S.90-37

SIMON FRASER UNIVERSITY

MEMORANDUM

To:	Senate	**From:**	L. Salter Chair, SCAP
Subject:	Ph.D. Program in Engineering Science	**Date:**	May 17, 1990

Action undertaken by the Senate Committee on Academic Planning/Senate Graduate Studies Committee gives rise to the following motion:

Motion:

> "That Senate approve and recommend approval to the Board of Governors as set forth in S.90-37 the proposed Ph.D. Program in Engineering Science."

SIMON FRASER UNIVERSITY

MEMORANDUM

To: Secretary
Senate Committee on Academic Planning

From: B.P. Clayman
Dean of Graduate Studies

Subject: Proposed Ph.D. Program in Engineering Science

Date: May 7, 1990

The proposed Ph.D. Program in Engineering Science was approved by the Senate Graduate Studies Committee, at its Meeting on May 7, 1990, and is now being forwarded to the Senate Committee on Academic Planning for approval.

B.P. Clayman
Dean of Graduate Studies

mm/
encl.

S I M O N   F R A S E R   U N I V E R S I T Y

MEMORANDUM

DEAN OF GRADUATE STUDIES

TO:	Senate Graduate Studies Committee	FROM:	B.P. Clayman
SUBJECT:	**ENGINEERING SCIENCE Ph.D. PROPOSAL**	DATE:	17 April 1990

I am pleased to present the proposal submitted by the School of Engineering Science for the introduction of an **Engineering Science Ph.D.** program. This proposal, the first draft of which was received on 12 January 1989, has been sent out for external review. The external reviewers were:

1. Dr. V. Bhargava, Dept. of Electrical and Computer Engineering, University of Victoria
2. Prof. J. Hayes, Electrical and Computer Engineering, Concordia University
3. Dr. H. Kobayashi, Dean of School of Engineering, Princeton University
4. Dr. B. Peters, Chairman and C.E.O., NEXUS Engineering Corporation, Burnaby
5. Dr. D.L. Pulfrey, Professor of Electrical Engineering, University of British Columbia
6. Dr. G.S. Rordan, Dean of Engineering Science, Carleton University
7. Dr. M. Salcudean, Professor and Head, Department of Mechanical Engineering, University of British Columbia
8. Dr. A.S. Sedra, Chairman of Electrical Engineering Department, University of Toronto

The comments of the external reviewers are given in Appendix 5; the response of the School of Engineering Science is in Appendix 6. As a result of the external review and subsequent internal deliberations, several modifications were made to the original proposal.

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The Assessment Committee for New Graduate Programs approved the final proposal and recommended that it be submitted to the Senate Graduate Studies Committee. The Assessment Committee for New Graduate Programs, a sub-committee of the S.G.S.C., had the following membership:

Chair	B.P. Clayman
Faculty of Arts	R. Jennings
Faculty of Applied Science	M. Laba
Faculty of Business Administration	E. Love
Faculty of Education	R. Barrow
Faculty of Science	A. Lachlan
SGSC (faculty)	T. Perry
SGSC (faculty)	P. Percival
SGSC (student)	D. Miller
Secretary	N. Hunter
Registrar's Office	M. McGinn

I recommend approval of this proposal. It gives the University an excellent opportunity to continue to build on our strengths in a very important area and, in so doing, to help Canada meet a shortage of personnel.

cc: V. Cuperman

\CMT\M-SGSC

MAR 15 1990
DEAN OF GRADUATE STUDIES OFFICE

SIMON FRASER UNIVERSITY

SCHOOL OF ENGINEERING SCIENCE

MEMO

To:	Dr. Bruce Clayman Dean of Graduate Studies
From:	Dr. Vladimir Cuperman Director, Graduate Program
Date:	March 1, 1990
Subject:	Amended Comprehensive Requirement for Ph. D. Proposal

Please find enclosed the pages which include all the changes made in the Ph.D. proposal after the approval by the Assessment Committee for New Programs. The amended sections and the corresponding old ones are highlighted on the new and original drafts. The reasons for these changes are as follows:

The original version was found to have two drawbacks. First, requiring a comprehensive examination in Signals and Systems for all students allowed too little flexibility. Other Ph.D. programs allow a choice of areas for the comprehensive examinations. Second, the comprehensive in Signals and Systems was found unsuitable for Microelectronics students.

In the new version of the comprehensive, the area of Signals and Systems is included among the comprehensive for the Communications and the Intelligent Systems and Control options, but not for Microelectronics. To increase the flexibility and recognize the importance of Computing as an area of study, a comprehensive in this area has been introduced. Now all students will choose 3 exams in 3 out of 4 areas. One of them is declared a major, the other two are minors.

We believe that these changes improve our program and do not change the essence of the proposed Ph.D. program in Engineering Science.

V Cuperman

Vladimir Cuperman
VMC/br

SCHOOL OF COMPUTING SCIENCE
SIMON FRASER UNIVERSITY

MEMO

To: Bruce Clayman, Dean
Graduate Studies

From: Joseph Peters, Chair
Applied Sciences Graduate Studies Committee

Date: March 15, 1990

Subject: Engineering Science Ph.D. Proposal

At a meeting on February 23, 1990, the Faculty of Applied Sciences Graduate Studies Committee approved the School of Engineering Science Ph.D. proposal subject to changes. Those changes have now been incorporated into the proposal.

Joseph Peters

Joseph Peters

Enclosure

cc A. Beale, Communication
V. Cuperman, Engineering Science
I. Mekjavic, Kinesiology
R. Peterman, Natural Resource Management

School of Engineering Science
Simon Fraser University
Engineering Science Ph. D. Proposal

	January 26 1989
Revised:	February 21 1989
	March 28 1989
	May 16 1989
	January 18 1990
	January 31 1990
	February 5 1990
	March 9, 1990

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School of Engineering Sciences - Ph. D. Program Proposal.

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I. GENERAL INFORMATION.

1. Title of the program

   Ph. D., Engineering.

2. Credentials to be awarded to graduates

   Doctor of Philosophy

3. Faculty or school to offer the program

   School of Engineering Sciences

4. Schedule for implementation

   September 1990 - Admission of first intake.
   August 1993 - Graduation of first intake.

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II. NEED FOR THE PROGRAM.

Our future as an advanced industrial nation depends on our ability to sustain innovation. Several studies have identified the shortage of trained people as the main impediment to growth. The Science Council of B.C., for example, in its 1988 SPARK (Strategic Planning for Research and Knowledge) reports, states:

> "The development of the required number of people with appropriate skills and motivations is the most significant factor in achieving the science-based vision for the year 2000. Without trained researchers, technologists, tradespeople, entrepreneurs, managers, marketers and enthusiastic technology receptors', we cannot get there."

We spoke to Dr. Robert Kavanaugh, Director General of NSERC's Scholarship and International Programs, who warned that there is an impending serious shortage of research scientists, especially in the area of Electrical Engineering. He went on to point out that we cannot expect to make up the shortfall by hiring trained personnel from other countries - the shortage is worldwide, and those countries, particularly the United States, will themselves be trying to lure our own graduates away with attractive job offers.

Quantifying demand is a notoriously risky business as it depends on both economic conditions and technological trends. However, from discussions with Bell-Northern Research, a major national technology-based company, we were able to make some indirect estimates.

Bell-Northern Research in Ottawa employs 4342 employees with a Bachelor's degree or higher, of whom 272 hold a doctorate (1986-87 figures). The disciplines in which SFU Engineering Science plans to offer a PhD program, which BNR designates as "Electrical Engineering" account for 124 of the PhD holders. The company currently hires about 75-100 people with advanced degrees each year, of whom 15-20 would hold a PhD in Electrical Engineering, or equivalent.

In a recent speech to the Canadian Association of University Business Officers, A.J. de Grandpre, Chairman of Bell Canada Enterprises Inc, the parent company of Bell-Northern Research, stated:

> "In the next five years Northern Telecom will invest hundreds of millions of dollars in R&D facilities, buildings and equipment. It will have to hire some 1,000 researchers a year to do the essential job of maintaining its leadership. The financial resources are there, but the brain power will not be available in Canada. We will have to go abroad. What a pity. Strong links between industry and the university must continue. In tomorrow's jobs, workers will need lots of training to get started - and still more to stay employed. The interaction between educational institutions and the workplace is bound to increase as emerging jobs call for higher levels of skill."

On a smaller scale, a local company, MacDonald Dettwiler and Associates, employs a total of 600 technical, nontechnical and support people. Of them, 19 hold PhDs. MDA hires about 1 or 2 PhDs per year. The importance of advanced degrees to MDA is clearly evidenced by an internal scholarship fund which provides employees returning for graduate study $12,000 per year for 2 years.

At present Canadian universities do not train enough PhD students to meet the demand. For example, there were only 78 PhD degrees awarded in Electrical Engineering in 1987 (Canadian Association of Graduate Schools Statistical Report 1988). Of this number, approximately 25% were visa students, leaving about 60 graduates eligible to join the work force. As we saw above, Bell-Northern Research would absorb between one-quarter to one-third of the graduates.

While this shortage of PhDs creates a seller's market in industry, it makes hiring good engineering faculty generally difficult and in some areas almost impossible. The competition from industry and among universities is indicated by the numerous, long-running "Position Available" notices in the engineering section of the CAUT Bulletin.

Of course there are other reasons for establishing a PhD program than satisfying the demand for graduates. As we all know, much research is conducted and many innovated ideas generated by PhD students working with other graduate students, undergraduates and faculty members. We therefore believe that having a PhD program is essential to the intellectual health of both graduate and undergraduate studies in Engineering Science.

III. PROGRAM OUTLINE.

1. Objectives of proposed program.

The objective is to produce specialists in three core areas:

- Communications and Signal Processing.
- Microelectronics.
- Intelligent Systems and Control.

The proposed program will add strength to Canada's postgraduate engineering programs due to:

- Strong interdisciplinary emphasis and breadth of knowledge.
- Strong industrial orientation.
- Choice of core areas as specialization areas of peak demand.

2. Personnel and Core Areas.

At present the School of Engineering Sciences employs 19 tenure-track faculty members: six full professors, seven associate professors, and six assistant professors. No additional faculty is needed for the proposed Ph.D. program.

Engineering Science is in a strong position to begin supervision of doctoral students. Three of its senior faculty members - Don George, Tom Calvert and Jim Cavers - have among them 67 years of academic experience, including the supervision of 53 Master's students and 19 Ph.D. students. In addition, many of its faculty members have joined the university from senior positions in industrial or government research laboratories. Their many years of experience in supervising research teams and individuals gives the School a unique foundation on which to build the Ph.D. program. Only 6 of the 19 faculty members in Engineering Science have joined directly following doctoral or postdoctoral work, and we are confident that they will benefit from the supervision of more experienced faculty. The resumes of faculty members are included in Appendix 4.

The proposed Ph.D. program will be organized around three core areas: Communications and Signal Processing, Microelectronics, and Intelligent Systems and Control. The table shown below illustrates how the existing faculty's area of specialization and research interest fulfill the requirements for successful implementation of the program.

Core Area: Communications and Signal Processing.

J. Bird, J. Cavers, V. Cuperman, D. George, S. Hardy, P. Ho, S. Stapleton.

Core Area: Microelectronics.

G. Chapman, J. Deen, S. Hardy, R. Hobson (associate member), A. Leung, S. Stapleton, M. Syrzycki.

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Core Area: Intelligent Systems and Control.

T. Calvert, J. Dill, K. Gupta, W. Havens, D. Ingraham, J. Jones, T. McGeer, A. Rawicz, M. Saif.

The research interests of faculty members are given in Appendix 1. A significant part of current research work brings together members of different core areas, giving a strong interdisciplinary emphasis to the entire program. This integration is reflected by the fact that several faculty members work in more than one core area.

The core areas are well supported by the existing and the new graduate course offerings. The table below shows the graduate course offerings related to each core area. Course descriptions are given in Appendix 1 for existing courses and in Appendix 2 for new courses.

Communications and Signal Processing.

ENSC 801*	Linear Systems Theory.
ENSC 802*	Stochastic Systems.
ENSC 805	Techniques of Digital Communications.
ENSC 832	Mobile and Satellite Communications.
ENSC 833	Network Protocols and Performance.
ENSC 834	Optical Processing and Communications.
ENSC 810	Digital Signal Processing.
ENSC 815	Signal Processing Electronics.
ENSC 861	Source Coding for Speech and Images.

Microelectronics.

ENSC 801*	Linear Systems Theory.
ENSC 802*	Stochastic Systems.
ENSC 851	Integrated Circuit Technology.
ENSC 852	Analog Integrated Circuits.
ENSC 853	Digital Semiconductor Devices and Circuits.
ENSC 855*	Passive Microwave Circuits.

Courses offered by other departments:

PHYS 425/821	Electromagnetic Theory.
PHYS 810	Fundamental Quantum Mechanics.
PHYS 861	Introduction to Solid State Physics.
CMPT 750	Computer Architecture.
CMPT 851	Fault Tolerant Computing and Testing.
CMPT 852	VLSI Systems Design.

(*) New course.

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Intelligent Systems and Control.

ENSC 801*	Linear Systems Theory.
ENSC 802*	Stochastic Systems.
ENSC 881	Engineering Modelling of Dynamic Processes.
ENSC 883*	Optimal Control Theory.
ENSC 887*	Vision for Robots.
ENSC 888*	Finite-Element Methods in Engineering.
ENSC 889*	3-D Object Representation and Solid Modelling.

Courses offered by other departments:

BUS 820	Analysis of Dynamic Processes.
CMPT 720	Artificial Intelligence.
CMPT 815	Algorithms of Optimization.
CMPT 821	Robot Vision
CMPT 822	Computational Vision.
CMPT 827	Expert Systems
CMPT 853	Computer-Aided Design/Design Automation for Digital Systems
KIN 885	Seminar on Man-Machine Systems.
MATH 851	Numerical Solutions to Ordinary Differential Equations

(*) New courses.

3. Academic requirements.

To qualify for admission to the Ph.D. program a student must have a Master's degree in Electrical Engineering, Mechanical Engineering, Physics, Computer Science or a related field, have submitted evidence that he or she is capable of undertaking substantial original research in Engineering Science, and have identified a faculty member willing to act as Senior Supervisor.

The school does not encourage students to proceed to a PhD without first completing a Master's degree. However, a student may be admitted after at least 12 months in the M.A.Sc. program if he or she has completed all the Master's course work requirements with a CGPA of 3.67 or better, has shown outstanding potential for research, and has the approval of his or her Supervisory Committee, the Graduate Program Committee, and the Senate Graduate Studies Committee.

The minimum course requirement for the Ph. D. program is six semester hours of graduate course credit beyond those taken for the Master's degree. No Special Topics or Directed Studies courses may be counted towards this requirement.

Within 12 months of admission to the Ph. D. program, students will take a qualifying examination in which they must demonstrate a sophisticated understanding of material normally associated with undergraduate and first level graduate studies. This

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examination will be organized by the Departmental Graduate Studies Committee in the Spring semester so that students will take the qualifying examination between the 6th and the 12 months after enrolment in the Ph.D. program. Written examinations will be set in each of four subjects, the scope of which can be conveniently defined by associating them with selected courses, plus any other material to be announced by the Departmental Graduate Committee:

- communications: ENSC 327, ENSC 429, ENSC 382, ENSC 426, ENSC 428, ENSC 801, ENSC 802;
- electronics: ENSC 321, ENSC 425, ENSC 453, ENSC 495;
- intelligent systems and control: ENSC 280, ENSC 382, ENSC 423, ENSC 439, ENSC 438, ENSC 436, ENSC 480, ENSC 801, ENSC 802;
- computing: CMPT 205, CMPT 300, CMPT 307, ENSC 385, CMPT 351, CMPT 412, CMPT 720, CMPT 390;

With the approval of the Supervisory Committee students select three examinations: one is declared a major (specialty) area, while the other two are minor areas. The written examination in the major area is based on all of the courses listed above and is followed shortly by an oral examination in which the scope can range from undergraduate to first-level graduate material. The material required for the minor area examination is based on the first two courses listed for communications, electronics and intelligent systems and control, and the first three courses listed for computing.

Outcomes of the qualifying examination are pass, marginal (student may be required to take more courses and is permitted a second and last attempt to pass the full qualifying exam within 12 months, and fail (the student withdraws from the Ph.D. program). The outcomes are given for the full qualifying exam.

The main requirement of the Ph.D. program is a thesis based on original research to be defined by the student in consultation with the Supervisory Committee. Students' progress will be reviewed every 12 months by a Supervisory Committee of no fewer than three faculty members. At the first such review, which takes place within 14 months of admission, the student will present a thesis proposal defining the intended research topic. Students not making satisfactory progress on their research topic, or who fail to demonstrate satisfactory knowledge and understanding of recent publications in the general area of research, or who fail to have their revised thesis proposal approved by the Supervisory Committee within 18 months of admission, may be asked to withdraw, as per section 1.8.2 of the General Regulations.

All the general requirements outlined in the Graduate Calendar apply. For details, see the proposed calendar entry (section VI).

4. New courses.

We consider that the existing graduate courses offered by the School of Engineering represent a strong basis for the proposed program. For the Communications option the course ENSC 800 was replaced by two new courses, ENSC 801 and ENSC 802. These courses will give more depth in linear systems and stochastic systems, including such topics as Estimation Theory and Detection Theory; ENSC 801 and ENSC 802 are considered as basic preparatory courses for the Ph.D. research in this area. These courses will not be waived any more for M.Eng. students; a calendar change to this effect will be introduced for the 1990/91 year. For the Microelectronics option, a course on "Passive Microwave Circuits", to be called ENSC 855, represents an enhancement of the existing program (see Appendix 2).

Intelligent Systems and Control is a new option in our graduate program. Three new courses are proposed for this option and described in Appendix 2: ENSC 887, ENSC 888, and ENSC 889. This brings the total of graduate offerings for this option to sixteen, seven offered by the School of Engineering and nine by other departments. Some other topics, such as Classical Dynamics, Advanced Manufacturing Systems, and Reliability will be covered by Special Topics courses. The title of ENSC 883 has been changed and the content improved.

The course denomination for the thesis will be "ENSC 899 Ph.D. Thesis".

IV. RESEARCH FACILITIES

Thesis research is carried out in the School's laboratory, in interdisciplinary laboratories, and in external laboratories. Additionally, research is supported by the University's Centre for Systems Science, and by the Computing Services facilities. The Centre for Systems Science (CSS) provides support for specialized laboratories such as the Artificial Intelligence Laboratory, and the Laboratory for Computer and Communications Research, while Computing Services provides a UNIX service plus access to a main frame. Descriptions of the School's major facilities follow. CSS also provides the School with an extensive Sun-based research network which includes SUN 350 workstations and SPARC workstations. Each graduate student has access to these workstations.

Device Electronics.

The device electronics group currently has capabilities for both static and dynamic characterization and DC and pulsed stressing of semiconductor as well as superconductor devices. The equipment includes an HP4145A semiconductor parameter analyzer, an electrometer, several sensitive digital multimeters, a C-V meter, a high speed pulse generator, a low frequency spectrum analyzer, several power supplies, and a closed cycle helium refrigerator with temperature range from 4.5K to 400K. Most of the equipment is automated with a PC-AT computer used as the central controller for data collection and analysis.

The group has also developed custom software for semiconductor parameter extraction of short channel and narrow width devices. SPICE is also used for circuit simulation.

VLSI/Computer Design.

The Microelectronics Research Group has available, within the School of Computing Science, a Tektronix DAS 9100 system for board and system testing, plus oscilloscopes and other logic analysis equipment. A Wentworth probe station and HP test equipment are available for IC testing. Facilities for VLSI design include SUN workstations and an HP plotter. A variety of software for VLSI design and simulation is available. This Research Group has, within the School of Engineering Science, software tools for design, simulation, layout, and circuit extraction, including tools provided by Mentor Graphics, and SDA. Access to the VLSI Technology silicon compiler tool set is also available through Microtel Pacific Research, located within the University's research park.

Microelectronics Fabrication.

The School currently has a complete facility for producing semicustom bipolar arrays and CMOS gate arrays. This facility includes photoresist application and processing equipment, a laser direct-write system for exposing resist on integrated circuit wafers, a wet chemical processing station, and an annealing furnace. This equipment is housed in a class 100 clean room. The equipment complement also includes two wafer probing stations for testing integrated circuits on the wafer level, and a packaging facility which includes a diamond scriber, wafer fracturer, die bonder and a semi-automatic wire bonder for packaging integrated circuits. The FABRICS statistical process simulator is available for design and optimization of IC fabrication processes and for statistical characterization of IC performance. The School has access to the CMOS full custom fabrication service provided by the Canadian Microelectronics Corporation.

Microwave Electronics

In microwave electronics there are currently capabilities for both passive and active microwave characterization of devices and circuits. The group has access to a vector network analyzer, signal generators, power meters, VSWR meters and spectrum analyzers. The group also has a number of PC-AT computers, Apollos and SUN workstations for designing GaAs Monolithic Microwave Integrated circuits. The group has access to IC-EDITOR, PSPICE, and TOUCHSTONE, CAD tools for circuit design, performance analysis, and mask design of microwave circuits.

Communications and Signal Processing.

The Communications and Signal Processing Group's Computer Signal Analysis Facility (CSAF) consists of a network of SUN workstations supported by a SUN-3/260 with analog input/output and a SUN-4/260 with floating point accelerator and 800 MB hard disk for signal data-bases. The existing data-bases include speech data-bases for research on speech coding and recognition and signal data-bases for research on modulation techniques and error correcting codes.

Research on signal processing hardware is supported by a number of PC (XT and AT) based DSP workstations and development systems for such DSP chips as TMS320C25 (TI), Data Flow Processor (NEC), Motorola 56000, DSP 32 (AT&T), Transputer (Inmos).

The available signal processing software includes standard software such as DADiSP and DFDP (by ASP Inc.) as well as an extensive library of in-house developed software for speech coding and recognition, vector quantization, modulation techniques, error correcting codes, and signal enhancement.

Communications Networks.

Facilities available to support this research include discrete-event simulation software (GPSS and SIMSCRIPT II.5, PC and SUN versions) and custom software for performance evaluation of ring and bus networks. Hardware resources include protocol analysis instrumentation, a high speed pattern generator, and access, through local firms, to mobile radio data communications measurement instrumentation.

Underwater Communications.

The underwater acoustics test-bed (UAT) is a unique facility designed for research related to underwater communications and sonar. The UAT is a portable, programmable system whereby the researcher may project carefully controlled acoustic pulses into the water and record the result. This system is used for fundamental research on acoustic propagation as well as for prototyping candidate communications and sonar systems.

Intelligent Systems and Control.

Facilities available to support research in this area include Apollo and SUN workstations (including a Apollo DN 590 high performance engineering/graphics workstation), IRIS 2400 Turbo Graphics workstations (2), one Symbolics 3650 AI/Graphics workstation, Excalibur six-axis robot manipulator, Roland milling machine, Fishertechnick Workcell modeling set, PCVision hardware and software, miscellaneous video equipment, plus a well-equipped machine shop.

Software includes RobCAD, a SUN-based robotic workcell modelling and simulation package, PC-MATLAB for numerical linear algebra, EXCEL+ manufacturing system simulator, ChronOS real-time operating system, Autocad and CADKEY 3D MCAD packages, Neural Network software, and Mentor Graphics tools for electronics design and manufacturing.

V. ENROLMENT AND SOURCES FOR SUPPORTING PH.D. STUDENTS

Our target for steady-state graduate enrolment in Engineering Science is an average of about 2 1/2 graduate students per faculty member, of whom about 1/3 would be Ph.D. students. This produces a target enrollment of about 12 to 14 Ph.D. students at any time.

As a relatively young school, we are far from steady state. Our newer faculty members are still in the process of establishing their research programs and funding. Moreover, the development of a reputation which would encourage sufficient numbers of good graduate applicants takes some time. We expect to reach our target numbers in three to five years.

Funding sources are much the same as those we currently tap at the Master's level: NSERC and B.C. Science Council Scholarships, Research Assistantships drawn from research grant or contract funds, SFU Graduate Scholarships and Entrance Scholarships, and a small number of Teaching Assistantships. A significant part of the funding for Research Assistantships comes through the Center for System Sciences (CSS) and through industrial cooperation with local companies.

VI. CALENDAR ENTRY.

Admission Requirements - Ph. D. Program.

To qualify for admission to the Ph.D. program a student must have a Master's degree in Electrical Engineering, Mechanical Engineering, Physics, Computer Science or a related field, have submitted evidence that he or she is capable of undertaking substantial original research in Engineering Science, and have identified a faculty member willing to act as Senior Supervisor.

See the graduate general regulations for admission requirements for entry to the Ph.D. program.

Admission from the Master's Program to the Ph.D. Program.

The school does not encourage students to proceed to a PhD without first completing a Master's degree. However, a student may be admitted after at least 12 months in the M.A.Sc. program if the student has completed all the Master's course work requirements with a CGPA of 3.67 or better, has shown outstanding potential for research, and has the approval of the student's Supervisory Committee, the Graduate Program Committee and the Senate Graduate Studies Committee.

Degree Requirements - Ph. D. Program.

Course Work.

The minimum course requirement is 6 semester hours of graduate course credit beyond those taken for the Master's degree. No Special Topics or Directed Studies courses may be counted towards this requirement. Courses are selected in consultation with the Senior Supervisor. Some students may be required to supplement their graduate studies with undergraduate courses, or to take more than 6 semester hours of graduate course credit.

Qualifying examination.

The student will take a qualifying examination at a time determined by his/her Supervisory Committee, normally between the 6th and the 12th month from admission to the Ph.D. program. The student must demonstrate a sophisticated understanding of material normally associated with undergraduate and first level graduate studies. There will be written examinations set in each of the following four subjects:

- communications
- electronics
- intelligent systems and control
- computing

The material for the comprehensive examinations will be determined by the Departmental Graduate Committee. With the approval of the Supervisory Committee students select three subject areas to be covered by examinations, as follows: one is declared a major (specialty) area and the other two are minor areas. The written examination in the major area is followed shortly by an oral examination.

Outcomes of the qualifying examination are pass; marginal (student may be required to take more courses, and is permitted a second and last opportunity to take the full qualifying exam within 12 months); fail (the student withdraws from the Ph. D. program). The outcomes are given for the full qualifying exam.

Research.

Students are to define and undertake a program of original research, the results of which are reported in a thesis. The Examining committee will be formed as defined in section 1.9.3 of the General Regulations. Students will conform to residence requirements as outlined in section 1.7.3 of the General Regulation. The Senior supervisor shall be an ENSC faculty member approved by the Departmental Graduate Program Committee.

The student's progress will be reviewed each 12 months by a Supervisory Committee of not fewer than three faculty members. At each annual review the student presents the summary of his/her work to date. At the first such review, which takes place within 14 months of admission, the student will present a thesis proposal defining the intended research topic. Students not making satisfactory progress on their research topic, or who fail to demonstrate satisfactory knowledge and understanding of recent publications in their general area of research, or who fail to have their revised thesis proposal approved by the Supervisory Committee within 18 months of admission, may be asked to withdraw, as per section 1.8.2 of the General Regulations.

Research Seminar

A graduate student enrolled in the Ph.D. program is required to present at least one research seminar per year as a part of regularly organized departmental seminars, including one based on completed or nearly completed thesis work. Students are expected to attend all the research seminars of the School.

APPENDIX 1

Personnel and Present Graduate Programs and Courses

SCHOOL OF ENGINEERING SCIENCE | GRADUATE PROGRAM | January 1990

Location:	Room 9851, Applied Science Building 291-4371
Director:	Donald A. George, B.Eng. (McG.), M.S. (Stan.), Sc.D (MIT), P.Eng.
Graduate Program Chairman:	Vladimir Cuperman, M.S. (Polytechnic of Bucharest), M. S., Ph.D. (Calif.)

Faculty and Areas of Research

John S. Bird	statistical signal processing, system performance analysis, underwater acoustics and optics, radar, sonar and communications applications
Thomas W. Calvert	information processing in man and machines, biomedical applications, computer graphics and animation
James K. Cavers	mobile communications, signal processing, network protocols
Glenn H. Chapman	microelectronics (fabrication, defect avoidance techniques, device physics), laser processing of materials, ULSI/wafer scale integration, computer aided engineering.
Vladimir Cuperman	signal processing, speech coding and recognition, digital communications, digital signal processing structures and hardware
M. Jamal Deen	microelectronics, low temperature electronics, semiconductor devices, device reliability, IC technology
John C. Dill	computer graphics, computer aided engineering, design and manufacturing
Donald A. George	adaptive signal processing for communications and remote sensing systems
Kamal K. Gupta	computer vision, robotics, interpretation of 3-D scenes, motion planning, spatial reasoning
R.H. Stephen Hardy	computer networks, VLSI implementation of communications protocols, interaction between network and device technologies and network performance
Paul K.M. Ho	modulation techniques, signal processing, communication theory, adaptive error control techniques

Diane V. Ingraham	adaptive systems including neural network theory, flexible manufacturing systems
John D. Jones	applications of artificial intelligence to engineering design, design for manufacturing, finite-element analysis, heat transfer and thermodynamics
Albert M. Leung	microelectronics, integrated circuit technology, integrated sensors
Tad McGeer	robotics, automatic control, aircraft design, bipedal locomotion
Andrew H. Rawciz	reliability physics and engineering, VLSI reliability, physical transducers, integrated sensors, film technology, nonlinear optics, materials processing in microelectronics
Mehrdad Saif	control theory, large scale systems, optimization theory and application to engineering systems
Shawn Stapleton	passive RF/microwave circuits, GaAs monolithic microwave integrated circuits, nonlinear RF/microwave devices, active RF/microwave circuits
Marek Syrzycki	microelectronics, semiconductor devices, digital and analog VLSI design, integrated circuit technology, integrated sensors, IC fabrication defects, yield and reliability of VLSI IC's

DEGREES OFFERED

Engineering Science offers two distinct programs of study, leading to a Master of Engineering (M.Eng.), or Master of Applied Science (M.A.Sc.). The M.Eng. program is designed for part-time study by practicing engineers and is based on a set of courses, normally offered in the evenings, plus a project performed in industry. The principal areas of study offered in the M.Eng. program are electronics, communications and signal processing. The M.A.Sc., on the other hand, is a full-time program in which primary emphasis is on the thesis, rather than course work. It is more exploratory than the M.Eng., and hence the areas of study cover a greater range.

Admission

The normal admission requirement to the M.Eng. and M.A.Sc. program is a Bachelor's degree in electrical engineering, computer engineering, engineering science or a related area, with a cumulative G.P.A. of at least 3.0 (B) from a recognized university, or the equivalent. Note that the size of the faculty limits the number of M.A.Sc. students.

DEGREE REQUIREMENTS - M.Eng. Program

Course Work

M. Eng. candidates are required to complete a minimum of 24 semester hours course work, at least 20 of which must be at the graduate level. Of the courses listed below, ENSC 805, 810, and 820 are required. The prerequisite ENSC 800 will be waived if the student has equivalent preparation.

A key component of the M. Eng. program is a significant industrial project which integrates knowledge gained during the course of the student's graduate studies. This project is to be performed in the workplace, typically in industry or government laboratories. An appropriate level of design, documentation and reporting responsibility is required. The project would be expected to take a minimum of two person-months.

During the project, the student will receive academic supervision, as required, from the student's senior supervisor at the university, and day-to-day supervision from the student's manager, or a designated associate, in his or her place of work. The industrial supervisors, who will sit on the student's Supervisory Committee, will be appointed by the Faculty. In the case of very small companies, alternative arrangements will be made for supervision.

DEGREE REQUIREMENTS - M.A.Sc. Program

M.A.Sc. candidates are required to complete 30 semester hours work, as a minimum of 12 semester hours course work, plus a thesis with a weight of 18 semester hours. The courses will, in consultation with the Senior Supervisor, normally be selected from the list below. Additional courses may be required to correct deficiencies in the student's background. The M.A.Sc. thesis is to be based on an independent project with a significant research component. The student is required to defend the thesis at an examination, in accordance with general university regulations.

1. **M. A. Sc. - Thesis work in industry**

In addition to the Degree Requirements for the M. A. Sc. Program the following conditions will apply if a student wishes to undertake thesis work in industry.

a) Proposal. The proposal must be approved by the Supervisory Committee and by the Graduate Committee. The proposal must include the following:

- justification for undertaking the work in industry
- agreement regarding intellectual property and publications
- funding arrangement

b) On Campus Presence. During the thesis work in industry the student must spend one day per week (or equivalent as approved by the Graduate Committee) on campus to meet with his/her supervisor and attend regular seminars. This is in addition to time spent on campus for course work.

c) Oral Presentations. A minimum of two oral presentations for the Supervisory Committee (not including the thesis defence) on the progress of the student's work will be given during the duration of the thesis.

d) Failure to Comply. See General Regulations p. 208, 1.8 of the University Calendar.

Transfer from M. Eng. Program to M. A. Sc.

Normally transfer from M. Eng. Program to M. A. Sc. Program will be considered under the following conditions:

a) Undergraduate GPA. Minimum undergraduate cumulative GPA. of 3.3 required.

b) M. Eng. GPA. On at least 2 courses, a minimum cumulative GPA of 3.5.

ENGINEERING SCIENCE GRADUATE COURSES (ENSC)

ENSC 800-3 Linear Systems Dynamics
A unified presentation of systems and signals analysis techniques. Linear algebra up to Cayley-Hamilton. Linear systems: superposition, convolution for differential and difference equations. State variables: canonic forms, modal decomposition. Transforms: Fourier, Laplace, Z. Random processes: discrete time processes, AR and ARMA models, least squares estimation. Communication signals and their representation.
Prerequisite: undergraduate degree in engineering, mathematics or physics.

ENSC 805-3 Techniques of Digital Communications
Modulation, detection and synchronization techniques for digital transmission. Decision theory and optimum detectors. Channel impairments: random phase, random gain, restricted bandwidth, nonlinearities. Comparison of signal sets. Carrier and bit synchronization. Precoding for dispersive channels. Adaptive equalization. Sequence decoding by Viterbi algorithm.
Prerequisite: ENSC 800

ENSC 810-3 Digital Signal Processing
Techniques for digital processing of one and two dimensional signals. Filter design. Finite word length effects. Canonical forms, lattice filters. Estimation of power spectrum. Homomorphic signal processing.
Prerequisite: ENSC 800

ENSC 815-3 Signal Processing Electronics
Hardware implementation tools and design techniques. CCDs, switched capacitor filters. Noise and dynamic range in sampled analog circuits. Special purpose and general purpose digital signal processors. Signal processing architectures: pipeline, systolic arrays, data flow architectures.
Prerequisite: ENSC 800

ENSC 820-3 Engineering Management for Development Projects
This course focuses on the management and reporting activities of typical engineering development projects. Through seminars and workshops it builds the

student's skills at estimating project cost and schedule, keeping a project on track, and handing over the completed project to a customer or another team. A writing workshop emphasizes techniques for writing proposals, and writing and controlling documentation.
Prerequisite: Permission of instructor.

ENSC 832-3 Mobile and Satellite Communications
Propagation phenomena, modulation techniques and system design considerations for mobile and satellite networks. Topics include: fading and shadowing, noise and interference effects, analog and digital transmission, cellular designs, multiple access techniques.
Prerequisite: ENSC 800

ENSC 833-3 Network Protocols and Performance
Practical techniques of design and performance analysis of data networks up to layer 3 of the Open System Interconnection protocol hierarchy. Point to point and polling data links. Networks of queues: stochastic and mean value analysis. Packet networks: loading, transit time, routing strategies.
Prerequisite: ENSC 800

ENSC 834-3 Optical Processing and Communications
This course will give an overview of fibre optics communications and integrated optics, with emphasis on the latter. The discussion will include multimode and single-mode technology, semi-conductor sources, photo detectors, communications systems and fibre optic sensors.
Prerequisite: ENSC 800

ENSC 851-3 Integrated Circuit Technology
Review of semiconductor physics. Technology of semiconductor devices and integrated circuits: material evaluation, crystal growth, doping, epitaxy, oxidation, thermal diffusion, ion implantation, lithography and device patterning, and thin film formation. Design and fabrication of active and passive semiconductor devices, packaging techniques and reliability of integrated circuits.
Prerequisites: Permission of the Instructor.

ENSC 852-3 Analog Integrated Circuits
Integrated-circuit (IC) technology, IC component models and analog circuit configurations. Computer aided design tools for circuit simulation and physical layout of ICs. Students are required to complete a project in which he/she will design, layout, fabricate and test a semicustom IC using the fast turnaround IC fabrication facility at the School of Engineering Science. (Limited enrolment.)
Prerequisites: ENSC 321 or equivalent.

ENSC 853-3 Digital Semiconductor Circuits and Devices
MOS device electronics. Second Order Effects in MOS transistors. BJT device electronics. Static and transient analysis of inverters. Digital gates, circuits and circuit techniques. Speed and power dissipation. Memory systems. Gate arrays, semicustom and customized integrated circuits. CAD tools. Students are required to complete a project.
Prerequisites: Permission of the Instructor.

ENSC 861-3 Source Coding for Speech and Images
Source characterization and rate-distortion functions. Sampling and quantization: uniform, optimal, adaptive. Entropy coding, variable length codes. Predictive encoding, optimal linear predictors, noise feedback coding. Tree and trellis coding, search techniques. Transform coding, optimal and suboptimal transforms, subband coding, bit allocation algorithms. Vector quantization. Analysis-synthesis techniques. Speech coding at 2.4 to 16 kbps. Image coding at 0.25 to 1 bit/pixel.
Prerequisite: ENSC 800

ENSC 881-3 Engineering Modelling of Dynamic Processes
Effective design requires a good model of the system you work with. This course uses case studies and labs to introduce the student to systematic techniques of modelling: simplification and approximation of dynamical mechanisms, expression in appropriate mathematics, and comparison of mathematical results with observed phenomena. Topics include modelling philosophy and strategy; classification of mathematical models; dimensional analysis; approximate solutions of dynamical equations; perturbation methods; approximate physical models; experiment design; accuracy bounds on models and measurements. Examples are drawn from mechanical, electrical, thermal, fluid, and biological systems.
Prerequisites: ENSC 800

ENSC 883-3 Optimization and Modern Control
This is a second control course for students with a background in classical control. The course begins with a discussion of the philosophy and process of optimization. This includes a review of objectives in optimization and figures of merit. Both variational and numerical methods are introduced, and applied to component design and trajectory planning problems. Appropriate and inappropriate applications are critically reviewed. The discussion then turns to control of dynamic systems. Alternative design techniques are developed and compared: classical linear design; 'modern' linear design; trajectory optimization; hybrid techniques.
Prerequisites: ENSC 382 or equivalent.

ENSC 891-3 Directed Studies I

ENSC 892-3 Directed Studies II

ENSC 894-3 Special Topics I

ENSC 895-3 Special Topics II

ENSC 897 M.Eng. Project

ENSC 898 M.A.Sc. Thesis

COURSES OFFERED BY OTHER DEPARTMENTS

Of particular interest to graduate students in Engineering Science are the following courses, for which complete descriptions can be found elsewhere in the University Calendar.

BUS 820 Analysis of Dynamic Processes.
CMPT 720 Artificial Intelligence.
CMPT 750 Computer Architecture.
CMPT 815 Algorithms of Optimization.
CMPT 821 Robot Vision
CMPT 822 Computational Vision.
CMPT 827 Expert Systems
CMPT 851 Fault Tolerant Computing and Testing.
CMPT 852 VLSI Systems Design.
CMPT 853 Computer-Aided Design/Design Automation for Digital Systems
KIN 885 Seminar on Man-Machine Systems.
MATH 851 Numerical Solutions to Ordinary Differential Equations
PHYS 425/821 Electromagnetic Theory.
PHYS 810 Fundamental Quantum Mechanics.
PHYS 861 Introduction to Solid State Physics.

APPENDIX 2

New Courses

SIMON FRASER UNIVERSITY

New Graduate Course Proposal Form

CALENDAR INFORMATION:

Department: School of Engineering Science Course Number: ENSC 801

Title: Linear Systems Theory

Description: A Comprehensive treatment of finite dimensional linear dynamical systems.

Credit Hours: 3 Vector: 3-0-0 Prerequisite(s) if any: Grad. standing

ENROLLMENT AND SCHEDULING:

Estimated Enrollment: 15 When will the course first be offered: Fall 1990

How often will the course be offered: Every year

JUSTIFICATION:

This is a core course of great importance to all those graduate students who wish to pursue graduate studies in communication, control, and system engineering.

RESOURCES:

Which Faculty member will normally teach the course: M. Saif

What are the budgetary implications of mounting the course: None

Are there sufficient Library resources (append details): yes

Appended: a) Outline of the Course
b) An indication of the competence of the Faculty member to give the course.
c) Library resources

Approved: Departmental Graduate Studies Committee: [signature] Date: JAN 31 90

Faculty Graduate Studies Committee: Joseph Peters Date: 12/3/90

Faculty: [signature] Date: 15/3/90

Senate Graduate Studies Committee: Date: 7/5/90

Senate:

ENSC 801-Linear Systems Theory

State-space analysis of finite dimensional continuous and discrete time linear systems. Linear vector spaces, linear operators, normed linear spaces, and inner product spaces. Fundamentals of matrix algebra, induced norm and matrix measures, functions of a square matrix, Cayley-Hamilton and Sylvester's Theorems. Analytical representation of linear systems, state-space formulation, solution of the state equation and determination of the system's response. Controllability, observability, duality, canonical forms, and minimal realization concepts. Stability analysis, Lyapunov's method, and design of feedback regulators.

Instructor: Dr. M. Saif
M. Saif holds a doctoral degree in Electrical Engineering with a specialization in systems and control. His research and publications are in the general area of analysis and control of linear dynamical systems.

Library Facilities:

SFU library holds an adequate number of books and journals in the subject area.

New Graduate Course Proposal Form

CALENDAR INFORMATION:

Department: School of Engineering Science Course Number: ENSC 802

Title: Stochastic Systems

Description: This is a course in probability, random variable and stochastic processes, and the application of these theories to analyse different engineering systems.

Credit Hours: 3 Vector: 3-0-0 Prerequisite(s) if any: Grad.Stand.

Bachelor degree in Engineering, mathematics or physics.

ENROLLMENT AND SCHEDULING:

Estimated Enrollment: 15 When will the course first be offered: Fall 90

How often will the course be offered: once a year

JUSTIFICATION:

This course teaches the students the required tools to undertake advance courses and research in Communications, Signal Processing, and Systems.

RESOURCES:

Which Faculty member will normally teach the course: Dr. Paul Ho and Dr. John Bird

What are the budgetary implications of mounting the course: No additional faculty, staff and library resources are required

Are there sufficient Library resources (append details): YES

Appended:
a) Outline of the Course
b) An indication of the competence of the Faculty member to give the course.
c) Library resources

Approved: Departmental Graduate Studies Committee: [signature] Date: JAN 31 90

Faculty Graduate Studies Committee: Joseph Peters Date: 12/3/90

Faculty: [signature] Date: 15/3/90

Senate Graduate Studies Committee: [signature] Date: 7/5/91

Senate: Date:

ENSC 802
STOCHASTIC SYSTEMS

TEXT "Probability, Random Variables, and Stochastic Processes", by Papoulis, McGraw Hill 1984.

Calendar Description Review of elementary probability theory, random variables, and stochastic processes : autocorrelation, power spectral density, white noise. First order systems with stochastic inputs : AR and ARMA models, random walk. Point processes : Poisson and renewal processes, counting process. Discrete random processes : birth-death processes, markov chains, elementary queuing theory. Introduction to estimation theory : parameter estimation, linear estimation, spectrum estimation, Kalman filtering.

Appendix (a)
Detailed Course Outline

1. Review of Probability
Discrete probability, intersection and union of events, continuous probability, conditional probability and Bayes rule, transformation of random variables, expectation, moments, moment generating functions, complex and multidimensional variates. Decorrelation by similarity transform (KL) and by Gram Schmidt.

2. Review of Elementary Continuous Random Processes
Definitions, stationarity and ergodicity, autocorrelation and power spectra for continuous and discrete time, steady state effect of arbitrary linear systems, white noise, complex random processes.

3. Finite Order Systems with Stochastic Inputs
Rational power spectra, AR and ARMA models, spectrum factorization, whiteners, minimum phase filters, evolution of first and second order statistics using state variable model, random walk.

4. Point Processes
Poisson and renewal processes, counting processes, convergence of pooled processes to Poisson.

5. Discrete Random Processes
Birth-death processes, continuous time and discrete time Markov chains, transient behavoir, flow balance steady state solutions, first passage times elementary queueing theory.

6. Introduction to Detection and Estimation Theory
Simple binary hypothesis tests, M hypotheses, and composite hypotheses, detection in white and non-white Gaussian noise, signals with unwanted parameters. Parameter estimation, criteria, bias and consistency. Linear estimation and multivariable regression analysis with projection theorem. Kalman filtering. Rational power spectrum estimation.

Appendix (b)
Competence of the lecturers

Both Dr. Ho and Dr. Bird are well trained in the subject area, as indicated by their research areas (which include digital communications, information theory, detection and estimation theory, radar/sonar) and publications.

Appendix (c)
Library Resources

The library has a large number of reference books in the subject area. No additional library resources are required.

SIMON FRASER UNIVERSITY

New Graduate Course Proposal Form

CALENDAR INFORMATION:

Department: School of Engineering Science Course Number: ENSC 855

Title: Passive Microwave Circuits

Description: Review of Electromagnetic Theory, Transmission Lines and Waveguides, Passive Microwave Circuit Analysis, Filters, Couple lines and Directional Couplers.

Credit Hours: 3 Vector: 3-0-0 Prerequisite(s) if any: PHYS 324-3, ENSC 426-4

ENROLLMENT AND SCHEDULING:

Estimated Enrollment: 10 When will the course first be offered: Spring 1991

How often will the course be offered: Once per year.

JUSTIFICATION:

There is a strong demand from the local industry for Simon Fraser University to offer RF/Microwave courses.

RESOURCES:

Which Faculty member will normally teach the course: Shawn P. Stapleton

What are the budgetary implications of mounting the course: no cost

Are there sufficient Library resources (append details): Yes

Appended: a) Outline of the Course
b) An indication of the competence of the Faculty member to give the course.
c) Library resources

Approved: Departmental Graduate Studies Committee: [signature] Date: 10 Jan/89

Faculty Graduate Studies Committee: [signature] Date: Mar 12/89

Faculty: [signature] Date: 29/3/89

Senate Graduate Studies Committee: [signature] Date: 2/5/91

Senate: Date:

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Appendix

a) Outline of Course

I	Review of Electromagnetic Theory	2 weeks
II	Transmission Lines and Waveguides	3 weeks
III	Passive Microwave Circuit Elements and Analysis	2 weeks
IV	Stepped - Impedance Filters and Transformers	
V	Coupled - Transmission Line Directional Couplers	2 weeks
VI	Branch - Line Directional Couplers	1 week

b) Competence of Faculty Member

Shawn P. Stapleton's area of expertise is in Microwave Circuits.

c) Library Resources

I R.E. Collins, Foundations for Microwave Engineering , McGraw-Hill, 1966.

II T.C. Edwards, Foundations for Microstrip Circuit Design , Wiley, 1981.

III G. Gonzalez, Microwave Transistor Amplifiers , Prentice Hall, 1984.

New Graduate Course Proposal Form

CALENDAR INFORMATION:

Department: School of Engineering Science   Course Number: ENSC 883

Title: Optimal Control Theory

Description: Comprehensive treatment of the Optimal Control theory, variational calculus and continual optimal control, the maximum principle and Hamilton-Jacob theory, optimal control system examples such as minimum time, Regulators,, ~~minimum fuel, and minimum energy problems.~~

Credit Hours: 3   Vector: 3-0-0   Prerequisite(s) if any: ENSC 801-3
ENSC 423-4

ENROLLMENT AND SCHEDULING:

Estimated Enrollment: 10   When will the course first be offered: Spring 1991

How often will the course be offered: Once a year or upon sufficient demand

JUSTIFICATION:

Multivariable and optimal control theory are the minimum necessary foundations for any graduate student who wishes to pursue research in the field of Control Theory.

RESOURCES:

Which Faculty member will normally teach the course: Mehrdad Saif

What are the budgetary implications of mounting the course: No cost

Are there sufficient Library resources (append details): Yes

Appended: a) Outline of the Course
b) An indication of the competence of the Faculty member to give the course.
c) Library resources

Approved: Departmental Graduate Studies Committee: [signature] Date: JAN 31 90

Faculty Graduate Studies Committee: Joseph Peters Date: 12/3/90

Faculty: [signature] Date: 15/3/90

Senate Graduate Studies Committee: [signature] Date: 7/5/90

Senate: Date:

OPTIMAL CONTROL THEORY

COURSE OUTLINE

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1. Performance measure for optimal control Problems (1 week)

2. The Calculus of Variations (3 weeks)

   a) Variations of a functional
   b) Fundamental Theorem of calculus of variation
   c) Simplest problem of calculus of variation (Euler Equation)
   d) Functional involving several functions

3. The Maximum Principle, and Hamilton Jacobi theory (3 weeks)

   a) Necessary conditions for optimal control
   b) Pontryagin's Maximum (minimum) Principle

4. Dynamic Programming, and Bellman's principle of optimality (1 week)

5. Optimal control problems (2 weeks)

   a) Minimum time problems
   b) Minimum fuel problems
   c) Optimal Linear Regulator, and tracking problems
   d) Minimum time minimum fuel problems

Instructor: Dr. M. Saif
Dr. Saif's research and publications are in the area of optimal control, large scale system, and multivariable control theory.

Library Facilities: SFU library holds an adequate number of books and journals in the subject area, the notable ones are noted below:

<u>JOURNALS HOLDINGS</u>

1) International Journal of Control
2) International Journal of Systems Science
3) SIAM Journal of Control and Optimization
4) Journal of Optimization Theory and Application (JOTA)
5) Automatica-Journal of the International Federation of Automatic Control (IFAC).

6) IEEE Transactions on Automatic Control
7) IEEE Transactions on Circuits, and Systems
8) IEEE Transactions on Systems, Man, and Cypernetics

There are a number of good books on the subject available in the library some of which are mentioned below:

BOOK HOLDINGS

1) Sage, A. and White, C.C. Optimum Systems Control, Prentice Hall, 1977.

2) Kirk, D.E., Optimal Control Theory, Prentice-Hall, 1970.

3) Athans, M. and Falb, P.L. Optimal Control, McGraw Hill, 1966.

4) Russel, D., Mathematics of Finite Dimensional Control Systems, Marcell-Dekker, 1978.

5) Anderson, B.D.O. and More, J.B., Linear Optimal Control, Prentice-Hall, 1971.

6) Lewis, F.L., Optimal Control, Wiley, 1986.

7) Lee, B. and Markus, L.W., Foundations of Optimal Control Theory,

8) Bryson, A. and Ho, Y.C., Applied Optimal Control, Hemisphere, 1975.

9) Stengel, R.F., Stochastic Optimal Control, Wiley, 1986.

SIMON FRASER UNIVERSITY

New Graduate Course Proposal Form

CALENDAR INFORMATION:

Department: School of Engineering Science Course Number: ENSC 887

Title: Vision for Robotics

Description: Advanced Machine Vision Techniques as Applicable in Robotics

Credit Hours: 3 Vector: 3-0-0 Prerequisite(s) if any:

ENROLLMENT AND SCHEDULING:

Estimated Enrollment: 10 When will the course first be offered: Spring 1991

How often will the course be offered: Once a year

JUSTIFICATION:

For automation, vision is one of the strongest "sensing" candidates - absolute must for Intelligent Systems & Control students.

RESOURCES:

Which Faculty member will normally teach the course: K. Gupta

What are the budgetary implications of mounting the course: Machine time on existing Suns

Are there sufficient Library resources (append details): Yes

Appended:
a) Outline of the Course
b) An indication of the competence of the Faculty member to give the course.
c) Library resources

Approved: Departmental Graduate Studies Committee: [signature] Date: 10 Jan/89

Faculty Graduate Studies Committee: [signature] Date: Mar 12/89

Faculty: [signature] Date: 29/3/89

Senate Graduate Studies Committee: [signature] Date: 2/1/90

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Vision for Robots
Course Outline

1. A review of basic philosophy of machine vision – 2 weeks
2. Intermediate levels of processing, representation, 2-1/2 D sketch – 2-3 weeks
3. Some basic paradigms in machine vision: – 4-5 weeks
   (a) Shape from shading
   (b) Stereo
   (c) Motion
4. Models of representing 3-D Objects – Surface/Volumetric descriptions. Simple Polyhedral Representations. – 2-3 weeks
5. Pick and Place Tasks Using Vision (partially based on projects)

Instructor: Dr. Kamal Gupta

Dr. Gupta's research interests and publications are in the areas of robotics and machine vision.

Library Facilities:

SFU library holds adequate number of books, conference proceedings and journals in the general area of vision and robotics. A tentative list of the ones intended to be used in the course is given below:

B.K.P. Horn: Robot Vision
David Marr: Vision
IEEE journal on pattern analysis and machine intelligence (PAMI)
IEEE journal on robotics and automation
International Journal of Robotics Research (IJRR)
Proceedings of IEEE robotics and automation conference
Proceedings of the international symposia on robotics research (MIT Press).
Proceedings of the international conference on computer vision
Proceedings of the computer vision and pattern recognition conference

SIMON FRASER UNIVERSITY

ENSC 888

New Graduate Course Proposal Form

CALENDAR INFORMATION:

Department: Engineering Science   Course Number: ENSC 888

Title: Finite - Element Methods in Engineering

Description: Finite - Element Methods are examined from the viewpoint of the user (rather than the mathematician); the objective of the course is that the student should be able to use FEM with an intelligent grasp of its limitations.

Credit Hours: 3   Vector: 3-0-0   Prerequisite(s) if any: None

ENROLLMENT AND SCHEDULING:

Estimated Enrollment: 10   When will the course first be offered: Fall 1991

How often will the course be offered: Either annually or biennially

JUSTIFICATION:

Any practicing engineer will either use Finite-Element methods or rely on someone else to do it. In either case, it is essential that he or she have some idea of the method's basis, potential and limitations.

RESOURCES:

Which Faculty member will normally teach the course: John Jones

What are the budgetary implications of mounting the course: The only cost will be some computer time on PC's; it would be useful, though not essential, to buy several hundred dollars worth of reference books for the library.

Are there sufficient Library resources (append details): See Appendix III

Appended: a) Outline of the Course
b) An indication of the competence of the Faculty member to give the course.
c) Library resources

Approved: Departmental Graduate Studies Committee: [signature] Date: 10 Jan/89

Faculty Graduate Studies Committee: [signature] Date: Mar 12/89

Faculty: [signature] Date: 29/3/89

Senate Graduate Studies Committee: [signature] Date: 2/ /90

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<u>OUTLINE OF COURSE ON FINITE - ELEMENT METHODS IN ENGINEERING</u>

I Overview: FEM as one of a family of approximate methods, which also include finite differences, boundary integral methods, etc.

II Suitable problems for FEM; classification of physical problems as <u>discrete</u> (e.g., several masses linked by springs) or <u>continuous</u> (e.g., heat flow in a block). FEM is not applied to a physical problem, but to an <u>idealization</u> of the problem; considerations in developing the idealization.

III Mathematical foundations of FEM: Calculus of variations; trial functions; the Galerkin method; solution of the global matrix

IV Limitations of FEM: checking for convergence; estimation of error

V FEM in practise: pre-processing, processing and post-processing. Mesh generation. Review of available tools for these tasks.

VI Worked example: students are then assigned mini-projects to solve using NISA or other PC-based program.

COMPETENCE OF FACULTY MEMBER

I have worked with FEM in an industrial setting for four years; during this time I have used commercially available packages such as NASTRAN and NISA. I have also written my own finite-element package, together with a pre and post-processor. Some of this work is described in the publications listed below.

1. C.C. Ashcraft, G.M. Shook and J.D. Jones, "A Computational Survey of Conjugate-Gradient Preconditioners on the Cray 1-S", Proceedings of the 1986 SIAM Conference, Boston, MA, June 1986.

2. J.D. Jones, "Shuttle Heat Transfer in the Insulated Diesel", Proceedings of the Eighth International Heat Transfer Conference, August 1986, San Francisco, CA, USA.

3. J.D. Jones, "Application of the Galerkin Method to Analysis of Heat Transfer in a Low-Heat-Rejection Diesel Engine", Proceedings of the Fourth International Conference on Numerical Methods in Engineering, Concordia University, Montreal, June/July 1987.

4. J.D. Jones, "Heat Transfer Processes in Low-Heat-Rejection Diesel Engines", <u>Heat Transfer Engineering, 8,3, 1987.</u>

5. A. Alkidas and J.D. Jones, "An Experimental and Theoretical Evaluation of Thermal Loading in an Uncooled Open-Chamber Diesel Engine", <u>Heat Transfer Engineering, 8,2, 1987.</u>

6. J.D. Jones, "Use of the Galerkin Method to Calculate Temperature in a Body Exposed to Periodically Varying Boundary Conditions", <u>Int. J. for Num. Methods in Engr., 26,</u> pp 1311-1323, 1988.

7. J.A. Gatowski, J.D. Jones and D.C. Siegla, "Evaluation of the Fuel Economy Potential of the Low-Heat-Rejection Diesel Engine for Passenger Car Application", <u>Transactions of the SAE, 96, pp 5.317-5.329, 1987.</u>

LIBRARY RESOURCES

The library has a small number of books on FEM. This course requires $500 to purchase additional texts.

SIMON FRASER UNIVERSITY

New Graduate Course Proposal Form

CALENDAR INFORMATION:

Department: Engineering Science Course Number: ENSC 889

Title: 3D Object Representation and Solid Modelling

Description: Description of current approaches, limitations. Applications in manufacturing and engineering.

Credit Hours: 3 Vector: 3-0-0 Prerequisite(s) if any: ENSC 439 CMPT 351

ENROLLMENT AND SCHEDULING:

Estimated Enrollment: 10 When will the course first be offered: Fall 1990

How often will the course be offered: Alternate Years (on sufficient demand)

JUSTIFICATION:

Solid modelling is used increasingly in advanced CAE/CIM SYSTEM in indus[try]. It is a fundamental part of the design for manufacture concept.

RESOURCES:

Which Faculty member will normally teach the course: J. Dill

What are the budgetary implications of mounting the course: Library resource acquisition plus use of existing computer work stations plus some software cost (Acquisition: approx $5K; ongoing: approx $600/yr)

Are there sufficient Library resources (append details): No (see appended)

Appended: a) Outline of the Course
b) An indication of the competence of the Faculty member to give the course.
c) Library resources

Approved: Departmental Graduate Studies Committee: [signature] Date: 10 Jan. /89

Faculty Graduate Studies Committee: [signature] Date: Mar 12/89

Faculty: [signature] Date: 29/3/89

Senate Graduate Studies Committee: [signature] Date: 7/5/90

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3-D Object Representation and Solid Modelling

Outline of Course

Review of geometric principles	2 weeks
Solid models versus surface models	1 weeks
Mathematical basics of solid models	3 weeks
Descriptions of current systems (PADL, TIPS, Geomod)	2 weeks
Applications, limitations	2 weeks

2. Competence of Faculty Member

John Dill's area of expertise is in applications of computer graphics, including CAD/CAE and solid modeling.

3. Library Resources

The library has little material on solid modelling. It is estimated that $300-$400 worth of books are needed. This will be covered by the existing Library funding for Engineering aquisitions.

APPENDIX 3

Library Collections

SIMON FRASER UNIVERSITY

M E M O R A N D U M
****

TO: Vladimir Cuperman, School of Engineering Science

FROM: Sharon Thomas, Head, Collections Management Office

SUBJECT: Ph.D. Program Proposal

DATE: February 8, 1989

The present proposal for a Ph.D. program in Electrical Engineering falls well within the Library's collection policy for Engineering Science and, with a few fairly minor exceptions, would not require us to begin collecting materials in areas in which we are not already committing resources. However, the Engineering Sciences collection is young and has been developed in an era of restraint and tight library budgets. Consequently the question is not whether or not the collection is wide enough in scope but whether or not its depth is sufficient to support a doctoral program.

During the summer of 1983, after discussions between the Head of the Library's Science Division and the Dean of Engineering Science, the Library undertook to take the following steps, as soon as funding permitted, in order to support the new program:

1) Electrical and Electronics Abstracts
Begin a current subscription and purchase backfiles and indexes back to 1977. The cost was estimated to be approximately $7,500 with continuing annual subscription costs of $700. per year.

2) Computer and Control Abstracts
Complete backfile holdings back to 1977 at an estimated cost of $2,300.

3) IEEE Transactions and Journals
Increase our membership to full coverage at an annual cost of approximately $340.

4) Implement approval plan profiles which would ensure the automatic acquisition of monographs in those subject areas defined as part of the Engineering Science Core A areas of concentration: that is; computing, microelectronics and communications. Further expansion of the journal collection was deferred pending development of the Engineering Science Faculty.

5) Purchase urgently required, previously published reference and research materials at an estimated cost of $3,600.

...2

Recommendations 2 - 5 were fully implemented but no monies were available for <u>Electrical and Electronics Abstracts</u>. If, as you suggest, it would now be sufficient to purchase back-files from 1981-1988 and indexes from 1977 to 1980, the total cost would be approximately $14,533 now and $1,675 per year for the new subscription.

The next development occurred during the fall of 1986 when approval plan profiles were expanded to include proposed areas of concentration identified as Core B: that is, industrial automation, control and robotics, and computer-aided design and manufacturing.

There have been no substantial changes to our collecting policy for Engineering Science since that time and the increased costs associated with the acquisition of these materials as reflected in the following figures can be largely attributed to price increases and currency fluctuations.

ENGINEERING SCIENCE EXPENDITURES

	Serials	Monographs	Total
1988/89	$9,000 (est)	$21,000 (est)	$30,000(est)
1987/88	6,764	18,848	25,612
1986/87	5,568	17,254	22,822
1985/86	6,797	12,468	19,265
1984/85	4,349	12,402	16,751
1983/84	11,634	6,771	18,405
			$132,855

The situation with respect to journals is not quite as positive. The School of Engineering Science was established just as the Library, experiencing the first effects of fiscal restraint, halted the previously steady expansion of its journal collection. Since that time there have been virtually no funds available for new journals and new titles have only been added by cancelling existing subscriptions - a very difficult situation for new and developing departments. The review of existing serials which is now underway through the various faculty library committees has identified a number of journals previously required by other departments which are no longer of interest to them but which are now of primary concern to Engineering Sciences.

...3

These titles include:

Medical Electronics
Pattern Recognition
Automatica
Journal of Medical Engineering and Technology
Mechanical Engineering
Ocean Engineering

These titles, along with the complete output of the IEEE, now constitute the Library's journal holdings in Engineering Science.

I have also received requests for subscriptions to:

IEE Proceedings. Port F. Communications, Radar, and Signal Processing
Current Contents in Engineering Technology and Applied Sciences

Present budgeting levels allow for the annual acquisition of some 300 new monographs added to an existing collection of about 2,200 titles and current subscriptions to 70-75 journals, most of them published by the IEEE. The Library would require additional funding in order to correct the deficiencies identified above and to provide the normal support for four proposed new courses.

We would need a one-time grant to cover the following accessions:

Electrical and Electronics Abstracts (backfiles and indexes from 1977 to 1988	$14,500
Additional resources for proposed new courses	3,000
	$17,500

In addition, the annual cost for three new subscriptions (in 1988 dollars) is as follows:

Electrical and Electronics Abstracts	1,675
IEE Proceedings. Part F.	150
Current Contents in Engineering Technology	350
	$2,175

In other words, we would require $19,675 in 1989 and $2,175 of that would be added to the base for future years:

One time expenditure	$17,500
Recurring annual costs	2,175
	$19,675

This allocation would allow the Library to meet the goals established in 1985 and to provide modest but adequate support for the Core A and B areas of concentration.

The superimposition of a Ph.D program in electrical engineering could, in my opinion, be accommodated by the newly augmented collection during the early phases of its development. We would expect to provide enhanced Interlibrary Loan support to the program as it acquires doctoral candidates and to cooperate with the faculty in order to facilitate access to secondary collection materials. However, the continued growth of the program over the next decade will certainly create pressures for a more comprehensive journal collection and approval of the Ph.D. Program in Engineering Science should be seen as a commitment to support future requirements for an expanded primary collection and improved access to the infinitely larger secondary collection.

Sharon Thomas

ST/dab DAB248

APPENDIX 5

Comments of External Reviewers

EXTERNAL REVIEWER FOR PHD IN ENGINEERING SCIENCE

Dr. V. Bhargava
Dept. of Electrical and
Computer Engineering
University of Victoria
P.O. Box 1700
Victoria, B.C.
V8W 2Y2

Phone: 604 - 721-7211

FAX: 604 - 721-8676

Report on the Ph.D. Program Proposal of the School of Engineering Sciences, Simon Fraser University.

III. PROGRAM OUTLINE

1. Objectives of the proposed program

The stated objective to produce specialists in three core areas, namely *Communications and Signal Processing, Microelectronics, Automation* is a worthy one given the National and B.C. demand for specialists in these areas.

The referee though disagrees with *the strong interdisciplinary emphasis and breadth of knowledge.* A strong Ph.D. Program emphasizes specialization and depth given the strong research component of a Ph.D. and the need to advance the state of the art. Awareness of developments in other disciplines is also necessary, but breadth cannot substitute for depth of knowledge.

A strong Ph.D. program should also emphasize academic and research excellence. A *strong industrial orientation* is not contrary to to these objectives, but it is a subsequent rather than a prerequisite. The intention to have strong industrial links is certainly a good one.

The *choice of core areas as specialization areas of peak demand* will make the program attractive and attract good students.

2. Personnel and Core areas.

The reviewer found that the proposed courses in the three core areas cover the current state of the art. However, the reviewer would like to propose some changes/additions which to his opinion would enhance the program.

Communications and Signal Processing

A course dealing with probability theory and random variables is a must in any modern Communications discipline.

Automation

A sequence of courses in modern control covering such topics as nonlinear systems, stochastic control, adaptive control etc. is desirable.

A course covering the fundamentals of robotics (i.e. Robot dynamics, kinematics, path planning etc.) is desirable.

A course in numerical analysis is also desirable. This may be offered through Mathematics or Computer Science.

3. Academic Requirements

The reviewer found that the stated academic requirements and procedures conform with the established practises in most such programs.

IV. RESEARCH FACILITIES

The included list of Research Facilities is certainly adequate to support the proposed Ph.D. program.

August 9, 1989

Dear Dean Clayman:

Attached is my report on the proposed Ph.D. program in Electrical Engineering at Simon Fraser University. As you see, it is fairly concise. I would be happy to amplify on any of the points that I made. I have studied the documentation that you provided fairly carefully; consequently, I am reasonably firm in the view that I express.

Sincerely yours,

Jeremiah F. Hayes

Proposal for Doctoral Program Simon Fraser University

J.F. Hayes

Department of Elecrtrical and Computer Engineering

Concordia University

One may consider a Ph. D. program to have three different aspects: the course work, the research culminating in a thesis and the administrative detail covering items such as the formulation of a committee and qualifying examinations. I would like to deal with each of these aspect in what I deem to be increasing order of importance.

Administration

The procedures that have been set up for the program appear to be quite sound. The format of the qualifying examination and the review of progress are similar to those used in the other Ph.D. programs with which I am familiar. The admissions standards also seem to be in conformity with other programs as well. This aspect of the program may reflect the administrative experience of many of the members of the department.

Graduate Courses

I should begin my consideration of the graduate courses in each of the core areas by commenting on ENCS 800, Linear Systems Dynamics and ENCS 820, Engineering Management for Development Projects. The former contains material which is covered at the undergraduate level in most institutions. At best, it is a first-year graduate course for students with weak backgrounds. ENCS 820 may be appropriate for the M. Eng. degree but it has no place in a Ph.D. program. I might say that listing these courses creates a negative impression; they look like padding.

Of the three core areas, Communications and Signal Processing has the largest number of courses which are directly relevant to the area. Of the two sub areas, Communications seems to have the most courses, five out of seven. The problem is that all of the course are at the introductory level and are quite practically oriented. The is a real lack of higher level courses which would form a suitable prelude to research. For example, there is nothing on the theory of detection and estimation. Where does the student learn Wiener and Kalman filtering, for example? Moreover, there is neither a course on Error Correcting and Detecting Codes nor on Information theory. Where does a student learn about such important new developments as channel trellis coding? While there is a course on Networks and Protocols, the range of topics is vast and the student would hardly have the background to begin research. There should be separate courses on performance models and on protocol development and testing. My perception of the Signal Processing side of this core is even more critical from the point-of-view of a Ph.D. program. The are only two courses one of which implementation oriented. This simply is not enough to bring the student to a research level.

Of the three core areas, I am least familiar with Microelectronics; however, it seems to have the greatest depth, primarily because of the offerings in Physics and Computer Science. In the department there are three basic courses. While ENSC 855 is related, it is stretching things to call it microelectronics. My impression is that the three courses are fairly basic. As in the previous core, there does not seem to be any in-depth material which would be appropriate to a Ph.D. program.

Of the three cores, Automation seems to be the most deficient in course offerings. There is some depth in Computer Vision but this is only one aspect of Automation. There is only one basic level course in control. No where are the complex issues of stability and controllability treated. There is no material on robotics. Finally, it is difficult to see how ENCS Finite-Elements fits into an automation core. Could this be another example of padding?

Thesis Research

With respect to the third aspect of the program I take the orthodox position that, in order to guide students, the faculty members must be successful researchers themselves. As evidence of competence there is no substitute for publication in refereed journals. Further evidence would be support for fundamental research, whether theoretical or practical, in the form of external funding. I feel that the NSERC Operating grant is an important indication of the viability of a research program. I recognize that there is a alternative point-of-view which holds that industrial contracts and reports are also valid measures of productivity.

A fundamental problem is that many of the senior professors have not published very much recently in refereed journals. Of the six Full Professors only two have recent journal publications; only three have NSERC operating grants, at modest levels. One of those without recent publications has been heavily involved with industry. The merit of this particular work is attested to by the fact that he has an NSERC CRD grant. At the Associate Professor level there is more evidence of recent activity although the record is not strong. Of the six dossiers examined, there was no statement of an NSERC operating grant, although two or three of the individuals have records which could indicate support. I may be accused of placing too much emphasis on the operating grant as an indicator; however, even the alternative point-of-view yields the same result. There seems to be only one senior professor who has active participation with industry.

At the level of Assistant Professor, the picture is much brighter. Of the six dossiers examined, four indicate quite good performance. These four Assistant Professors hold NSERC operating grants, for example. As a group, the Assistant Professors are certainly up to the standard of good young people at any of our universities.

I would like to close with a mild complaint about the documentation that was provided. It would have been very convenient if there were a summary of funding, publications and other accomplishments for the whole department. It was difficult to get an overall picture since each of the individual dossiers had different formats and contained varying amounts of information. A particular deficiency on a number of them was external funding. One is led to suspect that in those cases there is none or little. Finally, there is repeated material on pages 8 and 14 of the proposal.

Princeton University
School of Engineering and Applied Science
The Engineering Quadrangle
Princeton, New Jersey 08544
609/987-2880

Hisashi Kobayashi, *Dean*
Sherman Fairchild Professor

July 20, 1989

Professor B.P. Clayman
Dean of Graduate Studies
Simon Fraser University
Burnaby, British Columbia
Canada V5A 1S6

Dear Dean Clayman:

This is in response to your letter of June 8, inquiring about my opinion concerning the proposed Ph.D. program in Engineering Science graduate program at Simon Fraser University. First of all, I was somewhat surprised to learn that a Ph.D. program in Electrical Engineering or Engineering Science has not already been offered at your institution. I find the proposed program to be a very solid and viable one, and recommend strongly that it be approved and implemented, in view of the increasing importance of the subject fields to respond to the national and regional needs of Canada.

Your School of Engineering Science corresponds to the departments of electrical engineering in many institutions including ones at Princeton, University of Pennsylvania, etc. The faculty size of 18 is comparable to what we have in our electrical engineering department (although we plan to grow to the level of 25 during the next several years), and a graduate Ph.D. program is feasible, if we focus on selected fields.

The three core areas -- i.e. communications and signal processing, microelectronics, and automation -- are excellent fields to focus on. As a matter of fact, our electrical engineering department also covers three core areas -- information sciences and systems, electronic materials and devices, and computer engineering -- and the first two roughly correspond to the first two in your proposal.

As far as the faculty is concerned, I think that you have a very good group of people in the proposed areas, and the proposed program size -- i.e. 12-14 Ph.D.s per year -- should certainly be manageable. I don't know the size of the undergraduate majors and corresponding loads, but two and a half graduate students per faculty sounds to me a little too modest. If you can attract enough qualified applicants, and the faculty can get sufficient research grants, three to four Ph.D. students per faculty will be more desirable in terms of the research productivity and the effectiveness of the program. There will be no question that the demand for graduating Ph.D.s in electrical engineering will grow enormously internationally. As you know, there is an tremendous shortage of engineers and scientists predicted in the United States. (Please see the enclosed articles from Science and The New York Times.) A real challenge will be whether you can attract a sufficient number of qualified candidates, and secure enough financial resources that will allow the School to compete effectively with other universities in Canada and the United States.

Let me comment on some specifics and raise questions, although they are rather minor issues.

Communications and Signal Processing

My overall impression is that this set of ENSL 800 series courses cover a significantly broad range of communications and signal processing applications, and all the chosen course subjects and their syllabi are relevant and up to date. However, the core curriculum lacks more fundamental and theoretical courses such as "Introduction to Communication and Information Theory" (EE525 in Princeton catalog, p. 249), "Information Theory" (EE528, ibid p. 249), and "Theory of Detection and Estimation" (EE530, ibid p. 249). In fact, if you compare the courses listed in our catalog with those in your proposal, you will notice that we offer much fewer courses in application fields, and perhaps that is our weak point. Nevertheless, I believe it is important to teach fundamental and basic theories followed by some selection of application fields of current interest.

It will be useful to identify some courses in the mathematics and statistics department that may serve as a mathematical foundation for communications and signal processing. For example, courses in probability and stochastic processes, statistical inference theory, real analysis and measure theory. Students should be encouraged to take some of these courses, and you may wish to include mathematics as one of the optional minors.

Microelectronics

I think that the idea of including physics and computer science courses as part of the core courses is excellent. The missing component in this core curriculum is a course on electronics (and optical) materials. The future of microelectronics depends on advances in materials as well as fabrication processing technologies. I am not familiar with contemporary microwave technology, but, to me, photonics and opto-electronics will be more important subjects as a new course.

Automation

The word "automation" sounds rather old-fashioned and unappealing because automation carries a connotation of assembly-oriented manufacturing plants of generations ago. Today's important technologies relevant to system design and manufacturing are machine intelligence, man-machine interface, processing technology, and large systems software. The core courses in the suggested area cover many aspects of the above, whereas the title "automation" implies a rather narrow subject field. I would rather prefer such titles as "Dynamic Systems and Control" and "Intelligent Systems and Control."

Again, the joint listing of related courses of computer science is commended. "CMPT 820-3 Artificial Intelligence" should be worth considering as another course to be listed. As for a new course, this department and the computer science department may want to introduce "Expert Systems Shell and Applications." In order to carry out strong research programs in the "automation" area, researchers have to have a working knowledge of computer systems software. It is not so clear from this menu of courses, how students will have the proper exposure to computer engineering and software aspects.

Additional Remarks

The research facilities described in the document seem reasonable, but graduate study and research facilities largely depend on the scale of sponsored research. The level of sponsored research (government contracts, industry grants, etc.) in the range of $200,000 per year per faculty should be the target for those who are involved in experiments and implementation. The institution has to provide budgets for new spaces, renovation and matching funds for equipment. These costs easily add up to millions of dollars, but the university (and the provincial government) must make such an investment in order to create and develop human resources necessary for the future of Canada and British Columbia.

In closing, I should mention that many of the research activities of the School of Engineering Science fall in the domain of B.C.'s ASI (Advanced Systems Institute) for which I serve as a member of the International Scientific Advisory Board, and with which Professor Thomas Calvert and Professor Nick Cercone are involved as key members. I recommend that the faculty of Engineering Science take advantage of the ASI program as a funding source as well as a source of intellectual stimulation that can be achieved by interactions with other leading institutions and industries in the region.

I am afraid that my comments and remarks might be somewhat off the mark, since I am not familiar with various constraints -- political, historical, resource, etc. -- under which the School of Engineering Science is currently operating. To recapitulate, the proposed program is well prepared and it should be implemented expeditiously. It will certainly strengthen the most important component of your engineering division, and will serve the nation most effectively. I hope that my observations and recommendations will be of some value to you. If you have any questions, I can be reached at 609/987-2880 before September 1, 1989 and 609/258-2880 after September 1, 1989.

Sincerely yours,

Hisashi Kobayashi

HK/cs

Enclosures

rec'd
8 August/89
BPC

NEXUS ENGINEERING CORP.

7000 Lougheed Hwy.
Burnaby, B.C.
V5A 4K4 (604) 420-5322

AUG - 1989
DEAN OF GRADUATE STUDIES

Aug 4, 1989

P.P. Clayman
Dean of Graduate Studies
Simon Fraser University
Burnaby, B.C.
V5A 1S6

Dear Dr. Clayman:

Thank you for your letter of June 8, 1989, requesting comment on the proposed Ph.D. Graduate Program in Engineering Science at SFU.

I strongly support the program concept. I have examined the proposed curriculum and I am quite familiar with the capabilities of the faculty from my many years of association as an adjunct professor with the school.

I very strongly support the focus of the program on communications, signal processing and microelectronics. As the application states, there is a critical shortage in Canada of post-graduate level electrical engineers. The technological platform in radio frequency communications is of vital importance to Canada. Its growth and enhancement will become increasingly limited in the years to come as the demand for new graduates exceeds the ability of the existing programs to supply.

This problem has been exacerbated in the disciplines of microwave and radio frequency communications electrical engineering. The growing sophistication and attractiveness of digital microelectronics has meant that fewer excellent candidates have focused on analog work. Yet the communications industry continues to demand more of these graduates.

As you may know, a task force of key industry executives, university academics, and various departments and agencies of the Federal and Provincial Governments have devoted thousands of hours over the last three years to bring into being the National Wireless Communications Research Foundation. The Foundation's aim is to develop a core of radio frequency communications expertise in Vancouver to further enhance Canada's competitiveness in this key area. One of the key motivations for the development of the Foundation is its capability to significantly add to the pool of trained high frequency and microwave engineers. Thus, the establishment of a Ph.D. program focusing on communications, signal processing and micro electronics will be of great benefit.

I, and other senior executives at Nexus Engineering Corp. have worked Drs. Cavers, Cuperman, Stapleton, and Ingraham and are familiar with the work of the other members of the faculty. With their combined decades of experience in these narrowly focused fields, I believe that there is excellent potential for them to develop skilled graduates.

I believe the faculty is well positioned to market its program effectively and attract the best students. I believe that the presence of an excellent research facility supported by adequately equipped labs, will be an important adjunct to successfully attracting the best students.

As indicated above, the demand for graduates of this program cannot be under estimated. Nexus Engineering could use as many as a dozen Ph.D. candidates over the next five years to expand its core communications research program. Several other companies and research labs in Canada has similar unfulfilled requirements. The Ph.D. graduates will be in heavy demand across the country and particularly here in British Columbia.

I hope the Assessment Committee will carefully consider Canada's need for experience graduates in microwave engineering and support the school of Engineering Science in its proposal to develop a Ph.D. program. If I can provide any further clarification or comment, please contact me at your convenience.

Sincerely,

Dr. J.Basil Peters
Chairman and C.E.O.

JBP/ta

THE UNIVERSITY OF BRITISH COLUMBIA

Department of Electrical Engineering
2356 Main Mall
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October 12, 1989

Dr. B.P. Clayman
Dean of Graduate Studies
Simon Fraser University
Burnaby, B.C.
V5A 1S6

Dear Dr. Clayman:

My apologies for being late with my comments on the Engineering Science Ph.D. program proposal. However, I hope that you and your committee will find the following of use.

The program has merit in that training more Ph.D.'s in electrical engineering is a laudable aim, for the reasons cited in Section II. The courses listed appear to be at a level suitable for Ph.D. candidates, but their focus is extremely narrow. However, as Ph.D. students would be taking only 6 semester-hours beyond M.A.Sc., this should not be viewed as a deficiency in the program. There comes a time when severe specialization is necessary, and it can be argued easily that such a time is during Ph.D. studies. My concern in this regard is that Ph.D. students entering from the S.F.U. Master's program would have already been restricted to this same pool of courses. Their entire graduate-level course background would, therefore, be very narrow. Such an esoteric, as opposed to eclectic, background may pose problems regarding flexibility of choice of future employment. It also means that the demand for S.F.U. Ph.D.'s in Engineering Science is likely to come from a very small and specialized segment of the community.

With respect to the appeal of the program to graduate students, I imagine that, at first, there will be considerable demand. The focus on current "hot topics" will be particularly attractive to students from countries with little development in these areas, e.g. P.R. China. How useful these students will be to Canada, and how good any of the students in the program will be are further questions. Regarding the latter, it is my experience that the best students are good in a variety of areas and like to keep their options open as long as possible. Such students may well find the proposed program emasculating.

The physical resources appear to be adequate for modest research efforts in the areas indicated. The Microelectronics Fabrication facility seems to be rather euphemistically described on page 10. The

.../2

facility is "complete" only in the sense that it can pattern the top level metallization in gate arrays. This is but a small part of the chip fabrication process, so research in the broad area of microelectronics technology could not be attempted in such a facility.

On the human resources side it is most disappointing that so very few of the faculty can offer demonstrable proof of real research activity. The publication (archival papers) records of most of the faculty are very poor, as are the extents of N.S.E.R.C. grants and the numbers of M.A.Sc. students supervised to completion. These are the yardsticks by which Ph.D.-type work is traditionally judged. Instead of concentrating on these, some of the faculty have sought industrial and B.C. Science Council grants, which are geared towards development work. This is an excellent course to follow for M.A.Sc. projects, but where, then, is the evidence of completed M.A.Sc. students? For Ph.D. projects a more fundamental basis is desirable.

To be confident that the faculty could attract high-calibre Ph.D. candidates and administer true, Ph.D.-quality research programs, I would have liked to have seen more evidence of scholarly papers in the last 5-10 years, more M.A.Sc. students graduated recently, and a higher profile in N.S.E.R.C. grants. The latter are often small compared to the sums dispensed by B.C.S.C., but they are only awarded after a very thorough peer review, so that they set a national standard against which research effectiveness or potential can be judged.

Perhaps before Ph.D.-type research programs can materialize one needs Ph.D. students. Therefore, we have to be careful to avoid setting-up a "chicken and egg" or "catch-22" situation. Being aware of this I am inclined to endorse the proposed program, but regret that I can only do so with the reservations expressed in this letter.

Yours sincerely,

D.L. Pulfrey

D.L. Pulfrey, Ph.D., P.Eng.
Professor

DLP/ds

Carleton University
Ottawa, Canada K1S 5B6

October 3, 1989

Dr. B. P. Clayman,
Dean of Graduate Studies,
Simon Fraser University,
Burnaby, B.C.
V5A 1S6

Re: Appraisal of Proposed Ph.D. Program in Engineering

Dear Bruce:

Attached is a copy of my appraisal of the proposed doctoral program in Engineering Science. I hope that it will be useful to you in pursuing the matter of its establishment.

Thanks to you and your colleagues, Bruce, I found my visit to Simon Fraser both enjoyable and informative. There is no doubt that you have a very good doctoral program in the making.

With best wishes,

Yours sincerely,

Bruce Riordon

J. S. Riordon,
Dean of Engineering.

A
Encl.

Office of the Dean □ Faculty of Engineering
Room 360 □ C.J. Mackenzie Building (613) 788-5645 FAX: (613) 788-5682

30October89

SIMON FRASER UNIVERSITY

APPRAISAL OF

PROPOSED PH.D PROGRAM IN ENGINEERING

J. S. Riordon

1. General

Prior to visiting Simon Fraser University, I reviewed the documentation associated with its proposed Ph.D. program in Engineering. Documentation included the proposal with three appendices dated 26 January 1989, with revisions to 16 May 1968. Also included were the resumes of 18 faculty members associated with the program.

The visit to the School of Engineering Science took place on 28, 29 August 1989. At that time additional written information was provided concerning the graduate program. A list of people interviewed is contained in appendix A. I should like to express my thanks to all of those whom I met for their cordiality and openness.

2. University and Faculty Context

a) School of Engineering Science

The administrative context of the School of Engineering Science at Simon Fraser University differs somewhat from that of more conventional Faculties of Engineering. The School is a unit within the Faculty of Applied Science and is not itself subdivided into departments. The first two years are common at the undergraduate level, while six options are offered during the final two years. There are 18 faculty members.

As stated in the 1988/89 calendar, the School envisages the development of three major areas of concentration:

Core A: Computing, microelectronics, communications;

Core B: Industrial automation, control and robotics, computer aided design and manufacturing;

Core C: Chemical and biochemical processing and biotechnology.

At the graduate level the School offers programs leading to the M.A.Sc. and M.Eng. degrees. Although the degrees are not designated as to branch, courses offered are oriented primarily towards electrical engineering, specializing in communications, microelectronics and control systems. To date, four M.A.Sc. students have graduated; two of these are in the communications and signal processing area, two in microelectronics.

b) Cognate Faculties/departments

The nature of the proposed program calls for close cooperation with the School of Computing Science, especially in the areas of microelectronics (VLSI design) and computer graphics. The requirement has been met in part through the placement of that School within the new Applied Science Building along with the School of Engineering Science. This proximity is important, and will prove a valuable ingredient in the continuing cooperation between the two units. It is evident as well that such cooperation is already established in the form of joint research projects and joint supervision of graduate students.

Some cooperation exists with the Department of Physics in the semiconductor area, although it was much less apparent than the Computing Science link. The notable orientation of Physics towards the solid state area suggests that full advantage of cooperative possibilities should be sought by engineering researchers in microelectronics. Joint research with some members of the Department of Mathematics in the areas of communications and controls is a further possibility to be explored.

c) Special features of the program

Features claimed for the program making it "distinct from other Canadian programs in the field" (proposal, page 6) are:

i) strong interdisciplinary emphasis and breadth of knowledge;

ii) strong industrial orientation;

iii) choice of core areas as specialization areas of peak demand.

The authors of the proposal have weakened it by overstating the case. Not only do major departments in large Canadian universities provide broader coverage in the fields chosen, but there exist a variety of interuniversity programs and research consortia engaging the efforts of scores of faculty members in joint academic programs and research. Typically, leading programs of a corresponding nature would involve cooperation between several departments such as electrical engineering, mechanical engineering and computer science.

Similar remarks apply to the matter of industrial involvement. To demonstrate a unique position here would be difficult for any university in Canada, given the success of consortia such as le Centre de Recherche Informatique de Montreal, the Telecommunications Research Institute of Ontario, the Computer Research Institute at the University of Waterloo, the Ottawa Carleton Research Institute, the Alberta Telecommunications Research Centre and the Manufacturing Research Centre of Ontario.

An unusual, if not unique, feature of the program is its organizational structure. In the absence of traditional departmental barriers, an integrated team exists already to address topics which might require the expertise of faculty drawn from different departments, faculties, or even universities in a more conventional environment. This inherently holistic structure is valuable in terms of the integration of research efforts. It is fully effective, however, only with small size. It can probably be maintained with a staff up to double the present number - say, 35 faculty. Beyond that, compartmentalization is extremely difficult to resist.

d) The University View

The successful inauguration of a Ph.D. program in Engineering is seen as an important step in the continuing development of Simon Fraser University. Dr. Ross Saunders, Associate Vice President (Academic), regards it as one of the top two priorities within the University. The intent is to launch the program with three designated specialities, and then to add to these as appropriate in the future under the general banner of the Ph.D. in Engineering.

3. Graduate studies

a) Areas

Three research areas are planned for the Ph.D. program: communications and signal processing, microelectronics, and automation. The first two of these areas fall within "core A" of the faculty's major areas of concentration, while automation falls within "core B". According to the 1988/89 calendar (page 57) "core A is fully operational and the first students have been enroled in core B".

It may be useful to place the research areas in the context of more traditional academic groupings. In these terms, the first two areas lie primarily within the domain of electrical engineering. Communications is of particular importance within the Canadian context, while microelectronics is an underlying feature and driving force in a vast range of modern technologies and enterprises. Automation is by its nature a somewhat more interdisciplinary field, encompassing automatic control, robotics and computer integrated manufacturing. Automatic control theory grew out of electrical and mechanical engineering; much the same theory is found in process control within chemical engineering departments. Robotics lies within the purview of electrical engineering, mechanical engineering and computer science. Computer integrated manufacturing tends to find its home as a discipline within mechanical engineering departments, with some elements relating to electrical engineering, computer science and business.

b) Courses

When the proposed new courses have been introduced, a total of 18 one semester courses will be in place. Two courses, ENSC 800 Linear Systems Dynamics and ENSC 820 Engineering Management for Development Projects, are common to all three streams. In addition to these two, it is planned to offer seven courses in the communications and signal processing area, four in microelectronics and five in automation.

The seven courses unique to the area of communications and signal processing appear to be well chosen to give coverage and a reasonable breadth. Necessarily there is an absence of depth, although this can be compensated for through directed studies courses.

The four courses available specifically in the microelectronics area give a minimal coverage of integrated circuits and solid state devices. These are reinforced by six other courses given in the Department of Physics and the School of Computer Science. The overall result seems adequate.

The area of automation appears to be the least well defined. While the five specialist courses are bolstered by four additional ones from the School of Computer Science, the result is an uneven coverage. There is no course in robotics although there is one on robot vision and another on computational vision. There is little or no coverage of manufacturing methods, including MRP, JIT, machine control, manufacturing databases and flexible manufacturing systems. Some of these subjects may be touched upon in directed studies or special topics courses.

c) Academic Requirements and Regulations

As stated in the proposal, the academic requirements and regulations are generally appropriate. In addition to a fairly rigorous entrance requirement (A- or higher), the student is required to pass a written and oral comprehensive examination and to present a thesis proposal. Each doctoral student is expected to present a research seminar annually within the School seminar series. Doctoral examination procedures and residence requirements will adhere to the general regulations on pages 211-214 of the 1988/89 calendar.

Two observations may be made concerning the comprehensive examinations. First, some concern was expressed that the requirement of three examinations in engineering was out of step with that in computing science, in which five areas must be addressed. Second, the rationale for the requirement that all students write the Signals and Systems examination is not apparent. It is not necessarily central for many students in microelectronics and computer graphics, for instance.

The course requirements for the doctoral program are somewhat light by national standards at six semester hour credits or, assuming lectures of three hours per week, two one semester courses. This is within the normal range found internationally within Faculties of Engineering, however.

d) Coordination with UBC

If this proposal is implemented, there will be two Ph.D. programs in engineering operating within the Vancouver environs. Unnecessary duplication should be avoided and some degree of synergy can be realized through suitable coordination with the University of British Columbia's Faculty of Engineering. As a minimum, such coordination implies some rationalization of course offerings and the ready availability of courses to students at the "other" university. At present, transfer of credits is possible, but there appears to be little active research cooperation between the two universities.

4. Research

In an overall sense, the University's Centre for Systems Science funds a range of projects within Engineering Science and Computing Science. As well, each of the areas in the proposed program undertakes substantial research acitivity on the basis of outside grants and contracts. Fifteen of the 18 faculty members in the School have received external research funding during 1989.

The Communications group is highly respected nationally for its research in mobile radio at both the circuit and system level. Work in modulation techniques and speech encoding is especially notable. Also under investigation is the area of underwater acoustics, particularly appropriate in view of the location. The group has strong ties with external agencies. These include Mobile Data International, Orcatron Manufacturing, Microtel Pacific

Research, Glenaryre Electronics and Nexus Engineering. Total industrial funding over the past five years is well over $600,000, exclusive of NSERC, BC Research Council, etc. During the current year this group has been awarded approximately $460,000 in research grants. Two M.A.Sc. theses have been produced in this area.

With the completion of the new building, the microelectronics group now has a first class facility for simulation, design, fabrication and testing of medium scale integration circuitry. The "quick chip" system, in particular, is an impressive innovation which allows the production of semi-custom chips with a turnaround time of as little as 24 hours. Low temperature research is another area of notable activity. Several members of the group work closely with faculty in the communications area, producing the kind of powerful research and development team which should be encouraged. Microelectronics researchers have received over $550,000 in grants during 1989. On the industrial front there is limited opportunity for local coporate interaction; while there are a number of sophisticated device users and systems integrators in the region (particularly in the communications sector), there is no local foundry. Two M.A.Sc. theses have been produced in this area.

The automation group is concerned with the fields of computer aided design, computer graphics and robotics. A central feature of this work appears to be the application of artificial intelligence methods - to the design process, to the user interface and to computer vision. Automation researchers have received approximately $106,000 in research grants during 1989. There is considerable industrial interaction, but as a group this one is less well defined and mature than those in either communications or microelectronics. No Master's theses have yet been produced in this area.

5. Faculty

This section examines measures of faculty experience, expertise and activity. Before embarking on this, I should like to comment upon the more intangible aspect of facultly morale and attitude. The School is new, and most members with whom I spoke were drawn to it because they see its operation as an innovative departure from that of more traditional institutions. All were enthusiastic, seemed to enjoy their work, and had confidence in the dynamism and leadership of the Director. It is clear that faculty members are proud of the accomplishments of the School, and look forward to the challenge of undertaking a doctoral program. This esprit de corps is a prize beyond price. Whatever immediate shortcomings may be present - and no one is free of them - this attitude augurs well for the future.

a) Number and distribution

The 18 faculty members of the School are equally divided within the ranks of Full Professor, Associate and Assistant. If it is assumed that the effort of faculty jointly involved in more than one area is uniformly divided, then the effective numbers in each area are those shown in table 1.

b) Experience

An extremely important aspect of any doctoral program is the record of the faculty in carrying out research and the supervision of graduate students. Table 2 indicates, for each of the three areas, the number of faculty members who have received major research awards during 1989, the total number of completed Ph.D and master's supervisions (not necessarily at Simon Fraser University), and the number of faculty members with such supervisory experience. For example, all six (equivalent) members of the communications group have received research funding in 1989; between them they have in the past supervised a total of ten doctoral and 44 master's students. All of the doctoral supervisory experience resides with one member, Dean George. The forty-four master's degrees were supervised by 3.5 equivalent members (actually four people: Professors Cavers, Cuperman, George and Hardy, the latter's efforts assumed split between communications and microelectronics). Since all of those with supervisory experience are senior faculty who also have substantial industrial contacts, it can be concluded that the group is strong by the measures used here.

In the microelectronics area, all members have received research awards in 1989. No doctoral supervisory experience resides within the group; three of its members (2.5 equivalent) have some experience supervising at the master's level.

In the area of automation, five of the eight members have received research awards in 1989. Graduate supervision experience, at both the master's and doctoral levels, appears to be concentrated entirely in the person of Professor Calvert, who is also the Vice President (Research and Information Systems) of the University and cannot be considered as full time within the School. Regardless of industrial experience, this does not constitute an adequate basis from which to launch a doctoral program.

Area	Prof	Assoc	Asst	Subtotal
Commun & signal proc	3.5	1.0	1.5	6.0
Microelectronics	0.5	2.0	1.5	4.0
Automation	2.0	3.0	3.0	8.0
Totals	6.0	6.0	6.0	18.0

Table 1: Faculty Distribution

Area	No. funded in 1989	Ph.D.'s Sup'vd	Faculty Sup'vsrs	Master's Sup'vd	Faculty Sup'vsrs
Commun	6.0	10	1.0	44	3.5
Microelect	4.0	0	0.0	5	2.5
Automation	5.0	5	1.0	10	1.0

Table 2: Research Funding and Graduate Supervision

Notes:

1. Faculty numbers are full time equivalent; where a faculty member works in two areas, he/she shows as 0.5 in each.

2. Source of funding data is School's statement on " Major Research Awards Since January 1989", dated 25 August 1989.

3. Source of graduate supervision data is curricula vitae.

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c) Publications and related indicators

The number of faculty in the School of Engineering Science has increased considerably in the recent past as the School has been built up. An effort has obviously been made to obtain recruits with a strong industrial background in many cases. Perhaps as a result of this policy, the publication of refereed journal papers is not a salient feature of research productivity. The publication of papers in high quality refereed conferences is, however, more prevalent and is a better indicator of research activity within the School. Fourteen of the 18 faculty members in the School hold NSERC operating grants. All operating grants are below $20,000; this is low for engineering, and is perhaps associated with the paucity of refereed publications. The situation should improve as the School matures. In the meantime funding from the B.C. Science Council and from industry is strong.

6. Resources

a) Laboratories and Equipment

The School of Engineering Science has recently occupied a new building of approximately 60,000 net sq. ft.; this space is shared with the Schools of Computer Science and of Kinesiology. Laboratories are modern, well laid out and well equipped. Space is entirely adequate for the expansion envisaged in this proposal.

An impressive aspect of the new equipment is the provison of some 70 Sun Sparcstations within Engineering and Computer Science. This major acquisition, made in part through a grant/discount arrangement with Sun Microsystems, will allow each faculty member to have desktop computing power equal to that available from mainframes only about a decade ago.

The SUN network is an important part of the equipment associated with communications. As well, that group has appropriate specialized signal processing hardware and software. An unusual and potentially very useful item is the underwater acoustics test bed.

The microelectronics group has a class 100 clean room. As previously mentioned, this and related facilities allow circuit design and testing as well as fabrication. The laboratory will undoubtedly prove valuable for both instruction and research purposes.

In the area of automation, good facilities exist for computer aided design. The graphics laboratory has an Apollo DN590 workstation in addition to access to the the facilities listed in the next section. Some equipment is also in place for experimental manufacturing and material handling. The latter, while comparable to that found at many Canadian universities, is not yet at the standard required for a doctoral program. For instance, there was no integrated flexible manufacturing cell, and the development of CAM (as opposed to CAD) seemed somewhat embryonic.

b) Computing

In addition to the Sparcstation network and the Apollo CAD workstation previously mentioned, the School has three Apollo workstations of the DN3000 class and 20 Sun 3/Sun 4 machines. These are linked by an ethernet local area network. There are also two PC networks, one available to undergraduate students. For heavier "number crunching", an IBM 3083 mainframe is available, and the School has on site an SGI IRIS 4D/240 dual processor minicomputer. The latter, in its class, is a formidable machine. I would judge the computing power available to be outstanding for the size of the School and the type of research being carried out.

c) Library

Appendix 3 contains a statement from Ms. Sharon Thomas, head of the collections management office of the university library. It is indicated that, to provide "modest but adequate support for core A and B areas" it will be necessary to incur a one time expenditure of $17,500 and a continuing annual cost of $2175 for the purchase of requisite periodicals. On the basis of the comments in appendix 3, I judge this to be an absolute minimum necessary for the support of the proposed Ph.D. program.

d) Support staff

The School has eight administrative and seven technical support staff members. While I did not formally interview any of this group (other than Mr. Richard Fortier, in his capacity as a part time student), I met some of them and was able to observe their handiwork while touring the laboratories. My impression was one of competence, cooperation and dedication. In terms of numbers, the ratio of support staff to students in the School of Engineering Science is substantially higher than average across the country. In this area, the School is indeed well served.

e) Student/faculty ratio

In the proposal (page 12) it is stated that the target for steady state graduate enrolment is "about 2 1/2 graduate students per faculty member, of whom about 1/3 would be Ph.D. students." With 15 or 16 of the 18 faculty members active in research, the objective is 12-14 Ph.D. students. The academic load which can be carried by a faculty member depends upon the total weighted student/faculty ratio, including both undergraduate and graduate, as well as the number of assistants. At the undergraduate level, the first year intake is approximately 50 students annually. Assuming some attrition, this means that the student/faculty ratio is less than 10:1. A typical faculty teaching load in the School is one course per semester for two semesters per year; this compares with a more typical Canadian average in the vicinity of 1.5-2.0. On the assumption that the faculty load associated with an M.A.Sc. student is double that of an undergraduate, and that of a Ph.D. student triple, the overall equivalent student/faculty ratio is about 15:1. This is lower than the typical level in many Canadian Engineering Faculties of 20-25:1. On the other hand, it was indicated that the School uses only a small number of teaching assistants; this factor will tend to increase the faculty contact time with undergraduate students - an effect which is both necessary and highly desirable. It can be concluded that faculty numbers are fully adequate to handle the program envisaged.

7. Students

As previously noted, four M.A.Sc. students have graduated to date. This number should soon increase considerably, as there are now 21 master's students enrolled in the program. The School is thus close to its stated steady state enrolment of 25-30 M.A.Sc. candidates.

Over 90% of full time engineering graduate students hold research assistantships, and a wide range of scholarships and fellowships is available. Relatively few students hold teaching assistantships. Providing that overall funding is adequate (and it seems to be so), this circumstance is probably an advantage to most students,and should allow them to complete their degree requirements more rapidly than would otherwise be possible.

Two graduate students (and one part time undergraduate) were interviewed. Both were studying in the communications field; they were happy to have made the choice of Simon Fraser for graduate work. The only concern which arose was the relatively small choice of courses available. Each was fairly confident of getting employment locally; however, they considered that local job prospects in microelectronics and automation were not as good as those in communications.

8. Demand

Demand occurs at two points: at the entry, demand for the program by prospective students; and at completion, demand for the graduates by society (ususally in the form of employers). Entry point demand cannot be gauged with certainty until the program is actually offered. However, demand for the current M.A.Sc. program is a fairly good indicator of potential demand for the Ph.D. program. The former is strong, and student numbers at the master's level have grown rapidly. There is every reason to believe that the doctoral program would similarly meet its enrolment targets with highly qualified students.

Societal need for graduates with advanced degrees in the fields under consideration is very strong indeed. The case has been well put in the program proposal, and needs little elaboration. Canada is in a crisis situation with respect to the supply of highly qualified engineers in research, design and manufacturing, not to mention marketing and sales. As a country we are facing intense industrial competition from the United States, Europe and southeast Asia. Our performance in this arena will have a substantial effect on the standard of living of the next generation of Canadians.

All of these points would be blunted with respect to this program if there were much excess capacity in other comparable ones elsewhere. In fact this is not the case. While graduate enrolments fluctuate, most other Canadian graduate engineering programs are limited, at least in part, by the availability of resources. The infusion of resources by Simon Fraser University to mount the Ph.D. program in engineering is thus particularly timely and appropriate from the demand viewpoint.

9. Recommendations

It is recommended that:

a) the proposed Ph.D. program in Engineering be offered in the fields of communications and microelectronics. In the case of microelectronics, engineering doctoral supervisions should initially be carried out jointly with faculty members drawn from communications, from the School of Computer Science or from the Department of Physics.

b) offering of the Ph.D. program in the field of automation be delayed until faculty members have attained collectively a satisfactory degree of experience in supervision at the M.A.Sc. level. Such a condition might be reached when, for instance, more than half of the members of the group had successfully supervised several master's theses. Prior to that time, members of the automation group should be encouraged to act as co-supervisors, where appropriate, of doctoral students whose primary research and supervision derives from the School of Computer Science or the communications group.

c) the School of Engineering Science take full advantage of joint research with cognate departments. In addition to Computer Science (which is already closely allied) further possibilities may exist with the Departments of Physics and of Mathematics.

d) the School consider increasing the range of courses offered at the graduate level. This may mean that some courses are not offered every year. Full advantage should be taken of the availablity of suitable sessional lecturers from the outside community.

e) the School of Engineering Science seek to re-examine with the School of Computer Science the comprehensive examination requirements, with a view to the development of a policy which is consistent between the two jusisdictions.

f) the School re-examine the question of whether the course in Signals and Systems is an appropriate requirement for all of its doctoral students.

g) the School consider the possibility of closer coordination of its graduate program with those of related groups at the University of British Columbia.

10. Conclusions

The School of Engineering Science is impressive. Its faculty members have a wide range of engineering experience, and approach their work with diligence and enthusiasm. Its students at both the graduate and undergraduate levels are academically strong. Facilities are first rate. Advantage is taken of the joint interests of Engineering Science and Computer Science. Solid links exist between the School and the community. Within the university, the School of Engineering Science deservedly enjoys the confidence of senior members of the administration.

The School is moving rapidly and ambitiously to establish a doctoral program in three areas. To ensure success in this venture, the introduction of this program must be paced. One area, communications, has clearly reached the required level of maturity and recognition. It is ready to go forward. A second, microelectronics, is poised on the brink. It is ready, with a little help. The automation group is still in its formative stage. Here the School should avoid rushing its bridges, and concentrate in the near term on the establishment of a sound M.A.Sc. program. In the long run this approach will help ensure a high reputation and continuing success.

APPENDIX A

INTERVIEWS

During the course of my visit on 28, 29 August 1989, I had the opportunity of speaking to the following people:

Dr. Donald A. George, Director, School of Engineering Science and Dean, Faculty of Applied Sciences

Dr. Ross Saunders, Associate Vice President (Academic), Acting President

Dr. James K. Cavers, School of Engineering Science

Dr. Bruce Clayman, Dean of Graduate Studies

Dr. John C. Dill, School of Engineering Science

Mr. Ian Radziejewski, MASc student

Mr. Henry Li, MASc student

Mr. Richard Fortier, staff member and part time undergraduate student, Engineering Science

Dr. John D. Jones, School of Engineering Science

Dr. Paul Ho, School of Engineering Science

Professor Ze-nian Li, School of Computing Science

Dr. Steve Hardy, School of Engineering Science

Dr. M. Sryzycki, School of Engineering Science

Dr. Jamal Deen, School of Engineering Science

Dr. Rick Hobson, Director, School of Computing Science

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August 2, 1989

Dr. B. P. Clayman
Dean of Graduate Studies
Simon Fraser University
Burnaby, B.C.
V5A 1S6

Dear Dr. Clayman:

I have looked through the material as requested on the proposed Ph.D. program in Engineering Science. As I mentioned in my earlier letter, I have difficulty in assessing this program as only two of your Professors have a Mechanical Engineering background; namely, Dr. John Dewey Jones and Dr. Tad McGeer. Therefore, I would suggest that you ask Dr. Yuri Stepanenko from the University of Victoria for an assessment. He is a specialist in robotics and could comment more on the program than myself. Meanwhile, I would like to make a few comments which you might find useful on the Professors who have a Mechanical Engineering background:

Professor J. D. Jones: he has worked extensively in Heat Transfer Engineering and has explored extensively Heat Transfer in Stirling Engines. He has a good publication record over the last three years, and has also acquired expertise in numerical methods. I consider Professor Jones as having a good record, and I believe that he could contribute to your Ph.D. program. I believe that his expertise is not on the main line of the presently proposed program. However, he has acquired expertise in numerical methods as reflected in some of his publications, and this certainly would be a contribution to the overall efforts.

Dr. Tad McGeer: he has a very good background from Princeton and Stanford Universities; his background was in Aeronautical Engineering, and later in his career he switched to Robotics. At this stage, we probably should assess Dr. McGeer more on promise that on his achievement, as he is still very young and has not spent enough time in the field of his recent interest. He seems to be active and I feel very sure that he is going to be a valuable contributor to your University.

In general terms, I make the following two comments:

1) I consider as a positive feature, the fact that many of your faculty members have industrial experience. This is healthy and reflects positively on Engineering Education.

2) I do have some concerns on the breadth of the field that this Ph.D. program proposes to address, as the critical mass of high academic achievement in the field does not seem to be there yet. I believe that more faculty addition with significant academic strengths would be needed before addressing all the fields of research proposed in the present program.

I want to underline again my latest comment, that you should rely more on Electrical Engineering expertise which you call in, as well as on Dr. Stepanenko who is in the field of research which one part of this program is proposed.

Yours sincerely,

Martha Salcudean

Dr. Martha Salcudean
Professor and Head

/hb
encl.

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Toronto, Canada M5S 1A4

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VIA FAX: (604) 291-3851

October 19, 1989

Dr. B. P. Clayman
Dean of Graduate Studies
Simon Fraser University
Burnaby, B.C.
V5A 1S6

Dear Dean Clayman:

This is a very late response to your request of June 8, 1989 regarding the evaluation of the proposed Ph.D. program in Engineering Science. Please accept my sincere apologies for this tardiness.

I have read the proposal and examined the supporting material provided. In the following I will attempt to respond to the four specific points raised in your letter and then draw conclusions:

- The academic merit and structural integrity of the proposed program, including possible implications of its relatively narrow focus.

The proposed program is academically sound and provides the intellectual challenge one expects in a doctorate program. Indeed, it is somewhat narrowly focussed. However, I consider this to be an advantage. The Faculty of Engineering at Simon Fraser is relatively small and therefore it makes a great deal of sense to offer a quality program in a carefully selected area rather than attempting to cover in a necessarily mediocre way the entire field. In fact, I would have preferred an even narrower focus. The proposed program appears to have structural integrity. However, I could not easily determine whether there will be a residency requirement. If this aspect is still under consideration, I would strongly recommend a residency requirement; there is an "academic apprenticeship" aspect to getting a doctorate and the only way to achieve this is by becoming totally immersed in the university environment. (Doing the work in industry simply would not do!).

- The adequacy of the faculty and of other resources available to the proposed program for achieving its intended goals.

The faculty, though small in number, are an impressive group They certainly have the credentials to supervise Ph.D. candidates. Dean George has an outstanding record of achievement, both as an engineering scientist and as an academic leader. There is no doubt in my mind that under his leadership the proposed program will succeed and flourish. I am also impressed with the industrial connections the academic staff have. Other resources appear to be adequate.

• The demand for the proposed program among prospective students:

The areas of concentration of the proposed program are currently very popular among students and should remain so for sometime. Also, the number of students contemplated is relatively modest and there should be no difficulty in attracting qualified candidates.

• The demand for graduates of the proposed program.

I agree wholeheartedly with the points made in the proposal regarding demand for graduates. The areas covered by the program are of strategic importance to Canadian industry. Also, there will be a severe shortage in the next two decades of qualified personnel to replace the retiring professoriate in Canadian (and indeed North American) engineering schools.

In conclusion, I believe that you have a good proposal. I would like to see this program in place soon and believe that its establishment will serve the interests of Simon Fraser University, of British Columbia and of Canada.

If you need further clarifications, please do not hesitate to call or write.

Yours sincerely,

Adel S. Sedra

Adel S. Sedra
Professor and Chairman

/msk

APPENDIX 6

Response to Reviewers' Comments

RESPONSE TO REVIEWERS

OF THE ENGINEERING SCIENCE PH.D. PROPOSAL

CONTENTS

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RESPONSE TO REVIEWERS

OF THE ENGINEERING SCIENCE PH.D. PROPOSAL

1. General Remarks

The PhD proposal was sent to seven external reviewers, numbered conveniently from 2 to 8:

2: V.K. Barghava, University of Victoria
3. J. Hayes, Concordia University
4. H. Kobayashi, Dean of Engineering, Princeton
5. B. Peters, President, Nexus Engineering
6. D.L. Pulfrey, University of British Columbia
7. J.S. Riordan, Dean of Engineering, Carleton University
8. M. Salcudean, Head of Mechanical Engineering, University of British Columbia

Reviewers 4 and 5 strongly supported the proposal. Reviewer 7 also supported it, and made specific recommendations for ways to strengthen it. Reviewer 3 was less positive. Reviewer 6 was quite negative, but misguided. Reviewers 2 and 8 did not have much to say.

This document addresses the issues raised by the reviewers. Where their concerns are legitimate, we have modified our proposal, as described below. Some criticism, though, was based on out-of-date information; our school is evolving rapidly, and information from 1988 is no longer a good indicator of research activity. In other cases, we feel the comments are simply incorrect in principle.

We have organized our response by dealing first with issues raised by several reviewers: the automation option, the course structure and the quality of our faculty. A response to each review follows.

2. The Automation Option

Reviewers 4 and 7 identified the automation option as a weakness of the proposal. We agree - the resources are not available to provide course and supervision support across the spectrum of automation research. We propose to rename this option "Intelligent Systems and Control", or ISC, as suggested by Reviewer 4. This is a rather more specialized designation, and it better reflects our original intent. It recognizes the fact that a small research group in Engineering Science is already active in the area, and requires doctoral students to flourish.

Some members of this group have not previously supervised PhD students. We will ensure that any supervisory committee has at least one member with doctoral supervision experience, drawn from Engineering Science or an appropriate discipline such as Computing Science. Moreover, we will keep the number of such students low initially, while the group gains the experience. Finally, no one will attempt to supervise a doctoral student without prior supervision experience at the Master's level. Note, however, that we have no concerns regarding the group's research ability, or its record in supervising industrial research projects.

Finally, we should have noted in our original documentation that we have a faculty position open, and are actively recruiting, for a senior person in the area of Intelligent Systems and Control. We expect this person to add both strength and academic experience to the group.

3. The Course Structure

Reviewers 3 and 4 pointed to an apparent lack of fundamental courses in the communications and signal processing area. Reviewer 7 noted the breadth, and commented that the depth could be achieved through directed studies courses. This was, in fact, our intent. We do not expect to have large numbers of doctoral students. Rather than establish a second tier of of underpopulated and seldom offered courses, we planned to offer more specialized material through directed studies, batching students where possible. It is worth noting here that the university minimum requirement for doctoral students is zero courses.

One misconception, held by at least Reviewer 3, is that students can take any of our courses, at whatever level and in whatever area, at his or her discretion. On the contrary, we stated that courses are selected in consultation with the Senior Supervisor.

The apparent narrow range of our courses attracted comment from Reviewers 2, 4, 6 and 7. In fact, though, graduate courses in physics and computer science are natural companion courses, especially in interdisciplinary areas such as microelectronics and ISC.Suggested courses are listed in the Engineering Science entry in the calendar. In addition, as noted above, much of the specialized material will be offered through directed studies.

ENSC 800, in particular, attracted criticism from Reviewer 3. We also have had some difficulty with the course. Its original objectives were to provide a unified treatment of analytical models taught in a fragmentary fashion at the undergrad and first graduate level, and to bring some of the older M.Eng. students back into analysis after some years in industry. These goals were somewhat incompatible, and the course contained too much material. Moreover, all the older students who would benefit from such a course are already in the M.Eng. program. We have therefore split ENSC 800 into two courses, ENSC 801 Linear Systems Theory and ENSC 801 Stochastic Systems, in which the material is clearly graduate level. They are comparable to standard courses in the graduate curriculum of other Canadian schools. They provide a stronger base on which to offer directed studies courses in, for example, applied estimation and information theory.

4. Ability of Faculty to Supervise Doctoral Students

Several reviewers (3, 6, 7 and 8) noted the low level of publications and NSERC operating grants among the faculty, and some of them questioned our ability to supervise PhD students. It is clear that none of them has had the experience of building a new school; although it is exciting, it is a time-consuming business, which takes its toll on publication records. However, the curriculum and procedures have begun to stabilize, and the number of publications has risen sharply, even since the time the original proposal was prepared. Appendix A lists very recent publications. It is already a respectable record, and is certain to improve further.

Appendix B lists very recent research grants and contracts. Our faculty won over $1.6 million for 1989 alone, which we view as an enviable record, especially for so young a school. In fact, of the 69 Science and Technology Development Fund grants awarded in 1989, two of the three largest came to the School of Engineering Science. We take strong exception to the suggestion of Reviewer 6 that BC Science Council grants, because of their industrial linkage, are an inappropriate basis for PhD projects. This remark reveals in a nutshell all that is wrong with engineering studies in many Canadian schools, and all that we are trying to counter with our own program.

We admitted our first M.A.Sc. student in 1986, and 6 have now graduated (see Appendix C). The current enrolment is 18. By the time the PhD program is in place, most of our faculty members will have had the experience of supervising graduate students.

We cannot help contrasting our experience in this proposal with that of the University of Victoria's school of engineering. UVic was allowed to offer all three degrees - bachelor's, master's and doctorate - at the time they began operations, before they had even hired faculty members. In contrast, we have proceeded conservatively, adding each new degree as we gained experience with the lower levels - yet we have to defend our ability to mount a PhD program.

5. Responses to Individual Reviewers

Reviewer 2

Reviewer 2 suggested new courses in signal processing/communications and in control/robotics. The new ENSC 801 and 802, as well as directed studies courses, will add strength in the communications area. In control, we have recast the material in ENSC 883 as optimal control theory. We also expect the new faculty member to prepare additional courses in the control area.

Reviewer 3

Reviewer 3 felt that our courses are at too low a level. We discussed this issue in Section 3.

We have also dealt separately (Section 4) with the reviewer's concerns regarding the quality of our faculty.

We have to agree with his complaint about the inconsistent format of the documentation we provided. Appendices A and B, which list the publications and research funding of the department, should remedy the greatest deficiency.

Reviewer 4

We have responded in Section 3 above to Reviewer 4's more general comments regarding courses. We are also acting on two specific suggestions: first, that we explicitly cross reference CMPT 820-3 Artificial Intelligence and other out-of-department courses; and second, that we name the automation option more accurately (see Section 2).

We agree with the target of $200,000 research funding per faculty member. We are at about half that figure in 1989, but we believe the goal is achievable.

Reviewer 5

Reviewer 5 supported the proposal enthusiastically. We feel he was right to do so.

Reviewer 6

This is a difficult review to deal with. Many of the remarks were surprising, some were misinformed, and some were just wrong.

First, the issue of narrow focus. We do not claim to offer doctoral studies in every area of research. However, our three areas - communications, microelectronics and intelligent systems and control - are complementary, and offer students a good opportunity to explore alternatives. It is also our experience that students undertaking a degree in established schools, even at the master's level, normally select an area of specialization and do not stray too far afield. Finally, we do not anticipate problems in the employment of our graduates!

The third paragraph speaks for itself:

> The focus on current "hot topics" will be particularly attractive to students from countries with little development in these areas, e.g. P.R. China. How useful these students will be to Canada, and how good any of the students in the program will be are further questions.

The fourth paragraph, claiming poor microelectronics fabrication facilities, is inverted reasoning. QuickChip is a facility unique in Canada and, we suspect, in North American universities. It opens the door

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to integrated sensors and micromachines, as well as to semicustom integrated circuits. An industrial firm is presently turning it into a product, and we expect several sales to other universities around the world. As for the fabrication process itself, we have access to a good facility just six minutes walk away, through our close links with Microtel Pacific Research.

Finally, we have dealt with the issue of the quality of our faculty earlier, in Section 4. The "evidence of completed M.A.Sc. students" is in Appendix C.

Reviewer 7

Reviewer 7 provided a detailed and thoughtful critique. We will respond to his comments consecutively, identifying them by his page number.

p. 2: "The authors of the proposal have weakened it by overstating the case". We agree. It is not that our claimed features are wrong, it is simply that our proposal is not "distinct from other Canadian programs in the field", as we incorrectly stated.

p. 4: Courses. Section 3 above dealt with courses. In particular, it noted that we rely on directed studies and special topics courses to make up gaps. The ISC option is no exception. After hiring a new faculty member in the area, we expect to put forward additional courses in control.

p. 5: Paragraph 2, regarding comprehensives. While it it true that Computing Science requires five examinations, to our three, we do not feel the need for identical requirements. In any case, the scope of the examinations may differ.

p. 5: Coordination with UBC. We also feel that cooperation, if not coordination, is desirable. As a first step, the two universities currently offer transfer credit on an informal basis for students taking courses at the other university. This further expands our pool of courses.

p. 7: Last paragraph, supervision experience in the ISC option. As noted in Section 2 above, we have a plan by which we can "bootstrap" into doctoral supervision by drawing on more experienced faculty members in Engineering science and other departments.

Reviewer 8

Reviewer 8 was concerned that the proposed scope of the program would be too ambitious, as "the critical mass of high academic achievement in the field does not seem to be there yet", both in faculty numbers and individual achievement. We assume the comment was directed to the ISC option, as the reviewer is a mechanical engineer. Again, we have outlined in Section 2 how we propose to enter the area cautiously. As for faculty numbers, we will be hiring another into ISC.

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Appendix A: Publications Since January 1988

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SCHOOL OF ENGINEERING SCIENCE

SIMON FRASER UNIVERSITY

PUBLICATIONS IN REFEREED JOURNALS SINCE JANUARY 1988

Cavers, Jim and Ho, P. "Analysis of the Error Performance of Trellis Coded Modulations in Rayleigh Fading Channels", to appear IEEE Trans. Communications, 1990.

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Stapleton, S. P. "Microwave Landing Systems, MMIC, Phase Shifter and Amplifier", TRL Microwave Technology Inc., for the Department of Communications, pp. 1-45 August 1988.

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Appendix B: Research Grants and Contracts Since January 1988

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SCHOOL OF ENGINEERING SCIENCE

Research Awards Since January 1989

Updated: November 23, 1989

NAME	AWARD	AMOUNT
J. Bird	NSERC Operating - 2nd Installment	18,100
J. Bird	ASI Fellow - 1st year of 3	35,000
J. Bird	DND Contract - 1st year of 3	60,000
J. Bird D. George S. Hardy	CSS "Communications Backbone for Underwater Sites"	62,000
J. Cavers	NSERC Operating - 3rd Installment	11,100
J. Cavers D. George S. Stapleton	BC Science Council - STDF	299,305
J. Cavers	ASI Senior Fellow - 1st year of 3	70,000
V. Cuperman	NSERC Operating - 2nd Installment	17,300
V. Cuperman P. Ho	BC Science Council - 2nd Year	67,692
V. Cuperman P. Ho	CSS "Integrated Speech Codecs for Telecommunications"	52,000
J. Deen	NSERC Operating - 3rd Installment	13,100
J. Deen J. Bird S. Hardy R. Hobson A. Leung S. Stapleton M. Syrzycki	NSERC Equipment Grant	85,723
J. Deen et al (above)	CSS Matching Grant for NSERC Equipment Grant	28,574

NAME	AWARD	AMOUNT
J. Deen S. Hardy S. Stapleton	CSS "Devices-Networks for High Speed"	46,000
J. Deen	Research Grant - Northern Telecom	30,000
J. Deen S. Hardy S. Stapleton	Special Research Projects, SFU	15,000
J. Deen S. Hardy S. Stapleton	President's Research Grant, SFU	4,160
J. Dill	NSERC Operating - 2nd Installment	14,000
J. Dill	BC Science Council - 2nd Year	43,700
J. Dill T. Calvert	CSS "Design Study Group"	20,000
J. Dill T. Calvert	BC Science Council "Building Design System" (Panabode)	48,000
J. Dill T. Calvert R. Baecker	NCE Iris Proposal "Human Interface Node)	70,000
J. Dill M.P.R. J. Dickinson D. Ingraham	Precarn Feasibility Study	98,000
K. Gupta	NSERC Operating - 2nd Installment	15,400
K. Gupta T. Calvert Z.N. Li	Western Softworks "Range Imaging"	22,000
K. Gupta	Coinvestigator - NSERC Equipment grant with T. Calvert, Z.N. Li	45,526
S. Hardy	NSERC Operating - 1st Installment	10,000
S. Hardy	BC Science Council-MART	11,200

NAME	AWARD	AMOUNT
S. Hardy S. Atkins	BC Science Council Grant	63,500
S. Hardy S. Atkins	CSS Matching Grant for BC Science Council Grant	21,167
S. Hardy P. Ho S. Stapleton	CSS "Performance Enhancement to Digital Mobile Communiations Networks"	40,000
S. Hardy	CSS "Data Communications over Mobile Radio"	22,000
P. Ho	NSERC Operating - 3rd Installment	18,000
D. Ingraham	Rick Hansen Man-In-Motion Legacy Fund	42,300
D. Ingraham	NRC IRAP - S.F. Univentures	10,408
D. Ingraham	NRC IRAP - Incubation Project	9,500
D. Ingraham	Coinvestigator with Softwords-Press Porcepic Ltd Canadian Space Program Stear Project Smart Sim Trainers	5,000
D. Ingraham	Coinvestigator with Softwords-Press Porcepic Ltd ASI Smart Sim Trainer	5,000
J. Jones	NSERC Operating - 1st Installment	11,500
J. Jones T. Calvert J. Dill W. Havens	CSS "Improved CAD"	25,000
A. Leung	NSERC Operating - 1st Installment	17,050
A. Leung	BC Science Council - STDF	264,050
A. Leung R. Frindt R. Morrison	CSS Research Grant	6,000
A. Leung	CSS "Quick Chip"	17,500
T. McGeer	NSERC Operating - 1st Installment	12,551

NAME	AWARD	AMOUNT
T. McGeer K. Gupta Z.N. Li	CSS "Yama"	40,500
A. Rawicz	BC Science Council - AGAR	40,000
A. Rawicz M. Syrzycki	CSS "IC Reliability Studies"	31,500
A. Rawicz	Presidents Research Grant, SFU	4,160
M. Saif	NSERC Operating - 2nd Installment	10,000
M. Saif	CSS "Fault Management Control"	23,000
M. Saif Intn'l Submarine Engineering (E. Jackson)	BC Science Council Grant	31,500
S. Stapleton	NSERC Operating - 1st Installment	19,180
S. Stapleton	CSS Research Grant	9,000
M. Syrzycki	NSERC Operating - 1st Installment	12,790
M. Syrzycki	CSS "Integrated Cells for Receptive Field Implementation"	7,000

Centre for Systems Science
SIMON FRASER UNIVERSITY
Matching Funds Summary

1990/91 fiscal year

Proposer	Agency	Grant Type	Request	Awarded	CSS Matching	Total
S.P. Stapleton Eng. Sci.	NSERC	Equipment	$200,000		$50,000	
McGeer et al. Eng. Sci.	NSERC	Strategic	$146,000		$36,500	
A. Rawicz M. Syrzicki Eng. Sci.	Med. Res. Council	Univ-Indus. Collaborative	$140,000		(B listed $35,000)	
M.J. Deen S. Hardy Eng. Sci.	BCSC	STDF	$180,000		$45,000	
S. Hardy S. Atkins Eng. Sci.	BCSC	AGAR	(2nd yr)$84,667		$21,167	
A. Leung M. Parameswaran Eng. Sci.	BCSC	STDF-AGAR	$100,000		$25,000	
K. Gupta Eng. Sci.	NSERC	Equipment	$60,000		$15,000	
T. Calvert J. Dill Eng. Sci.	NSERC/ SSHRC/MRC	Centres of Excellence	$93,867		$23,467	
T. Calvert et al. Eng. Sci.	NSERC	Equipment	$94,000		$23,500	

CSS Matching Total: $239,634

**Please note: the amount requested from the external agency includes the CSS portion for matching funds.

Appendix C: M.A.Sc. Graduates and Current Students

M.A.SC. STUDENTS - GRADUATED

SUPERVISOR	NAME	THESIS TITLE
BIRD, J.	GOULDING, Marty	Speech Enhancement for Mobile Telephony
CAVERS, J.	LI, Henry W.H.	Adaptive Filtering Techniques for Tone Aided Transmission Systems
CUPERMAN, V.	WATTS, Lloyd	Vector Quantization and Scalar Linear Prediction for Waveform Coding of Speech at 16kb/s
DEEN, J.	JAGGI, Bruno	Design of a Quantitative Microscope for Image Cytometry Using a Solid State Detector in the Primary Image Plane
DEEN, J.	WANG, Jing	Analysis and Characterization of Small Geometry PMOS Devices at Cryogenic Temperatures
RAWICZ, A.	XIE, Zi Wei	Investigation of Thermal Mapping Methods on Integrated Circuits

CURRENT M.A.SC. STUDENTS - FALL 1989

SUPERVISOR	NAME	AREA OF RESEARCH
BIRD, J.	HORVAT, Dion	Communication - Theory and Design
BIRD, J.	RADZIEJEWSKI, Ian	Underwater Communication
CALVERT, T.	FU, David	Image Processing Graphics, Pattern Recognition
CUPERMAN, V.	BUDDHIKOT, Milind	Digital Signal Processing
CUPERMAN, V.	CHEN, Xiangyang	Quantization in Speech Coding
CUPERMAN, V.	COSSETTE, Louis	Digital Communication
CUPERMAN, V.	PETTIGREW, Robert	Signal Processing Mobile Communication
CUPERMAN, V.	YANG, Guowen	Mobile Communication
DEEN, J.	LI, Xiaoming	Device Electronics
GUPTA, K.	ZHU, Xiaoming	Machine Visions and Robotics
HO, P.	FUNG, Dominic	Signal Processing Mobile Communication
HO, P.	WU, Yan	Communications and Signal Processing
INGRAHAM, D.	SKYE, Doug	Manufacturing Information and Control

SUPERVISOR	NAME	AREA OF RESEARCH
RAWICZ, A.	HUANG, Xiao Jian	Reliability Theory
SAIF, M.	GUAN, Yuping	Control Theory
SAIF, M.	HU, Zhowgzhi	Control Theory
STAPLETON, S.	KANDOLA, Gurmail	R. S. Communication
SYRZYCKI, M.	GRIGOLEIT, Mark	Communication System