The University Senate of Michigan Technological University

PROPOSAL 14-00

BS DEGREE PROGRAM IN BIOMEDICAL ENGINEERING

A. Executive Summary

This document presents a plan for the offering of a new baccalaureate degree, "Bachelor of Science in Biomedical Engineering" by Michigan Technological University. The degree program will be administered by the Center for Biomedical Engineering, an academic unit within the College of Engineering. The program of study will replace the focus in biomedical engineering within the current Bachelor of Science in Engineering (B.S.E.) degree program. That program is scheduled for ABET accreditation review in AY '01-'02, at which time the University will request the Biomedical Engineering curriculum be accredited separately under the cognizant ABET criteria.

B. Biomedical Engineering at Michigan Tech

According to the U.S. Department of Labor, biomedical engineers Aapply knowledge of engineering, biology, and biomechanical principles to the design, development, and evaluation of biological and health systems and products, such as artificial organs, prostheses, instrumentation, medical information systems, and heath management and care delivery systems.@[1]

History of Biomedical Engineering at Michigan Tech

Prior to 1992, there were very few biomedical engineering students at Michigan Tech. The rate of B.S.E. degree awards in bioengineering and/or biomedical engineering was less than one per year. A significantly greater number of students would enroll in Atraditional@ engineering curricula, supplemented with course work in biological sciences. This nucleus enabled us to maintain an active student Biomedical Engineering Society chapter, and to develop a limited number of senior-level courses to meet the needs of those students (e.g., ME 480 - Biomechanics and Human Factors in Design, Ch.E. 495 - Engineering Analysis of the Cell).

In the mid-90's there were large increases in the number of first-year students coming to Michigan Tech **specifically to pursue the B.S.E. degree in biomedical engineering**. In fall 1994, approximately twenty first-year students enrolled in the B.S.E. program -- *an order of magnitude increase* over the historic levels. A similar number of first-year students (twenty) entered the program in fall 1995. Clearly, a formal program structure was needed to meet the educational needs of these students and allow them to achieve their professional goals.

In 1997, Michigan Tech received a three-year Special Opportunity Award in the amount of $942,605 from The Whitaker Foundation of Rosslyn, VA. The grant was to enable the start-up of a formal baccalaureate program in biomedical engineering at Michigan Tech. The grant has enabled the hiring of faculty in essential technical areas, and led to the establishment of the MTU Center for Biomedical Engineering with the approval of the Center's charter in 1998.

Growth in undergraduate enrollment and interest has continued. Figure 1 shows the six-year trend (1995-2000) of undergraduate enrollment in the Bachelor of Science in Engineering (BSE) program. The BSE students in biomedical engineering are designated "EBS1" majors by the registrar. Prior to 1998, however, all BSE students had the same major designation ("EBS"); biomedical engineering students were not separable from manufacturing engineering, mechanical design engineering, or other BSE focus areas. For this reason, the pre-1998 enrollment data include all BSE degree students. The bulk of those students (>90%) were in biomedical engineering. Virtually all the growth in BSE enrollment is attributable to the increased population of biomedical engineering (EBS1) students.

As of January 3, 2000, ninety-two students have been admitted to the EBS1 program (biomedical engineering) for the class of 2004 (entering September '00). This is double the year-ago admission rate, which yielded forty entering students. **Approximately one-quarter of the students admitted to the program in the class of '04 are valedictorians**; 60% are in the 90th percentile or higher.

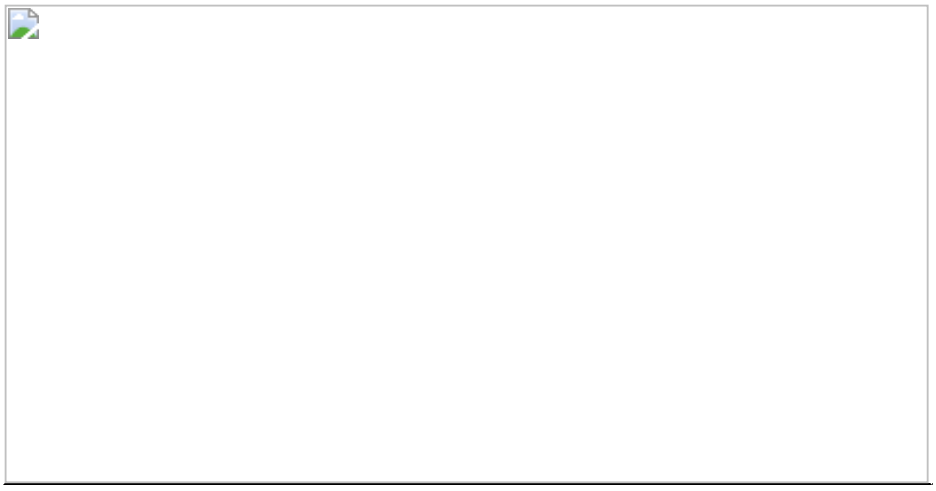

Figure 1: Bachelor of Science in Engineering (BSE) enrollment trends. "New" indicates the number of entering first-year students each year, while "Total" represents the number of students in the program each year.

The biomedical engineering program has by far the largest proportion of women students among engineering programs at Michigan Tech. It is one of very few engineering programs anywhere in which women constitute a majority (approximately 60% of EBS1 students are women). This program is attracting increasing numbers of talented women into engineering, where they have historically been severely under-represented.

C. Opportunities for Biomedical Engineering Graduates

With the rapid growth of the biomedical engineering program, placement of graduates has emerged as a major concern. We recently surveyed students in the BE101 AIntroduction to Biomedical Engineering@ course regarding their post-graduation plans. As most of those students are in their first or second years of college, their plans are prone to change.

Of the 58 respondents, 24 (41%) indicated they planned to find full-time employment upon graduation. The remaining students are planning full-time post-graduate education, either in a graduate program in biomedical engineering (21/58, or 36%) or professional school (medical school, dental school -- 13/58, or 22%).

Extensive efforts are directed at identifying career opportunities for those students planning to enter the labor market immediately upon graduation. There are few surveys which specifically address the job market for biomedical engineers. Some recent salary surveys indicate there is substantial demand for graduates, however.

The 1998 salary survey by the National Association of Colleges and Employers shows a mean starting salary of $37,845 for graduates with B.S. degrees in biomedical engineering or bioengineering, a 2.4% increase from 1997. Within engineering disciplines, the range of mean starting salaries in 1998 was $35,335 (civil engineering) to $45,104 (chemical engineering).

The 1999 salary survey by Medical Device & Diagnostic Industry, a trade journal, determined the mean annual salary is $72,500 for product design engineers, and $70,200 for production and manufacturing engineers in the medical products industry. (Note these are categorized by job function and not by degree, and include all levels of experience.)

The U.S. Bureau of Labor Statistics (Department of Labor) has recently added standard occupational classification for "biomedical engineering" to be included in forthcoming labor market reports and forecasts. This reflects the maturation of biomedical engineering as a distinct discipline, and recognizes its increasing presence in the labor market.

Biomedical Engineering encompasses not only clinical fields, but also industrial applications. For instance, this definition would include engineering industrial power tools to reduce worker fatigue and trauma. While our graduates are in increasing demand in the medical products field, we also see tremendous opportunities for our graduates to have impact in non-medical manufacturing areas (e.g., industrial ergonomics, engineering for safety). This point is particularly significant given the enormous manufacturing base of Michigan and surrounding states.

D. Cooperative Education and Internship Opportunities

Biomedical Engineering students are strongly encouraged to take advantage of opportunities for cooperative education or industrial internships, as those experiences can be extremely valuable starting points for full-time employment after graduation. A number of EBS1 students have taken advantage of co-op or internship opportunities with various employers,

including Scimed/Boston Scientific (Maple Grove, MN), Stryker Instruments and Stryker Medical (Kalamazoo, MI), and Mayo Clinic and Foundation (Rochester, MN). There are current placement opportunities for our students at Kimberly-Clark (which recently acquired Baxter Health Care), Ford Motor Company (industrial ergonomics) and numerous firms in the Minneapolis / St. Paul metropolitan area. The phenomenal growth of the medical and surgical device industry in Minnesota has created the so-called "Medical Alley"and presents great career opportunities for our students. Virtually all of the world's pacemakers are manufactured in the Twin Cities (Medtronic, Guidant, or St. Jude Medical). Continuing efforts will be directed at identifying additional opportunities for co-op or internship experiences for biomedical engineering students.

E. Off-Campus Resources

At the baccalaureate level, a quality biomedical engineering program does **not** demand affiliation with a medical school or teaching hospital. Still, students in the MTU biomedical engineering program have opportunities to gain professional experience through summer internships at medical schools, clinics, and governmental labs, as well as at industrial sites. There are ongoing faculty research collaborations with colleagues at Mayo Clinic (Orthopedic Biomechanics Laboratory), NASA / Johnson Space Center, Lawrence Livermore National Laboratory, U.S. Air Force Research Laboratory, Duke University Medical Center, Baylor College of Medicine, and Medical College of Virginia. All offer potential sites for students to gain research or clinical experience relevant to their professional goals. Additional opportunities are offered through the National Institutes of Health summer internships, as well as those offered at numerous other medical schools and research laboratories.

Students also will gain practical experience with "real-world" problems through the Senior Design Practicum. Each senior in biomedical engineering will be part of a team assigned a year-long project, sponsored by an industrial or corporate partner. The partner defines and sponsors the project and provides technical consultation and evaluative feedback. This program is being offered in AY '99-'00, with fourteen seniors participating.

F. ABET Accreditation Status

Michigan Tech's Bachelor of Science in Engineering (B.S.E.) comprises four distinct focus areas: Biomedical Engineering (EBS1), Mechanical Design Engineering -GM Distance Education (EBS2), Manufacturing Engineering (EBS3), and Manufacturing Engineering - GM Distance Education (EBS6). Two other focus areas were eliminated in 1999: Geo-environmental Engineering (EBS4), and Environmental Remediation and Reclamation (EBS5).

The B.S.E. program was reviewed in September 1998 by the Accreditation Board for Engineering and Technology (ABET). The result of that review was the reaccreditation of the B.S.E. to September 30, 2002. A request must be submitted to ABET by January 31, 2001 to initiate a reaccreditation evaluation during Fall, 2001.

At the time of the 1998 ABET visit, the Center for Biomedical Engineering was assuming responsibility for the biomedical engineering curriculum, which had historically been administered by the Mechanical Engineering - Engineering Mechanics Department. Concerns expressed by the ABET visitors reflected the fact that the program objectives and assessment processes had not yet been defined by the Center for Biomedical Engineering.

With the approval of the Bachelor of Science in Biomedical Engineering (B.S.B.E.) program, the biomedical engineering focus (EBS1) will be eliminated effective with the 2000-1 academic year. Students in the EBS1 curriculum will convert to the new degree, which will have the identical curriculum. No new students will be accepted into EBS1.

The B.S.B.E. will be in conformance with the ABET Program Criteria for Bioengineering and Similarly Named Engineering Programs.

G. Administration

The B.S.B.E. program will be administered by the Center for Biomedical Engineering (CBE), which currently administers the EBS1 focus area. The chief administrative officer of the CBE is the Director, D.A. Nelson, who reports to the Dean of Engineering. The Director of the CBE is responsible for the curriculum, including course offerings and scheduling, degree certification, and compliance with ABET criteria. The Director represents the interests of biomedical engineering within the college and the university.

H. Program Educational Objectives

Objective 1

Graduates should possess sufficient breadth and depth of knowledge, and the ability to acquire skills necessary to solve complex problems in medicine, physiology and the life sciences. This requires the ability to integrate knowledge in the physical and life sciences with a knowledge of engineering tools to creatively solve problems involving living systems.

Objective 2

Graduates should be able to evaluate and analyze problems and solutions from multiple perspectives: technical feasibility, economic viability, conformance with regulatory practices, ethical, social and aesthetic sensibility.

Objective 3
Graduates should be able to communicate effectively, orally and in writing, and express their ideas and conclusions clearly and persuasively.

I. Program Outcomes
Educational outcomes are those attributes to be demonstrated by graduates of the Biomedical Engineering program. Outcomes (or goals) are measurable or verifiable traits or bodies of knowledge which are consistent with, and indicate achievement of, the program objectives described above. The outcomes for the B.S.B.E. program include those broad outcomes expected of all engineering programs, as defined by ABET (a - k, below), plus the program-specific outcomes delineated for programs in biomedical engineering and bioengineering (l - n) and those specific to the biomedical engineering program at Michigan Tech (o - q).

Outcomes required of all ABET-accredited engineering programs.
Graduates should have the following attributes:

a. They should have a sound, fundamental knowledge of science, mathematics, and engineering. This includes knowledge of differential and integral calculus, differential equations, statistics, basic biology, chemistry, and physics. Students should also understand the principles of engineering mechanics, thermodynamics, basic circuit theory (including digital systems), and materials science.

b. They should be able to design and conduct experiments, including experiments involving living systems. This includes possessing the ability to analyze and interpret data, using appropriate statistical tools.

c. Graduates should be able to design a system, component, or process. They should be able to evaluate their design from the standpoint of technical feasibility, manufacturability, safety and reliability, and cost of production.

d. They should be able to function on multidisciplinary teams. This requires the ability to work effectively with professionals from other fields of technical expertise and from different backgrounds, to accomplish a common goal.

e. Graduates should be able to identify, formulate, and solve engineering problems

f. They should demonstrate an appreciation and understanding of standards of professional and ethical responsibility.

g. Graduates should communicate effectively, both orally and in writing. They should be able to utilize a variety of formats and media, and be capable of targeting their writing and presentations to the intended audience.

h. They should have a broad education and an understanding of the global and societal impact of the engineering profession.

i. Graduates should recognize the need for lifelong learning.

j. They should be aware of and understand contemporary issues.

k. Graduates should understand the techniques, skills, and tools used in modern engineering practice.

Outcomes for ABET-accredited programs in bioengineering and similarly named programs.

l. Graduates should have a knowledge of human anatomy and physiology.

m. They should be able to apply tools of advanced mathematics (including differential equations and mathematics), scientific investigation, and engineering analysis to solve complex problems at the interface of engineering and biology.

n. They should be able to make and interpret measurements on living systems, and understand the measurement problems associated with the interaction between living and nonliving materials and systems.

Outcomes specific to Michigan Tech's biomedical engineering program.

o. Graduates should know how to evaluate proposed solutions and designs from an economic standpoint. They should understand opportunity cost, cost of production, and marketability of a product or system.

p. They should have knowledge of U.S. and international regulatory issues in health care technology.

q. Graduates should have knowledge of issues in entrepreneurship and intellectual property.

J. Program Evaluation

Three primary tools will be used to evaluate the quality of the educational program:

1. *Engineering Fundamentals (FE) exam results*. Seniors will be encouraged to take the FE exam, as it is an important and necessary step toward obtaining the Professional Engineer license. Tracking the number and percentage of our seniors who pass the exam will yield an objective indicator of the rigor of the curriculum, and provide one benchmark we can use to compare ourselves with other programs.

2. Exit interviews of graduating students. Every spring semester, each senior will be interviewed by the Director of the Center for Biomedical Engineering, or by another designated member of the biomedical engineering faculty.

3. Surveys of alumni and employers. Periodically, we will survey alumni and employers of our graduates to assess the long-term value of the curriculum. While the survey results will be more subjective and anecdotal than some other measures, it will be perhaps the most valuable tool in telling us where we can improve the program.

K. Resources Required

The establishment of the new program imposes no additional demand on university resources, over what is needed for the EBS1 focus area. The curriculum will not change, and there will be **no increased resource needs attributable to the change in degree titles**. The need for increased resources will be driven by growth in the program, not by the change in the program title.

Resource requirements for the program are based on a nominal class size of 40 students (i.e., total of 160 students in the B.S.B.E. program). Classes significantly greater than that will require an incremental increase in resources, due to the need to run multiple class sections and increase laboratory capacity. That need is independent of the offering of the new degree.

The Center for Biomedical Engineering consists of five full-time faculty members, four of whom are untenured. Two of those faculty members are funded from the Whitaker Foundation Special Opportunity Grant, but the University has committed to funding those positions from general fund revenues effective with the '00-'01 academic year.

There are 1.4 FTE staff members funded from the Whitaker Foundation grant: a full-time Senior Secretary, and a part-time Instructor and academic Advisor. Both positions are essential to the program, independent of whether it exists as a B.S.E. or B.S.B.E. degree.

The increased enrollment in the existing biomedical engineering program has impacted other departments which offer some of the service courses required of biomedical engineering students. In particular, additional laboratory sections were needed for the BL 201 and 201 sequence (Anatomy and Physiology). This was anticipated, and the initial cost of added lab instruction (GTA) was funded from the Whitaker Foundation Special Opportunity Grant. The University has since assumed the cost of the added GTA, and this is expected to continue with the conversion of anatomy and physiology to a full-year sequence. The anatomy and physiology lecture sections have sufficient capacity to accommodate the increased enrollment without additional resources.

Additional library resources will be required to support the biomedical engineering program. The J.R. Van Pelt Library does subscribe to some relevant journals (e.g., IEEE Transactions on Biomedical Engineering, Journal of Biomechanical Engineering, Journal of Biomechanics), but additional periodicals may be needed to support the

undergraduate biomedical engineering curriculum. Similarly, book acquisitions in biomedical engineering and related fields will require support.

Itemized Program Costs for AY 2000-1 (based on 1999-2000 expenses)

The following budget estimates indicate the expenses of the biomedical engineering program which were or will be: 1) funded by an external grant in AY'99-00 ("Ext. Fund"); 2) funded by General fund revenues in AY '99-'00 ("Gen. Fund"); 3) required from the general fund for the EBS1 degree in AY '00-01; 4) required from the general fund for the BSBE degree in AY '00-01.

	Ext. Fund ('99-00)		Gen. Fund ('99-00)		EBS1('00-01)
BSBE('00-'01)					
Salaries & Wages					
Faculty Salaries (1999-2000)	117,000	188,000	305,000	305,000	
Secretary ('99-'00 wages)	21,000	0	21,000	21,000	
Fringe benefits (38%)	52,440	71,440	123,880	123,880	
Graduate Teaching Assistant (BE)	11,040	0	12,810	12,810	
Graduate Teaching Assistant (Biol. Sci.)		11,040	12,810	12,810	
Supplies, Services & Equipment	25,000	0	15,000	15,000	
Direct Program Cost	226,480	270,480	490,500	490,500	

*Funded from a Special Opportunity Grant from the Whitaker Foundation in 1999-2000; costs to be borne by General Fund in 2000-1.

26 April 2000: Adopted by University Senate
17 May 2000: Approved by President Tompkins

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[1] U.S. Bureau of Labor Statistics, Standard Occupational Classification, as modified Oct. 15, 1999. http://stats.bls.gove/soc/soc_d2d1.htm