Queen's UNIVERSITY

Senate Committee on Academic Development
Report to Senate – Meeting of May 20, 2009

Proposal to introduce a Collaborative Program in Biomedical Engineering in the School of Graduate Studies and Research

Introduction

The proposal to introduce a Collaborative Program in Biomedical Engineering in the School of Graduate Studies and Research (SGSR) was reviewed by the Senate Committee on Academic Development (SCAD) at its meeting April 29, 2009. B. Brouwer, Associate Dean of SGSR, and B. Amsden, Associate Professor, Department of Chemical Engineering, attended the SCAD meeting to speak to the proposal and answer questions from members of SCAD. Members of SCAD were also provided with the Program Approval Submission Form, which outlines the major components of the proposal. A copy of the proposal is attached to this report.

Analysis and Discussion

The following should be noted:

- this proposed program will focus on existing research strength at Queen's in the areas of Chemical Engineering, Mechanical Engineering and Electrical and Computer Engineering;
- this proposed program will promote shared learning and interdisciplinary research;
- students will be admitted to this proposed program from their home department in the Faculty of Applied Science;
- this proposed program will encourage students from a variety of backgrounds to learn through hypothesis-driven research and seminar-based courses;
- this area of study is considered to be a discipline of growth in the engineering field;
- the proposed program meets student demand and will attract graduate students allowing Queen's to remain competitive at the national and international level;
- graduates of the proposed program may decide to pursue studies at the Master or PhD level, or enter the workforce in the areas of pharmaceuticals, biomedical devices, health care support or academe.

Conclusions/Recommendation

Recommendation:

On academic grounds, SCAD recommends that Senate approve the establishment of the Collaborative Program in Biomedical Engineering in the SGSR, to commence in September 2009.

Respectfully submitted,

Patrick Deane
Chair, Senate Committee on Academic Development

Committee Members:

Members
C. Baker
J. Coates
P. Deane (Chair)
M. Hoidas
M. Lombardi
D. McKeown
K. O'Brien (Secretary)
P. Oosthuizen
M. Roberts
D. Stockley
M. Whitehead

Senate Budget Review Committee

Report to Senate – April 30, 2009

I. Proposal to establish a Collaborative Graduate Program in Biomedical Engineering

Introduction

On April 30, 2009, the Senate Budget Review Committee (SBRC) met to discuss the Proposal to establish a Collaborative Graduate Program in Biomedical Engineering.

Analysis and Discussion

The program consists primarily of courses that already exist. There will be a new course in "Topics in Biomedical Engineering" and attendance and participation will be required in Biomedical Engineering Seminars. The majority of the funding for the Seminar series will come from the Human Mobility Research Centre and participating Faculty members research funding and research overhead. The program will link graduate education in Biomedical Engineering currently being offered independently in Chemical, Electrical and Mechanical Engineering and expose the students to multidisciplinary issues, training and practice. It will provide education and recognition that identifies graduates as having specialized cross-discipline training in Biomedical Engineering. The proposed program should attract top quality students who currently go to other Universities that offer similar programs.

Conclusions/Recommendation

Members of the committee saw no major resource implications with the proposed program and voted unanimously to recommend to Senate that they approve the proposal to establish a Collaborative Graduate Program in Biomedical Engineering.

Respectfully submitted,

J. Medves,
Chair, Senate Budget Review Committee

Committee Members:
H. Averns
K. Brock
F. Davis
D. Hallett
J. Helland
D. Janiec
M. Koichopolos
M. Lombardi
J. Medves (Chair)
G. Willmott
I. Young

Senate Committee on Academic Development
and
Senate Budget Review Committee

Program Approval Submission

This form is to be used when seeking approval for all new or substantially revised programs of study leading to a degree, diploma or certificate

FACULTY/SCHOOL: GRADUATE STUDIES

PROPOSED NEW PROGRAM: COLLABORATIVE GRADUATE PROGRAM IN BIOMEDICAL ENGINEERING

PROPOSED IMPLEMENTATION DATE: SEPTEMBER 2009

DATE OF FACULTY BOARD APPROVAL: JANUARY 14, 2009

SUBMISSION CONTACT

NAME: Brian Amsden

TELEPHONE: 533 3093

EMAIL: brian.amsden@chee.queensu.ca

SIGNATURE OF THE DEAN: _____ DATE: April 6/09

Please note that program proposals must receive the approval of Faculty Board prior to being submitted to the Senate Office for referral to the Senate Committee on Academic Development (SCAD) and the Senate Budget Review Committee (SBRC), which will then make their recommendations to Senate.

The criteria requested in PART A should be regarded as the minimum criteria for the assessment of academic programs. Any unit planning a new program should show how not only the criteria listed below but also, where appropriate, those required by the Undergraduate Program Review Audit Committee and those of the Ministry of Training, Colleges & Universities have been taken into account. For further information, please refer to the Senate Policy "Policies and Procedures for Establishing New Undergraduate Programs" (http://www.queensu.ca/secretariat/senate/policies/newprog/index.html)

PART A

1. OBJECTIVES:

Please summarize the rationale for introducing this program. The program should be consistent with the Queen's mission, the academic plans of the unit including its teaching and research strengths, the relation of the unit with other academic units and the standards, educational goals and learning objectives of the degree. Explain how this program will achieve the expected academic quality. Please identify the Faculty, School or Department, which will be administratively responsible for the academic aspects of this program such as supervision of graduate students, curriculum development and the Internal Academic Review Process.

Investigators at Queen's University have been developing strong interdisciplinary collaborations in the area of Biomedical Engineering for over 25 years. This broad area of research involves the application of engineering principles to both medicine and the life sciences. This proposal outlines a Collaborative Graduate Program in Biomedical Engineering that will link OCGS graduate programs in Chemical, Electrical, and Mechanical Engineering and provide shared learning experiences with interdisciplinary content. The program would be available to doctoral students and research masters students associated with the three member programs at Queen's University.

The Collaborative Biomedical Engineering Graduate Program is intended to:

a) formally link graduate education in the areas of Biomedical Engineering currently being undertaken in each of the three constituent masters and doctoral programs
b) expand education in this area so that students are exposed to multidisciplinary issues, training and/or practice
c) offer education and recognition that identifies graduates as having specialized cross-discipline training in Biomedical Engineering
d) provide a coordinated list of graduate courses with a breadth and depth that promotes the training of Biomedical Engineering researchers and Professionals
e) bring students from a variety of backgrounds together to learn about research methodology and professional practice in the field of Biomedical Engineering
f) contribute towards the development of a cohesive group of Biomedical Engineering graduate students and faculty members at Queen's University to be competitive at the National and International level

The participating Departments will retain administrative responsibility for graduate students and for curriculum development in their specific area. Involvement of each department in the Collaborative Program will be reported as part of ongoing periodic appraisals.

2. ADMISSION REQUIREMENTS:

The admission requirements (preparation and achievement) should be appropriate for the learning objectives of the program and the institution to ensure the appropriate quality of student applicants. In no case should admission requirements be lower than the published minimum standards for the University. Indicators of student demand including applications, registrations, projected enrolment levels, and of the quality of students must be considered. Where admission is competitive, actual admission requirements may be higher than the published minimum standards. Information about anticipated enrolments should also be included.

Admission requirements for students entering the Collaborative Program will be consistent with those of the member Department in which the student will register. In general, this will represent a B+ average or higher in a relevant previous degree program. The Collaborative Program will not consider students who do not meet the specific requirements of the member Department in which they intend to register. Students are admitted to the Doctoral Program after receiving a Master's degree in a relevant area of research at Queen's, or from another institution. Students who have demonstrated excellent academic standards and research progress may transfer to the Doctoral program through

the promotion from the Master's to Ph.D. program route, as described in section 3.2 of the Division III Procedures.

3. CURRICULUM:

Provide a detailed overview of the proposed program, along with the proposed *Calendar* description. Details such as course requirements (core, supporting, recommended, optional courses), prerequisites, problems students may encounter and new courses being proposed for the program should be included. The structure and curriculum of the program should be appropriate for its learning objectives.

Students would be required to:

a) satisfy the coursework, thesis and other requirements of the specific member ("home") program in which they enroll
b) enroll in a new "Topics in Biomedical Engineering" graduate course focusing on research methodology, experimental design, development of journal articles and research proposals; this course would count towards the course work requirement of their home program (Appendix A)
c) participate in a new "Biomedical Engineering Seminar" graduate seminar series which features presentations from faculty members, graduate students or visitors, one afternoon each week to create a common learning experience and expose students to examples of research and practice in different areas of Biomedical Engineering; this non-credit course would substitute for the existing seminar course where the home program has a compulsory seminar requirement; participation would be for two terms for the masters, and four for the doctoral degrees (Appendix B)
d) not including the compulsory "Topics in Biomedical Engineering" graduate course, enroll in at least one course outside their home department; this is to ensure shared learning experiences with other Biomedical Engineering students and promote interdisciplinary education (Appendix C)
e) research degree (doctoral and research masters) students would undertake their thesis project in one or more of the areas of research expertise listed in Appendix D; coursework Masters students would not be permitted to enroll in the Collaborative Program

Graduate Coursework Requirements in the Three Member Programs

Program	MECH	CHEE	ECE
Number of courses for Masters	4 courses (no restrictions)	4 courses (min 2 inside dept)	4 courses (min 2 inside dept)
Number of courses for PhD after Masters	4 courses (no restrictions)	4 courses (min 2 inside dept)	4 courses (min 1 inside dept)
Number of courses for PhD without Masters	7 courses (min 4 inside dept)	7 courses (min 4 inside dept)	7 courses (min 3 inside dept)
Number of extra courses for Biomedical Engineering program	0 courses	0 courses	0 courses

Calendar Description

The Collaborative Graduate Program in Biomedical Engineering offers MSc and PhD students training in a multidisciplinary environment spanning engineering departments and linking with researchers in the health sciences and medicine. The Program allows students to undertake cutting-edge research under the supervision of internationally recognized investigators in diverse Biomedical Engineering fields. The Collaborative Program provides opportunities for intra- and interdisciplinary research and learning that will be invaluable for the graduate student's career development. Areas of research interest include Biomaterials For Tissue Engineering and Drug Delivery, Biomechanics and

Prosthetics, Medical Imaging, Biological Signal Processing and System Identification and Tissue Engineering and Regenerative Medicine.

4. TEACHING:

Briefly explain how the intended mode of delivery (including, where applicable, distance or on-line delivery) and standards of instruction for this program are appropriate to meet the program's learning objectives.

All but two of the courses linked to the Collaborative Graduate Program in Biomedical Engineering are existing courses offered through the contributing departments. The new Topics in Biomedical Engineering replaces the existing MECH 892 course while the new Biomedical Engineering Seminar Course has no resource implications. A seminar series is currently ongoing and funded through the Human Mobility Research Centre, and the new seminar series will replace it. It is expected that credit for existing seminar courses in the home departments (e.g. CHEE 897) will be provided through participation in the new Biomedical Engineering Seminar Course. No distance or online courses are required for this program.

5. EVALUATION OF STUDENT PROGRESS:

Briefly explain the intended method of evaluation of student progress and how it is appropriate for this program.

Students will be evaluated based on their course work and research progress. Course work will be evaluated and assigned a numeric grade. A supervisory committee will be established for each student according to their home departmental guidelines, that will include at least one faculty member associated with the Collaborative Program, and will be responsible for monitoring and evaluating the student's research progress.

6. EQUITY:

This program's planning, development and implementation should be consistent with the equity goals of the University and must avoid direct, indirect and systemic discrimination.

The program has been developed according to the general regulations of the School of Graduate Studies and Research. Any direct or indirect discrimination are avoided.

7. HUMAN RESOURCES:

Please demonstrate that the number, quality and academic expertise of the faculty in the area of the proposed program are sufficient to meet the demands of the program. Where appropriate, the availability of support staff, teaching and laboratory assistants should be indicated. (Additional details should be provided on the Resource Implications Checklist in **PART B** of this form).

More than 25 faculty members in the Departments of Mechanical & Materials Engineering, Chemical Engineering and Electrical & Computer Engineering will participate in this Program. These core faculty members have expertise in a number of areas of Biomedical Engineering as outlined in Appendix D. Details of their faculty appointments and some examples of their recent scholarly contributions are provided in Appendix E. The group has strong research grant and contract support including several millions of dollars awarded over the past two years, which comprises high levels of funding from the Natural Sciences and Engineering Research Council, Canadian Institute of Health Research, Canada

Foundation for Innovation, and Ontario Ministry for Innovation, in addition to research contract support from a variety of government and corporate sponsors in Canada and the United States of America. Many of these engineering faculty members have ongoing collaborations with faculty in the Department of Anatomy and Cell Biology and the Division of Orthopaedic Surgery in the School of Medicine.

The core faculty members collectively supervise in excess of 75 graduate students, most of whom are likely to choose to participate in the Biomedical Engineering collaborative graduate program.

8. PHYSICAL AND INFORMATION RESOURCES:

Please provide a summary of available or required program-specific resources, such as: classroom requirements, laboratories, information technology services and facilities, and library facilities and information resources (including unique and special collections). (Additional details should be provided on the Resource Implications Checklist in **PART B** of this form).

The proposed program will draw upon existing courses and research facilities. The core faculty associated with the program have strong research support from the Canadian Institutes of Health Research, the Natural Sciences and Engineering Research Council, the Canadian Foundation for Innovation, the Ontario Centres of Excellence, and the Ontario Ministry of Research and Innovation programs. The existing laboratory space, information technology services and facilities, and library and information resources will meet the needs of this program.

9. FINANCIAL RESOURCES:

There should be evidence of sufficient resources to introduce and maintain the program for a reasonable period of time. This should include consideration of any additional funds from internal sources and from government or other external sources as well as possible financial impact of the programs on other programs, within and outside the unit. (Additional details should be provided on the Resource Implications Checklist in **PART B** of this form).

Students enrolled in the collaborative program will be considered for funding support through their home departmental program. Students may be eligible to apply for personal studentship funding through the appropriate Tri-Council competition or through other agencies (e.g. OGS). Applications will be ranked as required by the student's home department. Stipend funding of students in the Collaborative Program will be in line with policies of their respective home departments.

10. SOCIETAL CONTEXT (STUDENT DEMAND, SOCIETAL NEED, DUPLICATION):

Please provide a summary of how this program is expected to meet student demand and societal need. Evidence of student demand could include: projected enrollment levels, application statistics, origin of student demand (domestic and international), and duration of projected demand. Evidence of review and comment by appropriate student organizations should be provided. Please explain how the program will fulfill a societal need in specifically identified fields (academic, public and /or private sector) and consider the probable availability of positions on graduation, the likelihood of attracting out of province or international students and the equity implications of the program, In the case of a professional program, discuss its congruence with the regulatory requirements of the profession. Please cite similar programs offered by other institutions and provide evidence of additional societal need and/or student demand as well as indicate innovative and distinguished aspects of the program.

Although the demand for some engineering specialties are expected to plateau or decline in the future, the US Bureau of Labour Statistics is forecasting a 21% growth for Biomedical Engineers

through to 2016. This growth is fueled by the demand for increasingly sophisticated medical devices and treatment modalities required by our aging society. There is an increasing interest in the undergraduate population in the field, as indicated by the number of students enrolled in CHEE 340 Introductory Biomedical Engineering which in its four years has risen from an enrolment of approximately 60 to over 100 students. However, unlike many engineering fields, most entry-level Biomedical Engineering positions require an advanced degree. Strengths in Biomedical Engineering research are found within several engineering departments at Queen's, but no one department provides the full breadth of research expertise, which can make it challenging for students in any one department to access the knowledge base and perspective on Biomedical Engineering research that they may desire. Thus, the development of the proposed Collaborative Graduate Program in Biomedical Engineering will meet the needs of both students and faculty by formally linking the unique strengths in research of the participating departments and thereby creating an optimal training opportunity. In addition, the development of the new Collaborative Program will provide students with the opportunities to share educational experiences and access to resources and expertise with a large peer group with similar interests. The proposed Program includes common requirements that will facilitate interactions between students in a wide range of Biomedical Engineering research areas, broadening their experience in the field. The Program will enhance our ability to advertise and recruit high quality students. We anticipate that joint advertising will enhance the profile for research in this area, making it easier for potential students to identify research areas and individual faculty with interests that complement their own, and to identify courses with content that focuses on Biomedical Engineering research themes. Finally, the formal notation of the training specialization as "Biomedical Engineering" provides a valuable tool for trainees seeking recognition of their new-found expertise and focus in achieving future educational and career goals or entering the job market.

11. LEARNING AND PROGRAM OUTCOMES:

While the aim of a university education is to produce educated individuals who possess good judgment and the capacity for critical thought, it is also important to consider specific indicators of learning and program outcomes, such as a graduation rate, length of studies, job placement, external scholarships, awards of graduating students, results of professional certification or licensing examinations, etc. Please discuss the anticipated outcomes of this program.

In general, it is anticipated that MSc students will graduate within 24 months and PhD students will complete in four years from initial registration, in keeping with expectations of the home departments. Registration in the Collaborative Program is not expected to prolong these times to completion as Collaborative Program courses are generally subsumed within the departmental requirements and electives.

Biomedical Engineering is the fastest growing engineering discipline. Our graduates will either continue their studies towards a PhD or find employment opportunities in the pharmaceutical industry, the biomedical device industry, in health care support (e.g. Health Canada), on in academe.

12. OTHER ISSUES:

Please describe any additional special considerations with respect to this program.

None.

Appendix A: Draft Outline of Topics in Biomedical Engineering Course

General

Title (Number):	Topics in Biomedical Engineering (previously listed as MECH 892 and will be designated as Biomedical Engineering course BME 801)
Term:	Fall
Hours:	3 hours per week
Instructor(s):	TBA

Background

a. Course Objective

Many Biomedical Engineering graduate students' programs are heavily skewed towards the technical skills required to do biomedical research, including mathematical methods, theoretical modelling and experimental procedures. Because of this bias, Biomedical Engineering research tends to be poorly planned and presented. The overall aim of this course is to have students learn how to propose and plan scientific research *a priori*, including using statistical methods to design experiments and develop skills for writing journal articles and research proposals, presenting scientific data and giving scientific talks.

b. Course Emphasis

The goals of course are to: (i) help each student to think critically about the research questions of his/her thesis project and to learn how to put these questions in proper context with respect to their discipline, (ii) introduce students to the process of experimental planning, (iii) help students develop an appreciation for the components of a clear, well-organized and well reasoned research proposal and journal article and (iv) help students to prepare collected data for presentation at a scientific conference.

c. Calendar Description

This course covers the skills needed to plan and present Biomedical Engineering research. Topics include hypothesis and research question generation, literature reviews, statistical methods to design experiments, proposal writing, data presentation and interpretation, information design, scientific speaking and article writing. *Instructors: Biomedical Engineering faculty.*

Course Evaluation

Activity	Proportion
Journal Article	25%
Research Proposal	60%
Class participation	15%

Appendix B: Draft Outline of Biomedical Engineering Seminar Course

General

Title (Number):	Biomedical Engineering Seminar (to be designated as Biomedical Engineering course BME 802)
Term:	Fall/Winter
Hours:	4 hours per month
Instructor(s):	TBA

Background

a. Course Objective

The objective of this course is to expose Biomedical Engineering students to the different areas of Biomedical Engineering research and practice, providing a shared learning experience to link students from each of the departments participating in the Collaborative Graduate Program in Biomedical Engineering. An additional objective is to provide opportunities to develop and refine presentation skills, the ability to give and receive constructive criticism, and to pose and respond to questions.

b. Course Emphasis

The course will emphasise the broad scope and interdisciplinary nature of Biomedical Engineering research and practice, through the preparation, delivery and audience participation in oral presentations.

c. Calendar Description

Illustrate all areas of Biomedical Engineering research and practice; emphasis on breadth and interdisciplinary aspects; preparation, delivery and audience participation in oral presentations; the course links students from departments participating in the Collaborative Graduate Program in Biomedical Engineering; opportunities are provided to develop and refine presentation skills, to give and receive constructive criticism, and to pose and respond to questions. *Instructors: Biomedical Engineering faculty.*

Seminar Schedule and Topic Selection

a. Twelve seminar hours will be held each term

b. Seminar sessions will be composed of presentations for one hour by an invited guest, and 20 to 30 minute presentations by graduate students. Each year, each student will deliver one presentation in an area of Biomedical Engineering chosen by the student, and one assigned by the instructor. While most invited speakers will present seminars in the general area of Biomedical Engineering, some presentations may cover topics like effective communication and use of library resources

Course Evaluation

Activity	Proportion	
Attendance at seminars	Pass/Fail	(at least 75%)
Presentations	80%	
Class participation	20%	

Note: **Masters students must take the course for two terms and doctoral students for four terms. The course will run each Fall and Winter term. This is a secondary, non-credit course and does not contribute to the course count requirements of the degree program.**

APPENDIX C: List of Current and Proposed Graduate Courses

The following list provides details of existing and proposed Biomedical Engineering graduate courses at Queen's University. Most courses are provided by core members of the proposed Biomedical Engineering Graduate Program. The proposed course outlines for the Topics in Biomedical Engineering and Biomedical Engineering Seminar course are located in Appendices D and E, respectively.

Course	Instructor	Status	Term
Topics in Biomedical Engineering (previously listed as MECH 892)	TBA	Proposed	Fall
Biomedical Engineering Seminar Series	TBA	Proposed	Fall/Winter
MECH 823 Micro-Electro-Mechanical Systems (MEMS)	Lai	Offered	Winter
MECH 827 Biomechanics of Human Joints and Spine	Dumas	Offered	Winter
MECH 828 Biomechanics of Human Gait	Deluzio	Offered	Winter
MECH 829 Tissue Mechanics	Bryant	Offered	Fall
MECH 924 Finite Element Analysis	Kim	Offered	Winter
CHEE 809 Colloid & Surface Phenomena	Docoslis	Offered	Fall
CHEE 872 Polymeric Biomaterials	Amsden	Offered	Winter
CHEE 874 Tissue Engineering	Waldman	Offered	Winter
CHEE 885 Current Topics in Biochemical Engineering	Neufeld	Offered	Fall
CHEE 990 Principles and Applications in Polymer Rheology	Kontopoulou	Offered*	Spring
ELEC 811 Biological Signal Analysis	Morin	Offered	Fall
ELEC 841 Nonlinear Systems: Analysis and Identification	Korenberg	Offered	Fall
ELEC 848 Control Systems Design for Robots and Telerobots	Hashtrudi-Zaad	Offered	Winter
ANAT 831 Cell Structure and Basic Tissues	F. Kan	Offered	Fall
ANAT 847 Research Projects in Anatomy and Cell Biology	S.C. Pang	Offered	Winter
BCHM 810 Protein Structure and Function	A. Mak	Offered	Fall

* Course offered as a six-week module only.

Appendix D: Details of Intellectual Focus: Areas of Biomedical Engineering Research Expertise

Biomechanics and Prosthetics

The biomechanics and prosthetics group focuses on the study of: (i) whole body and limb biomechanics during daily living and before/after surgical treatment and (ii) the design and development of medical implants and prosthetics (e.g. total joint replacements, lower limb amputee devices) for the industrialized world as well as novel approaches for applications in the developing world. This group employs the use of laboratory experimentation and numerical modeling with research facilities located in the Department of Mechanical & Materials Engineering and the Human Mobility Research Centre at Kingston General Hospital and Hotel Dieu Hospital.

Researchers:

- Tim Bryant
- Kevin Deluzio
- Genevieve Dumas
- Il-Yong Kim
- Yongjun Lai
- Quinggo Li
- Chris Mechefske
- Rick Sellens
- Andrew Pollard
- Ugo Piomelli

Biomaterials

The biomaterials group focuses on the (i) development of natural and synthetic materials used to facilitate the repair of damaged or diseased tissues and organs, (ii) materials to be used in conjunction with biomedical tools and devices, and (iii) understanding and modeling of tissue function. Specific examples include drug delivery devices, cell encapsulation devices, tissue engineering scaffold materials and synthetic synovial fluid as well as research on the function of connective tissues (e.g. cartilage, bone). This group employs the use of laboratory experimentation and numerical modeling with research facilities located in the Department of Mechanical & Materials Engineering, Department of Chemical Engineering, the Biosciences Complex, and the Human Mobility Research Centre at Kingston General Hospital.

Researchers:

- Brian Amsden
- Tim Bryant
- Aris Docoslis
- Lauren Flynn
- Marianna Kontopoulou
- Ron Neufeld
- Keith Pilkey
- Stephen Waldman
- Kim Woodhouse

Tissue Engineering and Regenerative Medicine

The tissue engineering/regenerative medicine group focuses on the development of new therapeutic approaches to advance healthcare based on improving or replacing the biological function of damaged or diseased tissues and organs. Research in this area is conducted on the development of (i) laboratory grown functional replacement tissues and (ii) cell encapsulation devices. Specific applications include

the development articular cartilage, ligament, blood vessels, intervertebral disc, adipose tissue and implantable insulin producing devices. This group employs the use of laboratory experimentation research facilities located in the Department of Chemical Engineering, the Biosciences Complex, and the Human Mobility Research Centre at Kingston General Hospital.

Researchers:

- Brian Amsden
- Aris Docoslis
- Lauren Flynn
- Ron Neufeld
- Stephen Waldman
- Kim Woodhouse

Biomedical and Intelligent Systems

The Biomedical and Intelligent Systems group comprises expertise in the areas of robotics, computer vision, discrete-event systems, nonlinear system identification, protein sequence classification, modelling and human performance monitoring. The research on robotic control is focused on the application of control systems in prosthetics, telerobotics, haptics and virtual environments with the integration of processed biological signals in the control structure. Research into computer vision is centred on object recognition, pose determination and 3D tracking with applications to robotics. Discrete-event systems techniques are being used in modelling emergency response to epidemiological outbreaks. Nonlinear system identification is used for protein sequence classification, for analysing gene expression, and for prognosis and diagnosis of disease. Human performance monitoring research is being conducted to assess kinetics, kinematics and energy expenditure during the performance of various tasks. This group employs the use of laboratory experimentation research facilities located in the Department of Electrical & Computer Engineering, the Human Mobility Research Centre at Kingston General Hospital and the School of Kinesiology and Health Studies.

Researchers:

- Michael Greenspan
- Keyvan Hashtrudi-Zaad
- Michael Korenberg
- Evelyn Morin
- Karen Rudie

Appendix E: List of Faculty Appointments and Examples of Recent Research Contributions

Chemical Engineering

Brian Amsden:

R. Chapanian, M.Y. Tse, S.C. Pang, and B. Amsden, "Role of oxidation and enzymatic action in the in vivo degradation of trimethylene carbonate based photocrosslinkable elastomers," Biomaterials 30(3) 2009 295-306.

L. Timbart and B.G. Amsden, "Functionalizable biodegradable photocrosslinkable elastomers based on 2-oxepane-1,5-dione," J Polym Sci A Polym Chem. 46(24) (2008) 8191-8199

Aris Docoslis:

F. L-Y Yuen; G. Zak; S. D. Waldman; A. Docoslis, "Morphology of fibroblasts grown on substrates formed by dielectrophoretically aligned carbon nanotubes," Cytotechnology 56, 1, 9-17, 2008.

J. A. Wood, B. Zhang, M. R. Tomkins, and A. Docoslis, "Numerical investigation of AC electrokinetic virus trapping inside high ionic strength media," Microfluidics and Nanofluidics 3, 5, 547-560, 2007.

Lauren Flynn:

Flynn, L.E., Prestwich, G.D., Semple, J.L., and Woodhouse, K.A., Proliferation and differentiation of adipose-derived stem cells on naturally derived scaffolds. Biomaterials. Apr;29(12):1862-71, 2008.

Flynn, L.E., Prestwich, G.D., Semple, J.L., and Woodhouse, K.A., Adipose tissue engineering in vivo with adipose-derived stem cells on naturally derived scaffolds, J. Biomed. Mater. Res A, May 8, 2008 epub ahead of print

Marianna Kontopoulou

H. Fam, JT Bryant, M Kontopoulou, "Rheological properties of synovial fluids," Biorheology 44 (2007) 59-74.

A. Tomkins, M. Kontopoulou, and B. Amsden, "Preparation and characterization of blends of star-poly(ε-caprolactone-co-D,L-lactide) and oligo(ε-caprolactone)," J Biomater Sci Polym Edn, 16 (2005)1009-1021.

Ron Neufeld:

AW Chan, RA Whitney, RJ Neufeld, "Kinetic controlled synthesis of pH-responsive network alginate," Biomacromolecules 9 (2008) 2536-2545.

B. Sarmento, A. Ribeiro, F. Veiga, D. Ferreira, R. Neufeld, "Oral bioavailability of insulin contained in polysaccharide nanoparticles," Biomacromolecules 8 (2007) 3054-3060.

Stephen Waldman:

J.M.T. Suits, A.A. Khan, and S.D. Waldman, "Glycogen accumulation in tissue engineered cartilage," Journal of Tissue Engineering and Regenerative Medicine 2, 6, 340-346, 2008.

J.A. Kaupp and S.D. Waldman, "The effects of mechanical vibrations on articular chondrocytes in high-density culture," Proceedings of the Institution of Mechanical Engineers. Part H, Journal of Engineering in Medicine 222, 5, 695-703, 2008.

Kim Woodhouse:

Srokowski, E.M., and Woodhouse, K.A., Preparation of novel crosslinked Elastin-Like Polypeptide Based Biomaterials, J. Biomater. Sci: Polymer edition 19(6):785-99, 2008.

Fromstein, J.D, Zandstra, P.W., Alperin, C. Rockwood, D., Rabolt, J.F., and Woodhouse, K.A., Seeding Bioreactor-Produced Embryonic Stem Cell-Derived Cardiomyocytes on Different Porous, Degradable, Polyurethane Scaffolds Reveals the Effect of Scaffold Architecture on Cell Morphology.Tissue Eng Part A. Mar;14(3):369-378. 2008

Electrical and Computer Engineering

Michael Greenspan:

L.I. Wang, M. Greenspan, and R. Ellis, Validation of bone segmentation and improved 3-D registration using contour coherency in CT data. IEEE Transactions on Medical Imaging, vol. 25(3), 2006.

M. Greenspan, L.I. Wang, and R. Ellis, Validation and improved registration of bone segmentation using contour coherency. 28th Ann. Int. IEEE Eng. Med. Biol. Conf., New York City, New York, USA, 2006. 4 pgs. (Invited paper)

Keyvan Hashtrudi-Zaad:

F. Mobasser, J. M. Eklund, and K. Hashtrudi-Zaad, Estimation of elbow-induced wrist force with EMG signals using fast orthogonal search, IEEE Trans. Biomed. Eng., vol. 54(4), pp. 683-693, 2007.

A.M. Tahmasebi, K. Hashtrudi-Zaad, D. Thompson, and P. Abolmaesumi, A framework for the design of a novel haptic-based medical training simulator, IEEE Trans. Information Technology in Biomedicine, vol. 12(5), 658-666, 2008.

Michael Korenberg:

M.J. Korenberg, R. David, I.W. Hunter and J.E. Solomon, Automatic classification of protein sequences into structure/function groups via parallel cascade identification: A

feasibility study, Ann. Biomed. Eng., vol. 28, pp. 803–811, 2000.

M.J. Korenberg, Gene expression monitoring accurately predicts medulloblastoma positive and negative clinical outcomes, FEBS Letters, vol. 533, pp. 110-114, 2003.

Evelyn Morin:

K.C. Mountjoy, K. Hashtrudi-Zaad, and E.L. Morin, Fast Orthogonal Search method to estimate upper arm Hill-based muscle model parameters, Proceedings, 30th Ann. Int. IEEE Eng. Med. Biol. Conf., Vancouver, BC, Aug. 2008. 6 pgs.

E.A. Clancy, E.L. Morin, and R. Merletti, Sampling, noise-reduction and amplitude estimation issues in surface electromyography. J. Electromyogr. Kinesiol., vol. 12(1). pp. 1-16, 2002.

Karen Rudie:

T. Brunsch and K Rudie, Discrete-event systems model of an outbreak response, 2008 American Control Conference, Seattle, Washington, USA, pp. 1709-1714, 2008.

S.L. Ricker, N. Sarkar and K. Rudie, A discrete-event systems approach to modeling dextrous manipulation, Robotica, Vol.14, pp. 515-525, 1996.

Mechanical and Materials Engineering

Stephen Waldman:

J.M.T. Suits, A.A. Khan, and S.D. Waldman, "Glycogen accumulation in tissue engineered cartilage," Journal of Tissue Engineering and Regenerative Medicine 2, 6, 340-346, 2008.

J.A. Kaupp and S.D. Waldman, "The effects of mechanical vibrations on articular chondrocytes in high-density culture," Proceedings of the Institution of Mechanical Engineers. Part H, Journal of Engineering in Medicine 222, 5, 695-703, 2008.

Tim Bryant:

H. Fam, J.T. Bryant, and M. Kontopoulou, "Rheological properties of synovial fluids," Biorheology 44, 2, 59-74, 2007.

G.E. Loeb, R.A. Peck, J. Singh, Y.H. Kim, S. Deshpande, L.L. Baker, and J.T. Bryant, "Mechanical loading of rigid intramuscular implants," Biomedical Microdevices 9, 6, 901-910, 2007.

Kevin Deluzio:

S.C. Landry, K.A. McKean, C.L. Hubley-Kozey, W.D. Stanish, and K.J Deluzio, "Neuromuscular and lower limb biomechanical differences exist between male and female elite

adolescent soccer players during an unanticipated side-cut maneuver," American Journal of Sports Medicine 35, 11, 1888-1900, 2008.

R.S. Newell, C.L. Hubley-Kozey, W.D. Stanish, and K.J. Deluzio, "Detecting differences between asymptomatic and osteoarthritic gait is influenced by changing the knee adduction moment model," Gait and Posture 27, 3, 485-492, 2008.

Rick Sellens:

M. Beek, P. Abolmaesumi, S. Luenam, R.E. Ellis, R.W. Sellens, and D.R. Pichora, "Validation of a new surgical procedure for percutaneous scaphoid fixation using intra-operative ultrasound," Medical Image Analysis 12, 2, 152-162, 2008.

M. Beek, P. Abolmaesumi, S. Luenam, R.W. Sellens, and D.R. Pichora, "Ultrasound-guided percutaneous scaphoid pinning: operator variability and comparison with traditional fluoroscopic procedure," Medical Image Computing and Computer Assisted Intervention 9, Part 2, 536-543, 2006.

Genevieve Dumas:

D.A. Dumas, T.R. Upjohn, A. Leger, A. Delisle, K. Charpentier, A. Plamondon, and E. Salazar, "Effect of a desk attachment board on posture and muscle activity in women during computer work," Ergonomics 51, 11, 1735-1756, 2008.

J. Wicke and G.A. Dumas, "Estimating segment inertial parameters using fan-beam DXA," Journal of Applied Biomechanics 24, 2, 180-184, 2008.

Keith Pilkey:

W.B. Lievers, S.D. Waldman, and A.K. Pilkey, "Minimizing specimen length in elastic testing of end-constrained cortical bone," Submitted to the Journal of the Mechanical Behavior of Biomedical Materials, 2008.

W.B. Lievers, V. Lee, S.M. Arsenault, S.D. Waldman, and A.K. Pilkey, "Volumetric shrinkage of cancellous bone measured at two levels of dehydration," Journal of Biomechanics 40, 9, 1903-1909, 2007.

Il-Yong Kim:

I.G. Jang and I.Y. Kim, "Computational study of Wolff's law with trabecular architecture in the human proximal femur using topology optimization," Journal of Biomechanics 41, 11, 2353-2361, 2008.

S. Amiri, D. Cooke, I.Y. Kim, and U. Wyss, "Mechanics of the passive knee joint. Part 2: interaction between the ligaments and the articular surfaces in guiding the joint motion," Proceedings of the Institution of Mechanical Engineers. Part H, Journal of Engineering in Medicine 221, 8, 821-832, 2007.

Yongjun Lai :

Y. Lai and E. Bordatchev, "Modelling and Fabrication of Mechanical Cell Stimulator," CSME Transactions 31, 4, 433-443, 2007.

Quinggo Li:

J.M. Donelan, Q. Li, V. Naing, J.A. Hoffer, D.J. Weber, and A.D. Kuo, "Biomechanical energy harvesting: generating electricity during walking with minimal user effort," Science 319, 5864, 807-810, 2008.

Chris Mechefske:

G. Li and Mechefske C.K., "Reduction of MRI Scanner Acoustic Noise using a Micro-perforated Panel Absorber," 16th International Society for Magnetic Resonance in Medicine Conference, Toronto, Ontario, Canada, 3-9 May, 2008.

C. Dundass, Yao G., and Mechefske C.K., "Biomechanical Analysis and Modeling of Transfemoral Amputee Gait," Journal of Prosthetics and Orthotics, 15, 1, 20-26, 2003.

Andrew Pollard:

C.G. Ball, M. Uddin, A. Pollard, Mean flow structures inside the human upper airway. Flow, Turbulence and Combustion 81(1-2), 155-188, 2008.

C.G. Ball, M. Uddin and A. Pollard, High resolution turbulence modelling of airflow in an idealised human extra-thoracic airway. Computers & Fluids 37(8), 943-964, 2008.

Ugo Piomelli:

Scotti, A. and Piomelli, U. Turbulence models in pulsating flows. AIAA J. 40(3), 537544, 2002.

Vanella, M., Piomelli, U. and Balaras, E. Effect of grid discontinuities in large-eddy simulation statistics and flow fields. J. Turbul. 9 (32), 123, 2008.

PART B - RESOURCE IMPLICATIONS

1. SUMMARY OF RESOURCES REQUIRED

As this is not a new program, but rather a collaboration among three existing engineering graduate programs, there are no new resources required.

If you are unsure of the resource implications for any of the following, please consult with someone in the affected department or unit.

Please summarize the ***additional*** resources needed to implement the program:

a) FACULTY — none
(number of half courses)

b) STAFF — none
(number or fraction of FTEs)

c) TEACHING ASSISTANTS — none
(number of student-courses)

d) PHYSICAL FACILITIES:

Please describe the space resource implications of the proposal in terms of the following (include both size (in terms of # of students) and frequency (number of hours per week required))

1. Classrooms — No additional classrooms required
2. Laboratories — No additional laboratories required
3. Offices — No additional office space needed

For number d) 3 above, please reallocation or reconfiguration of space is required. If so, appropriate approval must be appended.

e) INFORMATION FACILITIES

Please indicate the ITS resource implications for the proposal in terms of requirement for

1. Hardware — not applicable
2. Software / Internet — not applicable
3. Audio-Visual — not applicable
4. Telecommunications — not applicable

f) LIBRARY SERVICES

Please indicate which of following new library resources will be needed:

ρjournals
ρprint monographs
ρaudio visual material
ρhistorical documents
ρelectronic databases
ρstatistical / geospatial data

Indicate the likelihood of the program having an impact on Library staffing?
_____none_____
_____
_____

g)UNIVERSITY REGISTRAR

Please indicate the resource implications for the proposal in terms of requirement for

1. Scholarships / Bursaries not applicable
2. Registration / SIS Programming not applicable
3. Timetable not applicable
4. Admission (Graduate / Undergraduate) not applicable
5. Convocation not applicable

h)OTHER UNIVERSITY SERVICES

Please indicate the resource implications for the proposal in terms of requirement for

1. Financial Services _____ not applicable _____
2. Human Resources _____not applicable_____
3. Advancement _____not applicable_____
4. Student Services _____not applicable_____
5. Residences _____not applicable_____
6. Other _____not applicable_____

2. NEW EXPENDITURES

What **new** funds will be needed for each of the following? One-time $ are monies that will only be required once for startup. Base $ are funds that will continue to be needed year after year. Please attach some backup to show how the numbers were calculated.

e.g. Staff - Base $60,000 (1.5 FTE @ $40,000))

	ONE TIME $	BASE BUDGET $
FACULTY	$0	$0
STAFF	$0	$0
TEACHING ASSISTANTS	$0	$0
STUDENT ASSISTANCE (Grad)	$0	$0
OTHER NON-SALARY	$0	$0
TOTAL	$0	$0

3. FUNDING SOURCES

Please show the source of the **additional and/or re-allocated funds** needed for the proposal. What amount will be re-allocated from within the department's budget, from within the faculty's budget, from within the University's budget and how much will come from tuition or other sources. One-time $ are monies that will only be required once for startup. Base $ are funds that will continue to be needed year after year. The total costs in section 2 (Cost Breakdown) must match the total costs in section 3 (funding sources)

	ONE TIME $	BASE BUDGET $
DEPARTMENT BUDGET	$0	$0
FACULTY BUDGET	$0	$0
UNIVERSITY BUDGET	$0	$0
TUITION REVENUE	$0	$0
OTHER SOURCES	$0	$0
TOTAL	$0	$0

If other sources are used, please list the sources and indicate if the funds have been applied for and if they have been secured.

4. IMPACT ON ENROLMENT

a) How many students are expected in the program? 50

b) How many new students will the program attract to Queen's University? 10-15
(i.e. students in the program that are not transfers from existing programs currently being offered at Queen's)

c) How many students must be accommodated by other departments / units? 0
(Please indicate which departments / units will be affected and how.)

Students in the Collaborative Program will enter through an existing home departmental program.

5. NET IMPACT OF THE PROPOSAL

Please summarize any other resource or funding implications of the proposal.

There are no other resource or funding implications of the proposal.

6. SIGN-OFF

Following Faculty Board approval, signatures from the following individuals listed below must be obtained to verify that they have reviewed this proposal. Supplementary comments may be appended and so indicated by checking the box beside the appropriate signature.

Title	Comments Appended	Signature
Department Head	ρ	
Dean or Associate Dean	ρ	Brian Surgenor
Dean of Student Affairs	ρ	
University Librarian	ρ	(comments attached)
Director, Information Technology Services	ρ	
University Registrar	ρ	
Associate VP (Operations & Facilities)	ρ	
Vice-Principal (Operations & Finance)	ρ	
Vice-Principal (Academic)	ρ	

COLLABORATIVE GRADUATE PROGRAM IN BIOMEDICAL ENGINEERING: PART B: RESOURCE IMPLICATIONS

F) LIBRARY

Please indicate which following new Library resources will be needed:

Engineering & Science and Bracken Health Sciences Libraries currently commit significant funds to our extensive collection of information resources in Biomedical Engineering. These resources would need to be maintained to support this new program.

The entire suite of electronic journals from publishers such as Elsevier, Wiley, Springer, IEEE, ASME, SPIE, Blackwell, SAGE, and Taylor and Francis are available to students and researchers. Queen's University Library subscribes electronically to 100% of the biomedical engineering journals with impact factors greater than 1.0

Databases are available on and off campus and include, among others:

- *Compendex*
- *InSpec*
- *IEEE Xplore*
- *SPIE*
- *PubMed and Medline*
- *EMBASE*
- *Web of Science*

Indicate the likelihood of the program having an impact on Library staffing.

The document currently says that there would be no impact. However, any graduate/research program should involve librarians to integrate information literacy in the curriculum. *Topics in Biomedical Engineering, BME 801,* for example, would be an excellent candidate for librarian partnership in teaching research strategies and sources. Also, librarians spend time helping graduate students with their individual research needs.

Sharon Murphy, Head, Engineering & Science Library
Suzanne Maranda, Head, Bracken Health Sciences Library