. **Humanities & Social Sciences Core** (9 credit hours) – This core represents the 9-hour block of Humanities and Social Sciences credit that is standard for departments within the KSU College of Engineering. Given the student cliental, the *KIN 110 – Introduction to Public Health* course is strongly suggested as an alternative to the traditional macroeconomics course taken by students in other KSU engineering departments.

K-State 8 general education criteria have also been considered in the design of this course set (see https://www.k-state.edu/kstate8/):

- *A: Aesthetic Interpretation (the only K-State 8 tag not automatically covered)*
- D: Human Diversity within the U.S. (BME 200)
- E: Ethical Reasoning and Responsibility (BME 575, 590)
- G: Global Issues and Perspectives (BME 575, 590; KIN 110)
- H: Historical Perspectives (BME 200)
- N: Natural and Physical Sciences (BIOL 198; BME 674; CHM 2X0; CHM 531; PHYS 21X;)
- Q: Empirical and Quantitative Reasoning (BIOL 198; CHM 2X0; CHM 531; MATH 22X, 240; PHYS 21X; STAT 510)
- S: Social Sciences (KIN 110)

Once the traditional "N" and "Q" tags assigned to math/science classes are supplemented with the tags assigned to BME 200 (D, H), BME 575 (E, G), and KIN 110 (G, S), students in the BME undergraduate program will have more freedom relative to students in other KSU COE curricula to choose Humanities & Social Sciences courses that complete their K-State 8 requirements, since the ***only unaddressed K-State 8 area is A: Aesthetic Interpretation***.

These courses have been aligned with specific ABET-accreditation criteria, as discussed in *Section VI.A* later in this narrative.

Finally, it is worth re-emphasizing that these core courses, when coupled with the required technical electives for an emphasis area (see Section II.A.2 below) and 9 credit hours of properly chosen discretionary technical electives (e.g., CHM 550 & CHM 532 - Organic Chemistry II plus a lab – 5 hours; BIOL 455 – General Microbiology with a lab – 4 hours), ***provide all of the courses required for entrance into medical school***. In other words, this proposed 133-hour curriculum was designed, in part, to meet the needs of students that (a) wish to complete an engineering degree as their pre-medicine curriculum or (b) would not have otherwise considered an engineering degree for that purpose. Additional courses (up to 13 hours) are suggested as preparatory courses for the Medical College Admission Test (MCAT), but not all students take these courses – some do quite well on the MCAT without them.

MATH & SCIENCE CORE		Credits	Semester
MATH 220	Analytical Geometry and Calculus I	4	FSS
MATH 221	Analytical Geometry and Calculus II	4	FSS
MATH 222	Analytical Geometry and Calculus III	4	FSS
MATH 240	Elementary Differential Equations	4	FSS
PHYS 213[L]	Engineering Physics I	5	FS
PHYS 214[L]	Engineering Physics II	5	FS
STAT 510	Introductory Probability and Statistics I	3	FS
CHM 210[L]	Chemistry I	4	FSS
CHM 230[L]	Chemistry II	4	FSS
CHM 531	Organic Chemistry I	3	FS
BIOL 198[L]	Principles of Biology	4	FSS
BIOL 340[◊,L]	Structure and Function of the Human Body	8	FS
	Sub-Total Credit Hours	**52**	

[◊]Or KIN 360 - Anatomy & Physiology (8 credits, FS)

BIOMEDICAL ENGINEERING CORE		Credits	Semester
BME 001[**]	New Student Assembly	0	F
BME 200[**]	Introduction to Biomedical Engineering	3	F
BME 430[**]	Biomaterials	3	F
BME 451[**]	Biomechanical Engineering	3	S
BME 490/491[**,L]	Undergraduate BME Design Experience I/II	3	FS
BME 575[**,L]	Clinical Systems Engineering	3	S
BME 590/591[**,L]	Senior Design Experience I/II	6	FS
BME 674[**]	Medical Imaging	3	S
CIS 200[L]	Programming Fundamentals	4	FS
ECE 512[*,L]	Linear Systems	3	FS
ECE 540[*,L]	Applied Scientific Computing for Engineers	3	FS
ECE 772/3[L]	Theory & Techniques of Bioinstrumentation Lecture/Lab	3	F
	Sub-Total Credit Hours	**37**	

COMMUNICATION CORE		Credits	Semester
ENGL 100	Expository Writing 1	3	FS
ENGL 415	Written Communication for Engineers	3	FSS
COMM 105	Public Speaking 1A	2	FSS
	Sub-Total Credit Hours	**8**	

HUMANITIES & SOCIAL SCIENCES CORE		Credits	Semester
KIN 110[◊◊]	Introduction to Public Health	3	FS
	H&SS Elective	3	
	H&SS Elective	3	
	Sub-Total Credit Hours	**9**	

[◊◊]Or ECON 110 - Principles of Macroeconomics (3, FSS)

Figure 1. Core courses (106 credit hours) required for every BME student. [*] Denotes a modified course; [**] Denotes a new course; [L] Denotes a course requiring lab space.

A.2 Areas of Emphasis

The proposed BME curriculum was designed in a modular way to support a number of different areas of emphasis, depending on the career goals of each student enrolled in the program. As a starting point, the KSU faculty propose two areas of emphasis: ***Biomedical Sensors and Devices*** and ***Biomedical Computation*** – see Figure 2. Others will be added in the early years of the program as the number of students/faculty that support the curriculum increases. The ECE and BME faculty can collaborate with others to create new emphasis areas that may include ***Biomechanics & Human Performance*** (in collaboration with Mechanical Engineering, Kinesiology, and Human Nutrition), ***Mechatronics & Prostheses*** (in collaboration with Mechanical Engineering and Computer Science), ***Tissue Engineering*** (in collaboration with Biological & Agricultural Engineering, Chemical Engineering, and Anatomy & Physiology), ***Telemedicine & Pervasive Care Systems*** (in collaboration with Computer Science and Gerontology), ***Clinical Engineering*** (in collaboration with Industrial & Manufacturing Systems Engineering), and ***Veterinary Applications*** (in collaboration with Animal Sciences and Anatomy & Physiology).

These two initial areas of emphasis will help to focus the new BME program while at the same time demonstrating the potential that a modular approach to the curriculum will offer for future students. The two areas of emphasis were chosen for several reasons:

1. The College of Engineering already has a strong support base for the required courses, all of which are already 'on the books' and taught at least once per year.
2. The hardware and software subjects addressed in these emphasis areas are consistent with skill sets required by employers that already have strong relationships with the KSU College of Engineering.
3. Most of the courses in these areas of emphasis are already taken by Electrical Engineering and Computer Engineering students supported by the Electrical & Computer Engineering (ECE) Department, meaning that ECE will have enough control over these courses to ensure their availability as well as their suitability for the BME student base.
4. Most of these courses are taken by students enrolled in the existing Bioengineering Option within Electrical Engineering – these courses have proved sensible in that role.

As illustrated in Figure 2, each area of emphasis defines a set of required technical electives (that every student must take) accompanied by a set of discretionary technical electives. The required courses supplement the skill base that the students acquire from the core courses, whereas the discretionary courses will depend on student career goals, e.g., in the case of a pre-medicine student, as discussed above.

Representative course schedules for the two areas of emphasis are depicted in Figure 3 (Biomedical Sensors and Devices) and Figure 4 (Biomedical Computation).

AREA OF EMPHASIS: BIOMEDICAL SENSORS & DEVICES		Credits	Semester
ECE 210[L]	Introduction to Electrical Engineering	3	FS
ECE 241[L]	Introduction to Computer Engineering	3	FS
ECE 431[L]	Microcontrollers	3	FS
ECE 410	Circuit Theory I	3	FS
ECE 511	Circuit Theory II	3	FS
ECE 647[L]	Digital Filtering	3	F
	Additional Technical Electives	9	
	Sub-Total Credit Hours	**27**	
Illustrative Technical Electives			
ECE 690	Neural Interfacing	3	S
ECE 690	Thermal Therapy and Ablation	3	S
ME 615[L]	Applications in Mechatronics	3	S
MATH 615	Introduction to Digital Image Processing	3	S
BAE 620	Biotechnology and Biosensors	3	F
ECE 557	Electromagnetic Theory I	4	FS
ECE 771	Control Theory Applied to Bioengineering	3	S
PHYS 651	Introduction to Optics	4	F
PHYS 652	Applied Optics and Optical Measurements	3	S

AREA OF EMPHASIS: BIOMEDICAL COMPUTATION		Credits	Semester
ECE 241[L]	Introduction to Computer Engineering	3	FS
CIS 300[L]	Data and Program Structures	3	FS
ECE 431[L]	Microcontrollers	3	FS
ECE 519	Electric Circuits and Controls	4	FSS
CIS 501	Software Architecture and Design	3	FS
ECE 670[◊◊◊]	Engineering Applications of Machine Intelligence	3	S
	Additional Technical Electives	8	
	Sub-Total Credit Hours	**27**	
Illustrative Technical Electives			
MATH 510	Discrete Mathematics	3	FSS
MATH 551	Applied Matrix Theory	3	FSS
MATH 615	Introduction to Digital Image Processing	3	S
ECE 647[L]	Digital Filtering	3	F
CIS 734	Introduction to Genomics and Bioinformatics	4	S
ECE 690	Neural Interfacing	3	S
ECE 648	Multimedia Compression	3	S
MATH 655[L]	Elementary Numerical Analysis I	3	FS
CIS 544	Advanced Software Design and Development	3	SS

[◊◊◊]Or ECE 771 - Control Theory Applied to Bioengineering (3 credits, S)

[◊◊◊]Or CIS 730 - Principles of Artificial Intelligence (3 credits, S)

[◊◊◊]Or CIS 732 - Machine Learning and Pattern Recognition (3 credits, F)

Figure 2. Initial areas of emphasis (27 credit hours each). Each student will choose one area.

BIOMEDICAL ENGINEERING

Curriculum for Bachelor of Science in Biomedical Engineering

Area of Emphasis: Biomedical Sensors and Devices

(133 hours total)

Effective Fall 2018

Planned to be Accredited by the Engineering Accreditation Commission of ABET (http://www.abet.org)

Fall Semester Courses			Sem Hrs		Spring Semester Courses		Sem Hrs
FRESHMAN							
BME	001 New Student Assembly		0		ECE	210 Intro to Electrical Engg	3
BME	200 Intro to Biomedical Engg		3		MATH	221 Anal Geom Calc 2	4
KIN	110 Intro to Public Health	or	3		PHYS	213 Engg Physics 1	5
ECON	110 Prin Macroecon				CHM	230 Chemistry 2	4
CHM	210 Chemistry 1		4				
ENGL	100 Exposit Writing 1*		3				
MATH	220 Anal Geom Calc 1		4				
		TOTAL	17			TOTAL	16
SOPHOMORE							
COMM	105 Public Speaking 1A		2		BIOL	198 Prin of Biology	4
ECE	241 Intro to Computer Engg		3		MATH	222 Anal Geom Calc 3	4
MATH	240 Elem Diff Equations		4		CIS	200 Prog Fundamentals	4
PHYS	214 Engg Physics 2		5		ECE	511 Circuit Theory 2	3
ECE	410 Circuit Theory 1		3		STAT	510 Intro to Prob & Stat I	3
		TOTAL	17			TOTAL	18
JUNIOR							
BME	430 Biomaterials		3		CHM	531 Organic Chemistry I	3
BIOL	340 Struct Func Human Body	or	8		ECE	512 Linear Systems	3
KIN	360 Anatomy and Physiology				BME	451 Biomechanical Engineering	3
ECE	540 App Sci Computing		3		ENGL	415 Writ Comm Engr	3
BME	490 Undergrad BME Design Exp I		1		BME	491 Undergrad BME Design Exp II	2
					ECE	431 Microcontrollers	3
		TOTAL	15			TOTAL	17
SENIOR							
ECE	772 Biomed Instrumentation Lec		2		BME	674 Medical Imaging	3
ECE	773 Biomed Instrumentation Lab		1		BME	575 Clinical Systems Engineering	3
BME	590 Senior Design Exp I		3		BME	591 Senior Design Exp II	3
ECE	647 Digital Filtering		3		Technical Elective***		3
Technical Elective***			6		Humanities / Social Sci Elective**		3
Humanities / Social Sci Elective**			3				
		TOTAL	18			TOTAL	15

*Students must complete the appropriate prerequisite credits for ENGL 415, but may apply only 3 hours of ENGL 415 prerequisite credits toward degree requirements.

**Humanities and Social Science electives are to be selected from the approved College of Engineering H&SS list. Students should select these courses as needed to complete the requirements of the K-State 8 General Education program.

***Technical Electives must be selected to complete one of the areas of emphasis. Technical Electives must come from the approved technical electives list.

Figure 3. Representative schedule for the "Biomedical Sensors and Devices" area of emphasis.

BIOMEDICAL ENGINEERING

Curriculum for Bachelor of Science in Biomedical Engineering

Area of Emphasis: Biomedical Computation

(133 hours total)

Effective Fall 2018

Planned to be Accredited by the Engineering Accreditation Commission of ABET (http://www.abet.org)

Fall Semester Courses			Sem Hrs			Spring Semester Courses		Sem Hrs
FRESHMAN								
BME	001 New Student Assembly		0			ECE	241 Intro to Computer Engg	3
BME	200 Intro to Biomedical Engg		3			MATH	221 Anal Geom Calc 2	4
KIN	110 Intro to Public Health	or	3			PHYS	213 Engg Physics 1	5
ECON	110 Prin Macroecon					CHM	230 Chemistry 2	4
CHM	210 Chemistry 1		4					
ENGL	100 Exposit Writing 1*		3					
MATH	220 Anal Geom Calc 1		4					
		TOTAL	17				TOTAL	16
SOPHOMORE								
COMM	105 Public Speaking 1A		2			BIOL	198 Prin of Biology	4
CIS	200 Prog Fundamentals		4			MATH	222 Anal Geom Calc 3	4
MATH	240 Elem Diff Equations		4			CIS	300 Data Prog Structures	3
PHYS	214 Engg Physics 2		5			ECE	431 Microcontrollers	3
Humanities / Social Sci Elective**			3			STAT	510 Intro to Prob & Stat I	3
		TOTAL	18				TOTAL	17
JUNIOR								
ECE	519 Electric Circuits and Control		4			CHM	531 Organic Chemistry I	3
BIOL	340 Struct Func Human Body	or	8			ECE	512 Linear Systems	3
KIN	360 Anatomy and Physiology					ECE	670 Engg Appl Mach Intell	3
ECE	540 App Sci Computing		3			BME	491 Undergrad BME Design Exp II	2
BME	490 Undergrad BME Design Exp I		1			BME	451 Biomechanical Engineering	3
						ENGL	415 Writ Comm Engr	3
		TOTAL	16				TOTAL	17
SENIOR								
BME	430 Biomaterials		3			BME	674 Medical Imaging	3
ECE	772 Biomed Instrumentation Lec		2			BME	575 Clinical Systems Engineering	3
ECE	773 Biomed Instrumentation Lab		1			BME	591 Senior Design Exp II	3
BME	590 Senior Design Exp I		3			Technical Elective***		3
CIS	501 Software Arch and Design		3			Technical Elective***		3
Humanities / Social Sci Elective**			3					
Technical Elective***			2					
		TOTAL	17				TOTAL	15

*Students must complete the appropriate prerequisite credits for ENGL 415, but may apply only 3 hours of ENGL 415 prerequisite credits toward degree requirements.

**Humanities and Social Science electives are to be selected from the approved College of Engineering H&SS list. Students should select these courses as needed to complete the requirements of the K-State 8 General Education program.

***Technical Electives must be selected to complete one of the areas of emphasis. Technical Electives must come from the approved technical electives list.

Figure 4. Representative schedule for the "Biomedical Computation" area of emphasis.

B. Anticipated Outcomes and Other Academic Objectives

B.1 Anticipated Outcomes

An individual that completes the BME degree program offered by the KSU College of Engineering will be in a position to

- contribute to the Midwest biomedical industry as a new hire in a corporation that produces or supports hardware- and software-based biomedical devices and systems,
- enter biomedical graduate school at a division I university with a solid foundation in the core areas that define the discipline of biomedical engineering,
- enter medical school with the benefit of engineering training that will promote their success as a physician at a time when high-technology systems play a day-to-day role in health care delivery,
- approach system-level medical design problems with a solid technical understanding of the sensor, device, system, interface, and information management issues germane to this area of work,
- support a hospital-based care delivery enterprise with a clear understanding of the device-interfacing, interoperability standards, purchasing, training, and information management needs associated with the successful deployment of large scale health care delivery systems,
- practice and teach the principles of informed consent and the ethical design and use of biomedical technologies,
- effectively communicate with colleagues in oral and written form, and
- successfully contribute to a diverse team of engineers, physicians, and administrators whose common goal is to deliver a medical product or service.

B.2 Skills Future Graduates Will Possess

The skills possessed by each graduate of the KSU BME program relate directly to the anticipated outcomes listed in the prior section. These skills include the ability to

- apply calculus-based mathematics when analyzing and designing physical systems,
- statistically describe medical data properties and real-world system performance,
- quantify and report tissue movement,
- operate biomedical instruments and medical imaging systems, then store and analyze the resulting data and images,
- properly acquire biomedical data and analyze their characteristics in the time and frequency domains,
- develop software to enable hardware-based devices and to process biomedical data,
- pursue a component- or system-level biomedical design based on an understanding of customer requirements and resource availability,
- lay out a medical “system of systems” comprised of commercially available hardware and software that utilize industry interoperability standards,
- demonstrate professional skills centered around an understanding of personality profiles and an ability to communicate effectively in oral and written form, and
- design biomedical systems consistent with a student’s area of emphasis.

B.3 Knowledge Future Graduates Will Possess

The knowledge possessed by graduates of the KSU BME program relates directly to the anticipated outcomes and skills noted in the prior two sections. These knowledge includes an understanding of

- human/animal anatomy and physiology, including the chemistry that drives cellular-level processes and signaling mechanisms,
- application domains addressed by biomedical and clinical engineers,
- historical events that have influenced the development of medical technologies and the means by which these tools are made available to the public,
- diversity issues germane to health care delivery, including care delivery to traditionally underserved populations,
- global issues that affect the dissemination of medical knowledge and the deployment of new medical products,
- ethics principles related to access to care delivery, informed consent, intellectual property ownership, and day-to-day conduct in the workplace,
- biocompatibility issues related to material/tissue interactions,
- human movement and stresses imposed by tissue motion,
- the theory, operation, advantages, and limitations of biomedical instruments and medical imaging systems for use in multiple application environments,
- biomedical signal behavior in the time/frequency domains and the application of frequency-domain principles to medical imaging techniques,
- biomedical device markets, intellectual property, medical device regulation, customer-driven requirements, and formal design methods,
- interoperability standards for device interfacing, information storage, and data reporting that are needed to assemble systems of systems using commercial tools, and
- application-driven details based on a student's area of emphasis.

B.4 Internships and Practica

Consistent with other degree programs in the KSU COE, participation in internships will not be required for completion of the KSU BME degree. However, students and faculty are aware that internships play a key role in secondary education, offering students valuable professional experience while at the same time allowing the student and the employer an extended opportunity to evaluate one another in the context of future employment opportunities. Companies that hire KSU engineering graduates have stated that summer internships offer a preferred time frame within which to assess the technical and interpersonal abilities of a student in light of their company culture and products. The KSU COE and faculty will therefore promote internships and co-ops as desired components of the BME degree.

III. Program Faculty

Core and Affiliate Faculty

The initial faculty to support the B.S. program in Biomedical Engineering (see Table 4) will consist of four core ECE faculty members, two new faculty dedicated to the BME curriculum, and affiliate faculty from ECE and other departments at KSU, where the latter are potential collaborators that can engage depending on course, design project, and undergraduate research needs. The core program faculty have doctoral degrees relevant to Biomedical Engineering and maintain active research programs in this field. Two additional hires – one tenure-track faculty member and one instructor – are planned to support the BME program and will be recruited and vetted via a formal national search. The affiliate faculty listed in Table 4 are a representative set of a larger group that will grow over time and change demographically as the BME curriculum matures.

Table 4. KSU faculty that will support the proposed undergraduate BME program (continued on the next page).

Name	Rank	Areas of Expertise	Department
CORE FACULTY			
Dr. Steve Warren	Associate Professor	Light-based biomedical instrumentation; wearable wireless physiological monitoring; telemedicine	Electrical and Computer Engineering
Dr. Punit Prakash	Assistant Professor	Image-guided interventions; thermal ablation and hyperthermia; therapeutic medical devices	Electrical and Computer Engineering
Dr. Dave Thompson	Assistant Professor	Brain-computer interfaces; neural engineering; biomedical instrumentation	Electrical and Computer Engineering
Dr. Caterina Scoglio	LeRoy and Aileen Paslay Professor	Infectious disease modeling; complex networks	Electrical and Computer Engineering
FUTURE PROGRAM FACULTY			
TBD, 1.0 FTE	Tenure-track faculty	TBD	Electrical and Computer Engineering
TBD, 1.0 FTE	Instructor	TBD	Electrical and Computer Engineering

AFFILIATE FACULTY			
Dr. Amir Bahadori	Assistant Professor	Health physics; radiation exposure; radiation-induced cancer	Mechanical and Nuclear Engineering
Dr. Dwight Day	Associate Professor	Embedded systems and signal processing for biomedical applications	Electrical and Computer Engineering
Dr. Stephen Dyer	Professor	Instrumentation and measurement	Electrical and Computer Engineering
Dr. Steven Eckels	Professor	Body/environment heat transfer, mass transfer and fluid flow	Mechanical and Nuclear Engineering
Mr. Kim Fowler	Instructor	Medical device and system design	Electrical and Computer Engineering
Dr. Ryan Hansen	Assistant Professor	Synthetic biological interfaces; bacterial characterization	Chemical Engineering
Dr. Mei He	Assistant Professor	Micro/nanofluidics; point-of-care diagnosis; mobile health	Biological and Agricultural Engineering
Dr. William Kuhn	Professor	Biomedical sensor technology	Electrical and Computer Engineering
Dr. Ruth Miller	Associate Professor	Bioelectromagnetics; bioinstrumentation	Electrical and Computer Engineering
Dr. Bala Natarajan	Clair N. Palmer and Sara M. Palmer Professor	Biomedical signal processing; statistical signal processing	Electrical and Computer Engineering

Graduate Assistants

A total of seven graduate teaching assistants (GTAs), each on a 0.5 FTE appointment (total = 3.5 FTE), will be needed to support the B.S. program in Biomedical Engineering. GTAs will support instructors in the following courses: BME 200, 430, 451, 490/91, 575, and 674.

IV. Academic Support

Advising for this program will follow the ECE department advising model, where students will work with a general advisor in their first two years and then switch to a BME faculty advisor for the last two years of the curriculum. Administrative support will be offered through the current ECE staff. A large enrollment growth would likely require an additional staff position.

K-State Libraries strive to meet the breadth of information needs of the faculty and students across the university. Given the rich history of the College of Engineering and its importance to the university, the Libraries have always made the needs of the engineering program a priority in terms of providing access to information resources.

The ECE department maintains approximately 90 computers for use in teaching labs throughout the department. All labs are available during normal business hours, and many of the high-use labs have electronic locks to provide 24/7 access to students. Students in the College of Engineering have access to a broad and comprehensive range of computing resources provided by the College, the University, and departments and units in the College. Resources provided by the College and the University include over 200 college computers in engineering buildings and over 500 university computers in on-campus labs, residence halls and the main campus library.

Administrative support for this program will be handled by the four full-time ECE staff who already support the other two programs – electrical engineering and computer engineering. If and when BME undergraduate enrollment exceeds 150 students, an additional staff member will likely be necessary to support that additional load.

V. Facilities and Equipment

The Department of Electrical and Computer Engineering is located in Engineering Hall, where all faculty and staff have offices. Faculty utilize 29 individual offices on the third floor of this new building, which also offers office space for new BME faculty. Teaching assistants have desk space in a cubicle area in 3068 Engineering Hall, which contains 26 individual desks with access to computer resources.

This new program will require one teaching laboratory that will utilize reallocated space in an existing ECE teaching laboratory. This 640-square-foot laboratory is already equipped with the appropriate benches. Students enrolled in engineering courses are assessed an equipment fee that will support the purchase and maintenance of equipment needed to support hands-on BME laboratories and design projects in that laboratory, so no additional funds will be needed to purchase equipment. Students in the BME program would also have access to all department and college general purpose computer laboratories.

VI. Program Review, Assessment and Accreditation

The biomedical engineering program will seek ABET accreditation after the first graduates of the program have completed their degree. The standard ABET process used to seek accreditation of new programs will be followed, with the request that the accreditation would be granted effective the year before the first degree is granted. Assuming the first graduates complete their degrees in the year 2022, the initial accreditation would be sought for the 2021-2022 academic year. An assessment plan and process for measuring ABET student outcomes (a) through (k) will be developed – see the next section. Techniques include evaluation of tests, projects, senior design experiences, and surveys.

This program will also be subject to a similar assessment process in support of the Higher Learning Commission (HLC) accreditation of Kansas State University. The process developed for ABET accreditation will cover all requirements for HLC accreditation. Likewise, program review at the Board of Regents level will also be followed, as is currently done for other ECE programs.

Program review by the Kansas Board of Regents is also planned, using the same process utilized for the review of the KSU Electrical Engineering and Computer Engineering programs. The quality of the faculty, quality of the degree program, and demand for program graduates, in addition to other criteria, will be addressed in each review. The first review will occur in 2018, which is also the first year this program will have students. Therefore, the report will be an update of the program at that point and will not be flagged because it does not meet the KBOR minimum number of juniors and seniors.

A. Plan for Assessment of Student Learning

A.1 Student Learning Outcomes Measures

The Student Learning Outcomes (SLOs) for the B.S. degree in Biomedical Engineering are those required by our accrediting body (ABET). (Note that the SLOs required by ABET are identical for all engineering programs.) These SLOs follow:

(a) an ability to apply knowledge of mathematics, science, and engineering,
(b) an ability to design and conduct experiments, as well as to analyze and interpret data,
(c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability,
(d) an ability to function on multidisciplinary teams,
(e) an ability to identify, formulate, and solve engineering problems,
(f) an understanding of professional and ethical responsibility,
(g) an ability to communicate effectively,
(h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context,
(i) a recognition of the need for, and an ability to engage in life-long learning,
(j) a knowledge of contemporary issues, and
(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

A.2 Assessment Methods and Measures

Direct measurement methods will be utilized for the assessment of each of these outcomes. The ECE department maintains a list of principles of assessment that are utilized for both our ABET assessment process as well as assessment processes required by KSU and the KBOR. These principles follow:

1. All assessment for ABET student outcomes will be done in courses taught by the ECE department.
2. Most outcomes will be assessed in multiple classes. An effort will be made to limit the number of outcomes assessed in any one course.
3. Outcomes will be assessed in accordance with the ECE Outcomes Assessment Schedule.
4. Most assessment will be done in junior and senior level courses. End of semester assessment is preferred.
5. ABET assessment will be done only on undergraduate students that pass the course.
6. Electrical engineering, computer engineering, and biomedical engineering students will be assessed separately.
7. Assessment of the culminating design courses will be reviewed by the assessment committee in conjunction with the instructors of the courses. This group will meet each semester to evaluate the rigor and completeness of the design experiences of all culminating design courses. Note: In addition to outcomes assessment, the review of the culminating design courses will also address compliance with principle 5.

A.3 Assessment Timeline

The matrix in Figure 5 depicts the courses used to assess these SLOs and the semesters during which these assessments will occur. Note that "ALL" indicates each semester that course is offered, whereas "Fall" or "Spring" indicate that assessment occurs only in that particular semester.

Biomedical Engineering Assessment Matrix Student outcomes/required courses	**BME 200**	**ECE 512**	**BME 490/491**	**BME 451**	**ECE 540**	**BME 575**	**BME 590/591**	**ECE 772/773**
(a) an ability to apply knowledge of mathematics, science, and engineering		Fall		Fall				ALL
(b) an ability to design and conduct experiments, as well as to analyze and interpret data					Spring	Spring		
(c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability			ALL			ALL	ALL	
(d) an ability to function on multidisciplinary teams							ALL	
(e) an ability to identify, formulate, and solve engineering problems			Spring					ALL
(f) an understanding of professional and ethical responsibility	Fall						ALL	
(g) an ability to communicate effectively							ALL Oral &Written	ALL Written
(h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context	Fall						ALL	
(i) a recognition of the need for, and an ability to engage in life-long learning							ALL	
(j) a knowledge of contemporary issues	Fall						ALL	
(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice		Fall	Spring		Spring			

Figure 5. Biomedical Engineering assessment matrix.

A.4 Review of Assessment Data

Outcome data will be reviewed annually by a BME assessment committee and will also be presented annually for review in a meeting for all ECE department faculty. Recommendations for changes can be initiated by either the BME assessment committee or by faculty during a faculty meeting.

A.5 Assessment Alignment Matrix

Figure 6 contains an alignment matrix which indicates, for each SLO, where students have an opportunity to learn the outcome and where the outcome is assessed. The specific courses used for assessment are shown in the assessment matrix above.

Alignment Matrix – For each stated student learning outcome, where does the student have the opportunity to learn the outcome and where is student achievement of the outcome is assessed?

B.S. BME SLO/Required Courses/experiences	Required Mathematics	Required Science	University General Education	BME Core	BME Technical Electives	BME Senior Design
Degree program Slo's						
a. An ability to apply knowledge of science, mathematics, and engineering	X	X		A	X	X
b. An ability to design and conduct experiments, as well as to analyze and interpret data	X	X		A	X	X
c. An ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability				A	X	A
d. An ability to function on multidisciplinary teams				X	X	A
e. An ability to identify, formulate, and solve engineering problems				A	X	A
f. An understanding of professional and ethical responsibility			X	X	X	A
g. An ability to communicate effectively			X	X	X	A
h. The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context			X	A	X	A
i. A recognition of the need for, and an ability to engage in life-long learning		X	X	X	X	A
j. A knowledge of contemporary issues			X	A	X	A
k. An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice	X	X		A	X	A
University SLO's						
Knowledge	X	X	X	A	X	A
Critical thinking	X	X	X	A	X	A
Communication			X	A	X	A
Diversity			X	A		
Academic and professional integrity			X	A	X	A

Place an "X" for courses or experiences in which students have the opportunity to learn the outcome.
Place an "A" for courses or experiences in which student performance is used for program level assessment of the outcome.

Figure 6. Alignment matrix for student learning outcomes in the proposed undergraduate Biomedical Engineering degree program.

New Degree Request – Kansas State University

Criteria	Program Summary
1. Program Identification	Bachelor of Science in Biomedical Engineering CIP Code: 14.0501
2. Academic Unit	College of Engineering, Department of Electrical and Computer Engineering
3. Program Description	This is a new undergraduate degree program in biomedical engineering, also referred to as BME. Although it will administratively be located in the Department of Electrical and Computer Engineering at Kansas State University, it is truly a broad degree whose fundamentals are the same as almost all other biomedical engineering programs in the U.S. Program approval is requested for the fall 2017 semester so that recruitment may occur during the 2017-18 academic year. The 2018-19 academic year will be the first year of implementation.

4. Demand/Need for the Program	The KSU College of Engineering Office of Recruitment notes that biomedical engineering has, in recent years, been the most requested degree program by prospective students and their families. According to the Bureau of Labor Statistics (BLS), the job outlook for biomedical engineers is projected to grow by over 20% from 2014 to 2024. Biomedical companies in the Midwest will represent a significant portion of that growth, including those considered part of the Midwest Animal Health Corridor. Wichita State University started the only other undergraduate biomedical engineering program in Kansas, accommodating an enrollment of 60 students during the first year (2011) – a number which has increased to 193 students in the fall of 2016. In 2015, the WSU BME program awarded 20 B.S. degrees. In addition, the WSU program has indicated that approximately 70% of their undergraduate students originate from within 30 miles of Wichita. Most KSU engineering students originate from the Kansas City metropolitan area and are joined by many other students from all Kansas counties consistent with the engineering and agriculture missions of this land-grant university. Given the growing demand from Kansas students for biomedical engineering degree options, a need exists for another program in the state and region. It is prudent for KSU, the state's most comprehensive engineering college, to offer such a BME program. The KSU College of Engineering has also performed a market study through Hanover – an independent consultant. In this analysis, which also used BLS data, the regional employment projections are subdivided into two groups, since three states (Iowa, Kansas, and Ohio) had not yet updated their projections (the period of 2012 to 2022 is used for them). The study predicts a growth of 13.2% in biomedical employment during this period. All of the other states in the Hanover region (Minnesota, Missouri, Nebraska, North Dakota, South Dakota, Illinois, Indiana, and Wisconsin) have updated their 2014-to-2024 projections, and they show a 30.6% growth for this period. The results of this study support the conclusion that an undergraduate biomedical engineering program is needed at KSU. We also expect that the National Bio and Agro-defense Facility (NBAF) will provide unique opportunities for KSU BME students locally in Manhattan.

5. Comparative /Locational Advantage	For over 40 years, the KSU ECE department has supported a Regents-approved Bioengineering Option within Electrical Engineering, and the department offers a collection of biomedical courses. A number of ECE faculty have extensive biomedical engineering backgrounds, having taught biomedical courses and served as investigators on numerous biomedical research grants. This course work is complemented by a substantive research portfolio. For example, the four ECE faculty that form the faculty core for this proposal maintain active research laboratories that have supported more than 70 funded efforts for which these individuals have served as investigators since 2000. These efforts have garnered more than $17M from numerous funding sources, and most of that work was/is biomedical in nature. The diversity of ECE's biomedical teaching and research partners on the KSU campus is significant and includes faculty in at least 22 departments within 7 KSU colleges. Hence, ECE is the logical home for this new program. The university also has strong complementary programs in biology, chemistry, kinesiology, other sciences that will help provide strength to this program. As a land grant institution, Kansas State University has in its central mission the pledge to prepare students for successful employment or advanced studies through a variety of degree programs. With projected growth of biomedical engineering it is important for K-State to provide that degree program to all students in the state. The university's veterinary medical and agricultural programs in addition to the Johnson Cancer Research Center also make a BME undergraduate program a logical choice. The proximity of the Biosecurity Research Institute and NBAF also provide many unique opportunities for both the faculty and students of this program. The only similar program in the Kansas Regents system is the existing undergraduate BME program at Wichita State University. Their 133-credit-hour program is a traditional program with faculty emphases in the areas of sensing, biomechanics, and biomaterials, as evidenced by their published online listings of undergraduate research design projects. The two initial areas of emphasis for the KSU BME degree (biomedical sensors and devices; biomedical computation) exhibit minimal overlap with the WSU program, focusing on skill development toward the design of hardware- and software-based medical devices and systems, including requisite skills in biosignal and image processing in both the time and frequency domains. These courses have foundations in existing courses and research programs managed by KSU engineering faculty. As noted below, the proposed BME program at KSU offers two initial areas of emphasis that relate thematically to "bioelectronics" or "bioinstrumentation." Hanover identified 10 institutions in the Plains and Great Lakes regions offering a bachelor's degree program in biomedical engineering with a bioelectronics or bioinstrumentation concentration. The programs that are physically closest to Kansas are those at the University of Minnesota - Twin Cities and the Rose-Hulman Institute of Technology in Indiana. Three biomedical B.S degree programs exist in Missouri, and one resides in Oklahoma, but they all have very little overlap with this proposed program, especially from a biomedical devices and

	computation viewpoint.
6. Curriculum	This 133 credit hour curriculum consists of 1) 37 credits of biomedical engineering core courses; 2) 52 credits of math and science core courses; 3) 8 hours in a general engineering core; 4) 9 hours in a humanities and social sciences core; and 5) 27 hours in technical electives. As in many BME programs, this program is structured to support a variety of areas of concentration by defining a significant portion of the technical electives. Two such areas are defined at this point: *Biomedical Sensors and Devices* and *Biomedical Computation*.
7. Faculty Profile	The KSU ECE faculty already includes five individuals with extensive backgrounds in biomedical engineering and 5 others with moderate experience, equating to nearly half of the faculty roster. In the KSU College of Engineering, the ECE department is the logical home for this new program. The initial faculty to support the B.S. program in Biomedical Engineering will consist of four core ECE faculty members, two new faculty dedicated to the BME curriculum, and affiliate faculty from ECE and other departments at KSU, where the latter are potential collaborators that can engage depending on course, design project, and undergraduate research needs. The four key faculty members, who have doctoral degrees relevant to Biomedical Engineering and maintain active research programs in this field, are: • Dr. Steve Warren, leading faculty member of the biomedical group; taught biomedical classes at KSU since 1999; director of the Medical Component Design Laboratory • Dr. Punit Prakash, assistant professor since 2012; director of the Biomedical Computing and Devices Lab • Dave Thompson, assistant professor since 2014; conducts research on brain-computer interfaces and medical devices • Caterina Scoglio, LeRoy and Aileen Paslay Professor, director of the Network Science and Engineering Group Two additional hires – one tenure-track faculty member and one instructor – are planned to support the BME program and will be recruited and vetted via a formal national search. An instructor is planned to be hired for the first year (AY 2018-19). Assuming enrollment meets expectations, an additional faculty member would be hired the following year. At the moment, nine other affiliated faculty in the College of Engineering would be associated with this program, each of whom would either teach required courses or lead activities such as undergraduate research. These faculty are a representative set of a larger group that will grow over time and change demographically as the BME curriculum matures See http://www.ece.k-state.edu/people/faculty/index.html for more details.

8. Student Profile	The main pool of students that will enter this program are not thought to those that would only initially be considering engineering as their main discipline. Students interested in this program will be those with a strong interest in modern life sciences but also with a fundamental base in math and physics who see this as an exciting and promising degree that lead to a career with significant societal impact. Admission criteria will be consistent with the admission criteria for the KSU College of Engineering. Consistent with enrollment demographics in other BME programs across the U.S., an extremely diverse student population is expected with very significant enrollment from women and underrepresented groups.
9. Academic Support	Advising for this program will follow the ECE department advising model, which utilizes a general ECE advisor for students in their first two years. At that point, each student would be assigned to a BME faculty advisor for the last two years of the curriculum. Administrative staff support will initially be the same. Large enrollment growth would likely require an additional position.
10. Facilities and Equipment	This new program would require one teaching laboratory that would be reallocated from another teaching lab in the same department. Students enrolled in engineering courses are assessed an equipment fee that would be used to purchase and maintain the equipment needed to support the courses in this program. Existing classroom and laboratory spaces should meet the needs of this program in the near future.
11. Program Review, Assessment, Accreditation	The biomedical engineering program will seek ABET accreditation after the first graduates of the program have completed their degree. The standard ABET process used for requesting accreditation of new programs will be followed, with the request that accreditation would be granted starting the year before the first degree is granted. Assuming the first graduates complete their degrees in the year 2022, the initial accreditation would be sought for the 2021-2022 academic year. An assessment plan and process for measuring ABET student outcomes a through k has been developed. Techniques include evaluation of tests, projects, senior design experiences, and surveys. This program will also undergo a similar assessment process to support the Higher Learning Commission (HLC) accreditation of Kansas State University. This process developed for ABET accreditation will cover all requirements for HLC accreditation. Likewise, program review at the Board of Regents level will also be followed, just as is currently being done for the other programs in the department.

12. Costs, Financing	Two new faculty will be needed to eventually teach six of the seven new BME courses, while existing faculty will teach the other new course and ECE courses that would be modified for use in the BME program. The financial cost of the two new faculty is estimated to be $160,000 in faculty salaries and a one-time startup cost of $300,000. This assumes that one position is an instructor with no startup requirements and the second position is a tenure-track assistant professor. Financing for salaries would be provided by the College of Engineering, while startup costs would be shared equally by the Department of Electrical & Computer Engineering, the College of Engineering, and the Vice-President for Research.

CURRICULUM OUTLINE
NEW DEGREE PROPOSALS
Kansas Board of Regents

I. Identify the new degree: B.S in Biomedical Engineering

II. Provide courses required for each student in the major:

	Course Name & Number	Credit Hours
Core Courses	**(106 hours)**	
MATH 220	Analytical Geometry and Calculus I	4
MATH 221	Analytical Geometry and Calculus II	4
MATH 222	Analytical Geometry and Calculus III	4
MATH 240	Elementary Differential Equations	4
PHYS 213	Engineering Physics I	5
PHYS 214	Engineering Physics II	5
STAT 510	Introductory Probability and Statistics I	3
CHM 210	Chemistry I	4
CHM 230	Chemistry II	4
CHM 531	Organic Chemistry I	3
BIOL 198	Principles of Biology	4
BIOL 340	Structure and Function of the Human Body	
or		8
KIN 360	Anatomy & Physiology	
BME 001	New Student Assembly	0
BME 200	Introduction to Biomedical Engineering	3
BME 430	Biomaterials	3
BME 451	Biomechanical Engineering	3
BME 490/491	Undergraduate BME Design Experience I/II	3
BME 575	Clinical Systems Engineering	3
BME 590/591	Senior Design Experience I/II	6
BME 674	Medical Imaging	3

CIS 200	Programming Fundamentals	4
ECE 512	Linear Systems	3
ECE 540	Applied Scientific Computing for Engineers	3
ECE 772/3	Theory & Techniques of Bioinstrumentation Lecture/Lab	3
ENGL 100	Expository Writing 1	3
ENGL 415	Written Communication for Engineers	3
COMM 105	Public Speaking 1A	2
KIN 110	Introduction to Public Health	3
	Humanities and Social Science Elective	3
	Humanities and Social Science Elective	3

Technical Electives (27 hours)

Area of Emphasis: Biomedical Sensors and Devices

ECE 210[L]	Introduction to Electrical Engineering	3
ECE 241[L]	Introduction to Computer Engineering	3
ECE 431[L]	Microcontrollers	3
ECE 410	Circuit Theory I	3
ECE 511	Circuit Theory II	3
ECE 647[L]	Digital Filtering	3
	Additional Technical Electives	9

Area of Emphasis: Biomedical Computation

ECE 241[L]	Introduction to Computer Engineering	3
CIS 300[L]	Data and Program Structures	3
ECE 431[L]	Microcontrollers	3
ECE 519	Electric Circuits and Controls	4
CIS 501	Software Architecture and Design	3
ECE 670[◊◊◊]	Engineering Applications of Machine Intelligence	3
	Additional Technical Electives	8

Research: none required

Practice: none required

Total: 133 hours

IMPLEMENTATION YEAR FY 2018-2019

Fiscal Summary for Proposed Academic Programs

Institution: Kansas State University Proposed Program: Bachelor of Science in Biomedical Engineering

Part I. Anticipated Enrollment	Implementation Year		Year 2		Year 3	
	Full-Time	Part-Time	Full-Time	Part-Time	Full-Time	Part-Time
A. Full-time, Part-time Headcount:	30		60		90	
B. Total SCH taken by all students in program	900		1,800		2,700	
Part II. Program Cost Projection						
A. In implementation year one, list all identifiable General Use costs to the academic unit(s) and how they will be funded. In subsequent years, please include only the additional amount budgeted.						
	Implementation Year		Year 2		Year 3	
Base Budget Salaries	$75,000		$160,000		$160,000	
OOE						
Total	$75,000		$160,000		$160,000	

Indicate source and amount of funds if other than internal reallocation:

Financing for salaries would be provided by the College of Engineering. Associated startup costs would be shared equally by the Department of Electrical and Computer Engineering, the College of Engineering, and the Vice-President for Research.

Revised: September, 2003

Approved: _____

Department of Electrical and Computer Engineering

New Biomedical Engineering (BME) (B.S.)

Rationale: This new program is being created for two fundamental reasons: 1) biomedical engineering is one of the most sought-after degrees noted by prospective students who meet with the College of Engineering recruitment team; and 2) according to the Bureau of Labor Statistics, the job outlook for biomedical engineers is projected to grow nationally by over 20% from 2014 to 2024. Biomedical companies in the Midwest will represent a significant portion of that growth, including those considered part of the Midwest Animal Health Corridor. For over 40 years, the KSU ECE department has supported a Regents-approved Bioengineering Option within Electrical Engineering, and the department offers a collection of biomedical courses. A number of ECE faculty have extensive biomedical engineering backgrounds, having taught biomedical courses and served as investigators on numerous biomedical research grants. This course work is complemented by a substantive research portfolio. For example, the four ECE faculty that form the faculty core for this proposal maintain active research laboratories that have supported more than 70 funded efforts for which these individuals have served as investigators since 2000. These efforts have garnered more than $17M from numerous funding sources, and most of that work was/is biomedical in nature. The diversity of ECE's biomedical teaching and research partners on the KSU campus is significant and includes faculty in at least 22 departments within 7 KSU colleges. Hence, ECE is the logical home for this new program.

Effective: Fall 2017

Impact:

List of Programs Impacted by BME Curriculum			
Dept.	Contact	Courses	Note:
BIOL	Brian Spooner	198, 340	No concerns for BIOL 198; BIOL 340 is transitioning to a two-semester course, 4 credits each. DH email 9/30/2016
CHM	Eric Maatta	210, 230, 531	No concerns - DH email 9/20/2016
CS	Scott DeLoach	200, 300*, 501*	No concerns if CIS 200 can move to Fall or add a GTA. DH email 9/21/2016
COMM	Tim Steffensmeier	105	No concerns - DH email 9/20/2016
ECON	Bill Blankenau	110	No concerns - DH voice call 9/22/2016; But would like to know if all COE programs requiring ECON would be ok with giving flexibility of ECON 110 or ECON 120?
ENGL	Karin Westman	100, 415	No concerns – DH email 10/26/2016
KIN	Craig Harms	110, 330, 360	No concerns on KIN 110 or KIN 360; Changed the name of BME 451 to Biomechanical Engineering to avoid a conflict with KIN 330 – Biomechanics. Numerous email exchanges and meeting 10/28/2016.
MATH	Andy Bennett	220, 221, 222, 240	No concerns – 10/25/2016
PHYS	Brett DePaola	213, 214	Email of support – 11/17/2016; The increased enrollment load in physics courses is being discussed and managed between A&S and engineering.
STAT	Gary Gadbury	510	No concerns other than need a larger room or possible summer school – DH email 9/20/2016
BAE	Joe Harner	BSE program	Supported at college meeting.
CHE	Jim Edgar		Supported at college meeting.

Bachelor's degree requirements
Freshman year

Fall semester (17 credit hours)

- BME 001 - New Student Assembly Credits: (0)
- BME 200 - Intro to Biomedical Engg Credits: (3)
- CHM 210 - Chemistry I Credits: (4)
- *ENGL 100 - Expository Writing I Credits: (3)
- MATH 220 - Analytic Geometry and Calculus I Credits: (4)
- KIN 110 - Intro to Public Health Credits: (3)

or

ECON 110 - Principles of Macroeconomics Credits: (3)

Spring semester (16 credit hours)

- MATH 221 - Analytic Geometry and Calculus II Credits: (4)
- PHYS 213 - Engineering Physics I Credits: (5)
- CHM 230 - Chemistry II Credits: (4)
- Technical Electives Credits: (3)

Sophomore year

Fall semester (17 credit hours)

- COMM 105 - Public Speaking IA Credits: (2)
- MATH 240 - Elementary Differential Equations Credits: (4)
- PHYS 214 - Engineering Physics II Credits: (5)
- Technical Electives Credits: (6)
-

Spring semester (18 credit hours)

- BIOL 198 – Principles of Biology Credits: (4)
- MATH 222 - Analytic Geometry and Calculus III Credits: (4)
- CIS 200 - Programming Fundamentals Credits: (4)
- STAT 510 - Introductory Probability and Statistics I Credits: (3)
- Technical Electives Credits: (3)

Junior year

Fall semester (15 credit hours)

- BIOL 340 – Structure and Function of the Human Body Credits: (8)
- BME 430 – Biomaterials Credits: (3)
- ECE 540 - Applied Scientific Computing for Engineers Credits: (3)
- BME 490 – Undergraduate BME Design Experience I Credits: (1)

Spring semester (17 credit hours)

- CHM 531 – Organic Chemistry I Credits: (3)

- ECE 512 - Linear Systems Credits: (3)
- BME 451 – Biomechanical Engineering Credits: (3)
- ENGL 415 - Written Communication for Engineers Credits: (3)
- BME 491 – Undergraduate BME Design Experience II Credits: (2)
- Technical Electives Credits: (3)

Senior year

Fall semester (18 credit hours)

- ECE 772 – Theory and Techniques of Bioinstrumentation Credits: (2)
- ECE 773 – Bioinstrumentation Design Laboratory Credits: (1)
- ECE 590 - Senior Design Experience I Credits: (3)
- ***Technical Electives Credits: (9)
- **Humanities/Social Science Elective Credits: (3)

Spring semester (15 credit hours)

- BME 674 – Medical Imaging Credits: (3)
- BME 575 – Clinical Systems Engineering Credits: (3)
- ECE 591 - Senior Design Experience II Credits: (3)
- ***Technical electives Credits: (3)
- **Humanities/Social Science Elective Credits: (3)

Notes

*Students must complete the appropriate prerequisite credits for ENGL 415, but may apply only 3 credit hours of ENGL 415 prerequisite credits towards degree requirements.
For the good and benefit of the student and their future employer, the ECE department enforces a C- prerequisite policy for all courses listed by number in the curriculum and for any in-major technical elective course applied toward the degree. A grade of C or better must be earned in all prerequisites to such a course before enrolling in that course.
**Humanities and Social Science electives are to be selected from the list of courses approved by the College of Engineering. Students should select these courses as needed to complete the requirements of the K-State 8 General Education program.
***Technical electives must be selected from the list of accepted courses.
***** No more than twelve (12) credit hours of courses in electrical engineering, computer engineering, or biomedical engineering may be transferred to Kansas State University for credit toward a bachelor's degree in biomedical engineering. Further, those courses selected for transfer credit must be equivalent to courses in the list below and must be such that the prerequisites for the listed course are also satisfied. Any courses transferred must be taken from ABET accredited programs: ECE 210, ECE 241, ECE 410, ECE 511, ECE 512, ECE 519, ECE 590/591, ECE 772, BME 200, BME 430, BME 451, BME 490/491, BME 575, and BME 674. Students participating in exchange programs or transferring in from outside the United States may request waivers of this policy. Waivers must be obtained in advance of the exchange semester.
NOTE: K-State 8 General Education Requirements

IMPORTANT NOTE: Students must meet the requirements of the K-State 8 General Education Program.
Total credit hours required for graduation (133)