MPORU NEWSLETTER

Medical Physics Organized Research Unit
Physics Department, Carleton University

Editor: Carl Ross

Number 5, June 1993

Contents

1. The MPORU

In the fall of 1989, an Organized Research Unit (ORU) was formed at Carleton University to encourage communication among those working in medical physics within the Ottawa area and to help coordinate the graduate studies program in medical physics at Carleton. The ORU was named the Medical Physics Organized Research Unit, or MPORU, and eight objectives were defined. These were:

1. To promote basic and applied research in those fields of medical physics in which there is local strength, in conformity with the research objectives of the institutions involved.
2. To advise the Carleton University Physics Department and the Ottawa-Carleton Institute of Physics on matters of medical physics.
3. To develop collaborative research activity in these fields.
4. To promote graduate studies in medical physics.
5. To facilitate graduate student placement with a supervisor who is a member of the ORU.
6. To develop laboratory facilities for medical physics.
7. To encourage funding from government and from private agencies.
8. To organize seminars, meetings and other forms of communication among the members.

Membership in the MPORU is by invitation of the three-member Executive. Members are expected to be involved in teaching, research or the supervision of graduate students. The main method for the exchange of information among MPORU members is via the monthly seminar series, in which both graduate students in medical physics and MPORU members are invited to make presentations.

2. A Note from the Director

This has been another busy and productive year for the Medical Physics Organized Research Unit (MPORU). It has been its fourth year of operation and the number of graduate students has continued to grow as well as the membership of the MPORU. In spite of the difficult economic times and the increased competitiveness of peer review funding the members of the MPORU were able to maintain their grant funding and even increase it in the last year. This contributed to an increased research effort as well as an increased number of research students in the various research projects. These collaborative research efforts have resulted in new and exciting findings which are contributing directly to aspects of the Canadian health care industry as well as medical programs within hospitals.

The spring of 1993 was also the culmination of a great deal of effort of the medical physics community in Ottawa. It was the hosting of the meeting of the Canadian Organization of Medical Physicists and the Canadian College of Physicists in Medicine in

combination with the Canadian Medical and Biomedical Engineering Society meeting in Ottawa. A large amount of work went into this organization and above all the Chairman of the Medical Physics Organizing Committee, Paul Johns, put a large amount of effort into making this meeting a success. It was indeed a success. A large number of attendees, in excess of 300, were at the meeting. Also a large number of medical physics abstracts, in excess of 70, were received and presented at this meeting. The quality of science was excellent and resulted in much interest and discussion. In addition, the meeting was also supported by many commercial exhibitors who put their goods on display. There was also a joint symposium day on lasers in medicine. Many excellent speakers presented the latest in various aspects of lasers in medicine. This symposium was heavily attended by both medical physicists and biomedical engineers and turned out to be an unmeasured success. I wish to thank all members of the medical physics community and of the biomedical engineering community that devoted their efforts to making this meeting such a success. It has certainly put Ottawa on the map and has shown that there is a significant academic and research program in Medical physics ongoing in the medical physics community in Ottawa.

One of the key functions of the MPORU is to provide a stimulating academic environment for Medical physics graduate students. The members of the Medical Physics Organized Research Unit are committed to providing excellence in the teaching of graduate students and ensuring that high quality Medical Physicists will be available for the future. Consistent with this effort, many of the Medical Physicists within the MPORU have dedicated a significant amount of time to teaching graduate courses. I wish to thank all of these members for their efforts which have contributed to excellence in the large number of graduate courses being taught and providing a reputation throughout Canada for the quality of the Medical physics academic program within the MPORU. It is no small achievement that six courses in Medical physics are being offered at the graduate level, and two courses in Health Sciences are available to our students. These courses provide a good solid basis and background for the graduate students interested in Medical physics.

Throughout the year many specific activities have contributed to the success of the MPORU and some of these are highlighted below:

1. Two new peer reviewed grant proposals have been received.

2. Several graduate students received graduate student fellowships.

3. Our second Ph.D. student graduated from the program.

4. One new member joined the MPORU.

5. The successful hosting of the joint COMP, CCPM and CMBES meeting in Ottawa.

6. The development of a new course, Medical Physics Practicum to help the graduate students get hands-on practical experience in the medical physics field.

These and many other accomplishments which are outlined in the newsletter have helped to make 1992/93 another successful year and indicate that the MPORU is still rapidly moving forward. It is the interaction and collaboration of its many members that make this type of effort and success possible.

It is the participation of members from many disciplines and many institutions that provide the strength of the MPORU. Without this support and collaboration between many individuals the efforts described in this progress report would not have been possible. I

wish to deeply thank the institutions who have participating members for their participation and contribution of these resources into our program. Together we provide an important contribution to the next generation of medical physics specialists in industry, academics, and research. In fact, the recent announcement of the life sciences effort in Ottawa supported by both the provincial government and the city of Ottawa provide further opportunities for collaboration and our contribution of medical physics graduate students and graduates to participate in that program. Lastly, and most importantly, I wish to thank all members of the MPORU who have put their energies into making this another successful year for the MPORU. Considering the activity and the commitment of the members I do not doubt that we will continue to grow and that 1994 with its challenges will provide another exciting year of medical physics activity.

Peter Raaphorst
Director, MPORU

3. MPORU Executive and Advisory Board

The Executive of the MPORU consists of a Director (Peter Raaphorst), Secretary (Carl Ross); Academic Officer (Paul Johns) and a graduate student representative (Julia Wallace). Members are elected for two year terms. The Executive meets about once a month and has observers from other groups (Ian Cameron, Pavel Dvorak and Bog Jarosz). The MPORU seminars for 1992/93 were organized by Bog Jarosz.

Members of the Advisory Board are listed below:

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4. Seminars

4.1 MPORU Seminars

One of the main vehicles of the MPORU for developing and maintaining contacts is through a seminar series in which all the members and the graduate students in medical physics are required to make a presentation.

Seminars are scheduled monthly, and this year were held at 3:30 p.m. on Thursdays. In the past all the seminars were held at Carleton University. This year the location was rotated among the major centres involved in medical physics.

The following is a list of MPORU seminars held in 1992-93. Except for the session in September, the first speaker listed is a graduate student.

Date & Location	Speaker	Title
September 17 (Carleton University)	MPORU Executive	State of the Union
	Clive Greenstock (AECL Research, Chalk River)	Free Radical Dosimetry; Scientific Studies & Technical Criteria
October 15 (Ottawa General H.)	Dennis Akyurekli (Carleton University)	Cerebral and Skeletal Muscle Hyperthermia
	Dave Rogers (National Research Council)	Towards Clinical Dosimetry Based on Absorbed-Dose Standards
November 19 (N.R.C.)	Larry Gates (Carleton University)	Using MRI to Measure Diffusion of Water in Human Tissue
	Peter Raaphorst (Ottawa Regional Cancer Centre)	Radiosensitization and Prediction of Radiation Response; an Experimental and Modelling Approach
December 10 (Ottawa Civic H.)	Kevin Lenton (Carleton University)	Uptake of ^{125}I into the Thyroids of Hospital Users
	Alex Bielajew (National Research Council)	Why Proton Machines for Radiotherapy are a Big Waste of Money
January 21 (Carleton University)	Dennis Heller (Carleton University)	Low Dose-Rate Irradiation of Human Glioma Cells and Thermoradiosensitization by Preheating and Concurrent Continuous Mild Hyperthermia

	Tony Waker (AECL Research, Chalk River)	Microdosimetry at Work
February 18 (Ottawa Civic H.)	Ted Lawrence (Carleton University)	A Study of the Variables Controlling the Intensity and Purity of Fluorescence X Rays
	Bob Clarke (Carleton University)	Lesions for Lesions
March 1 (Ottawa General H.)	Miller MacPherson (Carleton University)	Absolute and Relative Dosimetry of Ytterbium-169
	Alan Mortimer (Canadian Space Agency)	Biomedical Investigations in Microgravity Standards
April 15 (N.R.C.)	Mazen Soubra (Carleton University)	Relative Output Factors for Asymmetric Jaws
	Cheng Ng (Ottawa Regional Cancer Centre)	Are DNA Topoisomerases Implicated in the Repair of X-Radiation Damage?

4.2 Carleton University Physics Department Seminars

Carleton University Physics Department runs a regular seminar series on Monday afternoons (with overflow to other days of the week) at 3:30 p.m. in room 252 of the Herzberg Building. The following seminars of interest to medical physics were held in 1992-93:

October 5	Jake Van Dyk, Ontario Cancer Institute - "Dose-Response and Isoeffect Considerations for Radiation-Induced Lung Damage".
November 6	Donald Plewes, Department of Medical Biophysics, University of Toronto - "Turbulence Effects in Magnetic Resonance Angiography".
November 16	Montague Cohen, McGill University - "Ernest Rutherford and Marie Curie: A Contrast in Genius".
December 7	Doug Salhani, Ottawa Regional Cancer Centre - "Treatment Planning Optimization".
December 14	OCIP Christmas Symposium - Bog Jarosz, Department of Physics, Carleton University - "Ultrasound Hyperthermia: Principles and Methods".
January 11	Ross Hallett, Department of Physics, University of Guelph - "Scattering and Fluorescence Studies of Vesicles".
February 8	Tom Cousins, Defence Research Establishment Ottawa - "The Radiation Effects Research Program".

February 9 Terry Thompson, University of Western Ontario - "NMR Spectroscopy in Medicine".

March 1 Peter N. Corry, William Beaumont Hospital, Royal Oak, Michigan - "Simultaneous Hyperthermia and Brachytherapy".

Fall Graduate Student Seminar Afternoon, November 25, 1992

David Wilkins - "Radiobiological and Magnetic Resonance Studies of Combined Radiation and Cisplatin Therapy in the 9L Rat Brain Tumour Model".

Patrick Rapley - "A Novel Approach to MRI Gradient Coil Design".

Winter Graduate Student Seminar Afternoon, May 6, 1993

Julia Wallace - "Identification of Therapy Resistance in Ovarian Cancer by Magnetic Resonance Spectroscopy".

5. Membership Directory of the MPORU

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6. Medical Physics Graduate Courses

The Carleton medical physics program has 3 specializations: imaging, therapy, and biophysics. Shown below is a menu of courses for each. Required courses are marked →; the others are recommended.

Depending on the thesis weighting, the MSc typically requires 6 half-courses in addition to the thesis; the PhD requires 4. PhD students who lack any of the relevant courses (or their equivalents) required for the MSc must complete them in their PhD. MSc students may be permitted to take up to 2 Fourth-Year half-courses and credit them towards the degree. PhD students can credit only graduate courses.

When a student has covered material in a prior program, such as an MSc in medical physics elsewhere, then the equivalent courses at Carleton are of course not required. The courses to be taken by a given student will be decided on in consultation with the student and the supervisor.

Listed for each course is the course number, the campus where taught, and the course name. Carleton courses are numbered with the prefix "75" indicating Physics, followed by a 400-series number if Fourth Year, or either a 500- or 600-series number for graduate courses.

SPECIALIZATION IN IMAGING

Fall Term	→	75.523 (Carleton)	Medical Radiation Physics
	→	75.427 (Carleton)	Modern Optics (prerequisite to 75.524; additional to degree if PhD)
		75.527 (Carleton)	Radiobiology
		75.529 (Carleton)	Medical Physics Practicum
Winter Term	→	75.524 (Carleton)	Physics of Medical Imaging
		75.526 (Carleton)	Medical Radiotherapy Physics
		75.528 (Carleton)	Radiation Protection
Fall & Winter (both terms)		ANA 7301 (Ottawa HSC)	Anatomy
		PHS 5210 (Ottawa HSC)	Physiology
Fall or Winter (one term)	→	75.5xx/6xx (Carleton or Ottawa)	Appropriate physics half-course outside of medical physics (permission may be given for 75.4xx if MSc)

SPECIALIZATION IN THERAPY

Fall Term	→	75.523 (Carleton)	Medical Radiation Physics
		75.527 (Carleton)	Radiobiology
		75.529 (Carleton)	Medical Physics Practicum

Winter Term		75.524 (Carleton)	Physics of Medical Imaging
	→	75.526 (Carleton)	Medical Radiotherapy Physics
		75.528 (Carleton)	Radiation Protection
Fall & Winter (both terms)		ANA 7301 (Ottawa HSC)	Anatomy
		PHS 5210 (Ottawa HSC)	Physiology
Fall or Winter (one term)	→	75.5xx/6xx (Carleton or Ottawa)	Appropriate physics half-course outside of medical physics (permission may be given for 75.4xx if MSc)

SPECIALIZATION IN BIOPHYSICS

Fall Term	→	75.523 (Carleton)	Medical Radiation Physics
	*→	75.527 (Carleton)	Radiobiology
		75.529 (Carleton)	Medical Physics Practicum
Winter Term		75.524 (Carleton)	Physics of Medical Imaging
		75.526 (Carleton)	Medical Radiotherapy Physics
		75.528 (Carleton)	Radiation Protection
Fall & Winter	*→	ANA 7301 (Ottawa HSC)	Anatomy
(both terms)	*→	PHS 5210 (Ottawa HSC)	Physiology
Fall or Winter (one term)	→	75.5xx/6xx (Carleton or Ottawa)	Appropriate physics half-course outside of medical physics (permission may be given for 75.4xx if MSc)

* = in the Biophysics specialization, *one* of Radiobiology, Anatomy, or Physiology must be taken.

Course Descriptions

75.523 - Medical Radiation Physics (1/2 course, Fall) - Basic interaction of electromagnetic radiation with matter. Sources: x ray, accelerators, nuclear. Charged particle interaction mechanisms, stopping powers, kerma, dose. Introduction to dosimetry. Units, measurements, dosimetry devices.
Reference: H.E. Johns & J.R. Cunningham, *The Physics of Radiology*, 4th ed., 1983.
Lecturer: P.C. Johns.

75.524 - Physics of Medical Imaging (1/2 course, Winter) - Outline of the principles of transmission x-ray imaging, computerized tomography, nuclear medicine, magnetic resonance imaging, and ultrasound. Physical descriptors of image quality, including contrast, resolution, signal-to-noise ratio, and modulation transfer function are covered and an introduction is given to image processing.
Prerequisites: 75.523 or equivalent, and 75.427 or equivalent.
Reference: H.H. Barrett & W. Swindell, *Radiological Imaging*, 1981.
Lecturers: P.C. Johns, I.G. Cameron

75.526 - Medical Radiotherapy Physics (1/2 course, Winter) - Terminology and related physics concepts. Bragg-Gray, Spencer-Attix cavity theories, Fano's Theorem. Dosimetry protocols, dose distribution calculations. Radiotherapy devices, hyperthermia.
Prerequisite: 75.523 or equivalent.
References: F.H. Attix, *Introduction to Radiological Physics and Radiation Dosimetry*, 1986.
H.E. Johns & J.R. Cunningham, *The Physics of Radiology*, 4th ed., 1983.
Lecturers: J. Cygler, D.W.O. Rogers, K.R. Shortt, L.H. Gerig

75.527 - Radiobiology (1/2 course, Fall) - Introduction to basic physics and chemistry of radiation interactions, free radicals, oxidation and reduction, G values. Subcellular and cellular effects: killing, repair, sensitization, protection. Measurement methods. Survival curve models. Tissue effects, genetic and carcinogenic effects, mutations, hazards. Cancer therapy. Radiation protection considerations.
Prerequisite: 75.523 or equivalent must have been taken, or must be taken concurrently.
Reference: E.J. Hall, *Radiobiology for the Radiologist*, 3rd ed., 1988.
Lecturer: G.P. Raaphorst

75.528 - Radiation Protection (1/2 course, Winter) - Biophysics of radiation hazards, dosimetry and instrumentation. Monitoring of sources, planning of facilities, waste management, radiation safety, public protection. Regulatory agencies.
Prerequisite: 75.523 or equivalent.
Lecturer: V. Elaguppillai

75.529 - Medical Physics Practicum (1/2 course, Fall) - This course provides hands-on experience with current clinical medical imaging and cancer therapy equipment, and with biophysics instrumentation. The student is expected to complete a small number of practical experimental projects during the term on topics such as magnetic resonance imaging, computed tomographic scanning, radiotherapy dosimetry, hyperthermia, biophysics, and radiation protection. The projects will be conducted at hospitals, cancer treatment facilities, and NRC laboratories in Ottawa.
Prerequisite: Physics 75.523 plus, as appropriate to the majority of projects undertaken, one of 75.524, 75.526, or 75.527 or other biophysics course.
Coordinator: B.J. Jarosz

ANA 7301 - Anatomy for Medical Physics Graduate Students (1/2 course, extends through Fall + Winter) - A basic course in anatomy for medical physics students utilizing the systemic approach to emphasize practical and clinical aspects of the gross structure of the human body. The course consists of lectures, laboratory demonstrations with dissected materials and a series of audio-visual presentations involving imaging techniques.

PHS 5210 - Mammalian Physiology (full course, extends through Fall + Winter) - A comprehensive study of mammalian physiology with an emphasis on regulating mechanisms. The course includes the biophysical basis of excitable tissues, and the physiology of the central nervous system, blood and cardiovascular system, respiratory system, endocrine system, G.I. tract and renal physiology. It is assumed that students have a basic knowledge of chemistry, physics, and biology.

75.427 - Modern Optics (1/2 course, Fall) - Diffraction theory, coherence, Fourier optics, spatial filtering; holography and its applications; laser theory: stimulated emission, cavity optics, modes; gain and bandwidth; design and characteristics of atomic and molecular gas lasers.
[This is a Fourth-Year half-course which covers material prerequisite to the Physics of Medical Imaging graduate course (75.524)]

Reference: J.W. Goodman, *Introduction to Fourier Optics*, 1968.
Lecturer: L. Resnick

Appropriate physics half-course outside of medical physics - A half-course in an area of physics outside of medical physics is required. Appropriate possibilities include nuclear, theoretical, quantum, particle, solid state, and computational physics.

Paul Johns
Academic Officer, MPORU

7. Students

7.1 Graduate Students Currently Enrolled in the Medical Physics Program

Student	Date Started*	Supervisor	Specialization	Thesis Topic
PhD Students				
Heller, Dennis	Sept 1988	Raaphorst	Biophysics	Radiobiology of low doserate irradiation
Soubra, Mazen	Sept 1988 (P.T.**)	Gerig	Therapy	Asymmetric linac fields for radiotherapy
Akyurekli, Dennis	Jan 1989 (following completion of MSc with R. Clarke)	Gerig	Therapy/ Biophysics	Physiology of blood flow during hyperthermia
Rapley, Patrick	Sept 1989	Saunders	Imaging	MR coil design, pulse sequences for ovarian cancer
Wallace, Julia	Sept 1989	Raaphorst	Biophysics/ Imaging	Biophysics of tumour cellular & tissue response

Ding, George	Sept 1991 (Transferred from U Manitoba)	Rogers	Therapy	via MRS OMEGA (online Monte Carlo radiotherapy planning)
Brown, Ruth	Sept 1991	Raaphorst	Biophysics	Biophysics of radiation damage and repair
Gates, Larry	Sept 1991	Cameron	Imaging	MRI measurement of water diffusion
Older, Julia	Dec 1991 (following completion of MSc with P. Johns)	Salhani	Therapy	Dynamic radiotherapy planning optimization algorithm
Lenton, Kevin	Sept 1992	Greenstock	Biophysics	Develop micronucleus assay for biological dosimetry
MacPherson, Miller	Feb 1993	Ross	Therapy	Measurement of electron stopping powers

MSc Students

Lawrence, Ted	Sept 1990	Johns	Imaging	Fluorescence x ray production for diagnostic radiology
Kaytar, Doru	Sept 1992	Jarosz	Therapy	Ultrasonic interstitial hyperthermia array applicator for brain tumours

Exchange Student

Werner, Martin [from U. of Heidelberg, for one year]	Sept 1992	Jarosz	Therapy	Ultrasound hyperthermia

* - date first started taking courses or commenced lab work, not the official date of first registration into degree
** - P.T. = Part Time

7.2 Student Directory

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7.3 Theses and Projects Completed in 1992/93

GRADUATE STUDENT THESES

David Wilkins	PhD	Thesis Title:	Radiobiological and Magnetic Resonance Studies of Combined Radiation and Cisplatin Therapy in the 9L Rat Brain Tumour Model
		Supervisor:	G. Peter Raaphorst
		Thesis Examination:	10 February 1993

HONOURS FOURTH-YEAR UNDERGRADUATE PHYSICS PROJECTS

Alan Dekok	75.499	Project Title:	Numerical Simulation of Fluorescence X-Ray Production
		Supervisor:	Paul Johns

8. Scientific Societies of Relevance to Medical Physics

The following scientific societies are of interest to students in medical physics. For further information contact the individuals shown:

COMP - Canadian Organization of Medical Physicists: Paul Johns, Ken Shortt.

CAP - Canadian Association of Physicists: Dave Rogers, Bob Clarke, Paul Johns.

SMRI - Society for Magnetic Resonance Imaging: John Saunders.

CRPA - Canadian Radiation Protection Association: Dave Rogers.

AAPM - American Association of Physicists in Medicine: Dave Rogers, Paul Johns.

HPS - Health Physics Society (US): Dave Rogers.

RRS - Radiation Research Society: Peter Raaphorst.

9. Report on COMP '93

On May 12-15 1993 we hosted in Ottawa the first formal joint conference of the medical physics and biomedical engineering communities in Canada. Over 110 members of the Canadian Organization of Medical Physicists (COMP) and the Canadian College of Physicists in Medicine (CCPM) and over 200 members of the Canadian Medical and Biological Engineering Society (CMBES) attended. The conference was held at Carleton University, and most attendees stayed on campus in residence.

The conference opened Wednesday May 12 with a symposium of 9 invited speakers on the topic "Lasers and Electro-Optics in Medicine" jointly sponsored by the CCPM and the CMBES. There then followed two days of parallel scientific sessions for the COMP and the CMBES. A total of 72 papers were submitted for the COMP sessions. A special information session was also held on The Role of Medical Physicists in the CAR Mammography Accreditation Program.

From Wednesday afternoon through Friday lunch a Commercial Exhibit was staged in the foyer of the Tory Building. Of the 24 organizations which purchased booths, 6 were of direct interest to medical physicists: Hilferdine Scientific, Keithley Instruments, Nucletron, Siemens, Theratronics, and Victoreen. In addition, material was on display on the Carleton medical physics program and the University of Ottawa medical engineering program.

The social highlight of the conference was the Banquet, held the Friday evening at the Museum of Civilization. Dinner was followed by the awarding of various honours of the COMP, CCPM, and CMBES. The evening's entertainment was the IMAX movie *Titanica*.

The conference wrapped up Saturday morning with a choice of tours to the Theratronics plant, the NRC Ionizing Radiation Standards labs, or the Heart Institute.

This conference put Ottawa on the Canadian medical physics map! As the Conference Co-Chair for COMP/CCPM, I thank all members of the Conference Committee for their hard work and patience in making this a very successful conference that we can look back on with pride.

COMP/CCPM Members of the Organizing Committee:

Paul Johns	Conference Co-Chair
Robert Clarke	Finances, Local Arrangements
Peter Raaphorst	Commercial Exhibits
Ken Shortt	Banquet, Commercial Exhibits
Dennis Heller	5 km Run, Local Arrangements
Ruth Brown	Local Arrangements
Julia Wallace	Local Arrangements
Aaron Fenster	Scientific Program
Peter Munro	Scientific Program

Paul Johns
Conference Co-Chair, COMP/CCPM

10. Recent Research by MPORU Members

In order that the Newsletter may serve as an annual report to the Dean of Graduate Studies and Research of Carleton University, this section describes briefly the research activities, recent publications and sources of funding of the MPORU members. The editor has attempted to reduce all the contributions to a standard format.

Alex Bielajew
Research: Improving Monte Carlo methods in the therapeutic range (10 keV-50 MeV) by modelling the physics more accurately. Most emphasis is on the EGS (electron gamma shower) Monte Carlo code. Using analytic and Monte Carlo methods to improve the foundations of theoretical dosimetry. Theoretical development of multiple scattering theory.

Publications:
P. Andreo, J. Medin and A.F. Bielajew (1993) *Constraints on the multiple scattering theory of Molière in Monte Carlo simulations of the transport of charged particles* submitted to Med. Phys. 92/10/26.
A.F. Bielajew (1993) *The effect of strong longitudinal magnetic fields on dose deposition from electron and photon beams* (in press) Med. Phys.
A.F. Bielajew, R. Wang and S. Duane (1993) *Accurate e^- transport calculations using single elastic scattering Monte Carlo* (in press) Nucl. Instrum. and Meth. B.
J.L. Karr and A.F. Bielajew (1993) *A 1-D cubic spline routine for fitting electron elastic scattering cross sections* (NRC report: PIRS-0366).
J.L. Karr and A.F. Bielajew (1993) PIF [Prepare Input File (for PEGS4)] (NRCC report: PIRS-0365).
A.F. Bielajew and D.W.O. Rogers (1992) *Implications of new correction factors on primary air kerma standards in ^{60}Co-beams* Phys. Med. Biol. 37 1283-1291.
A.F. Bielajew and D.W.O. Rogers (1992) *A standard timing benchmark for EGS4 Monte Carlo calculations* Med. Phys. 19 303-4.
S. Walker, A.F. Bielajew, M.E. Hale and D. Jette (1992) *Installation of EGS4 Monte Carlo code on an 80386-based microcomputer* Med. Phys. 19 305-306.
E. White and A.F. Bielajew (1992) *Optimizing sampling efficiency for Monte Carlo applications* (NRCC report: PIRS-0332).
J. Mizia and A.F. Bielajew (1992) *The density effect on electron stopping powers in condensed, granular materials* (NRCC report: PIRS-0322).
C. Malamut, D.W.O. Rogers and A.F. Bielajew (1991) *Calculation of water/air stopping-power ratios using EGS4 with explicit treatment of electron-positron differences* Med. Phys. 18 1222-1228.
W.R. Nelson and A.F. Bielajew (1991) *EGS - A technology spinoff to medicine* (Beam Line 21(1)7-11, Stanford Linear Accelerator Center).
A.F. Bielajew (1991) *Improved angular sampling for pair production in the EGS4 code system* (NRCC report: PIRS-0287).
C.M. Ma, A.E. Nahum, D.W.O. Rogers and A.F. Bielajew (1991) *Wall correction and absolute dose conversion factors for Fricke dosimetry using NRC vials* (NRCC report: PIRS-0285).
A.F. Bielajew and P.E. Wiebe (1991) *EGS-Windows - A Graphical Interface to EGS* (NRCC report: PIRS-0274).

Funding: Supported as a member of NRC staff.

Ian Cameron
Research: We use Magnetic Resonance Imaging (MRI) to study water diffusion and perfusion of blood in capillary beds. In order to better understand the effects of water diffusion in diffusion sensitized MR images at a basic level we have designed and built special gradient coils which allow us to study this process over a much larger range than is possible with the gradient coils provided with the imager. We are also developing similar

procedures for measuring placental blood flow to monitor intrauterine growth retardation.

Magnetic Resonance Spectroscopy (MRS) can be used to determine the concentration of a variety of important molecules in a given volume of interest (VOI) inside the body. The VOI can be as small as 2x2x2 cm^3 and it can, in principle, be positioned anywhere inside the body. We are using ^{31}P MRS in conjunction with an exercise protocol as a possible screen for malignant hyperthermia. ^{1}H and ^{31}P MRS are also being used in a study of brain tumours. In addition, we have the capability of doing ^{19}F MRS and we hope to make use of this to follow the metabolism of fluorinated chemotherapy drugs in vivo.

Publications:

I.G. Cameron and J.A. Ripmeester (1991) *^{19}F Spin-Lattice Relaxation in the Clathrate Hydrates of SF_6 and SeF_6*, accepted J. Chem. Phys.

L.J. Schreiner, I.G. Cameron, L. Miljkovic, M.M. Pintar, N. Funduk and D.W. Kydon (1991) *Proton NMR Spin Grouping and Exchange in Dentin*, Biophys. J., 59 629-639.

W.T. Sobol, I.G. Cameron and M.M. Pintar (1991) *A Zeeman Level Crossing Study of the Symmetry of the Potential Hindering the Torsion Oscillator CH_3*, Chem. Phys. 151 337-341.

Funding: NSERC operating grant, $15,000/year.

Robert Clarke

Research: Studying the use of highly focussed beams of ultrasound for the reduction or removal of benign and malignant lesions. The process of tissue destruction, consisting of energy deposition, diffusion and tissue response is being studied experimentally, theoretically and by computer modelling. Appropriate lens design, and the dosimetry of high intensity ultrasound are also being investigated.

Pavel Dvorak

Publications:

P. Dvorak and C. Lavoie (1992) *Exotic Filter Materials for Diagnostic X-Ray Equipment - Are they superior to Commonly Available Materials?* IRPA8 Meeting 1992, Montreal, Que. Proceedings 1 211-214.

P. Dvorak (1991) *Effects of Uncertainties in Values of X-ray Spectra and Macroscopic Absorption Coefficients on Numerical Simulation of X-Ray Absorption* COMP Conference 1991, Winnipeg, Man.

V. Elaguppillai

Research: Quantification of the risk to health (cancer, genetic and teratogenic effects) and environmental effects of exposure to low dose and low dose-rate of low and high LET ionising radiation, reduction of uncertainties in risk estimates, design and improvement of radiation practises at work places (hospital, research, power reactor, uranium mine, mill and refinery, radioactive waste disposal facilities) are the areas of main research interest.

Lee Gerig and Janos Szanto

Research: The Patient Position Monitoring System is being developed as a tool for the computer-controlled radiation therapy program. The design criteria are that this system will provide an independent means of measuring patient position in real time. Position can be reported in either absolute or relative terms and will provide both rotational in three planes, and translational motions updating every five seconds. This is a joint project spearheaded by the ORCC and being done in conjunction with the National Research Council and Siemens Medical Laboratories.

There is a well-defined need for the development and implementation of a stereotactic radiation surgery and radiation therapy program at the ORCC. The principal difference between radiation surgery and radiation therapy is that radiation surgery delivers a very high dose in a single fraction whereas radiation therapy has all the same requirements except the dose must be delivered in a fractionated manner. The program includes the development of special radiation therapy cones to provide a very well-defined, well colimated x-ray beam, patient immobilization devices specifically for the radiation therapy component, localization devices which can be correlated to the patient immobilization devices and treatment planning and dosimetry for the verification of dose distributions. It is hoped that the stereotactic radiation therapy program will be implemented fully by May of 1993, although preliminary patient work has been done as early as November of 1992.

The introduction of computer-controlled radiation therapy into clinical practice introduces a significant number of technical challenges. Among these are the ability to predict absolute dose as well as dose distribution for dynamic fields and for asymmetrically colimated or irregularly colimated fields. To properly address this problem it is necessary to be able to develop a model which describes the individual components, specifically the individual scatter components and the primary components that make up the total radiation dose within the patient. The purpose of this project is to develop a semi-empirical model capable of accurately predicting absolute dose under the conditions of moving jaws, asymmetric jaws, and irregularly blocked fields routinely found in computer-controlled radiation therapy.

Publications:

C.E. Danjoux, E. Zakhour, P. Raaphorst, L. Gerig and S. Grimes (1992) *Thermoradiotherapy for Local, Superficial, Recurrent Cancer*, Canadian Journal of Oncology, 2(1) 57-61.

L.H. Gerig, J. Szanto and G.P. Raaphorst (1992) *On The Spatial Resolution of Clinical Thermometers*, Medical Physics 19(3) 679-684.

L.H. Gerig, J. Szanto and G.P. Raaphorst (1992) *Frontiers of Medical and Biological Engineering* 4(2) 105-117.

G.P. Raaphorst, J. Szanto, J. Cygler, Al Laewen (1993) *A Safe Method of Analysis for Mechanical Damage in Spherical Radioactive Sources Used in Remote Afterloading Brachytherapy Devices*, Medical Physics 20(1) 247-249.

L. Grimard, J. Szanto, A. Girard, M. Howard, L. Eapen and L. Gerig (1992) *Asymmetric Jaw Arc Technique for Posterior Pharyngeal Wall and Retropharyngeal Space Tunours*, Proceedings of the 34th Annual ASTRO Meeting San Diego, CA.

L.H. Gerig, J. Szanto and P. Genest (1992) *Translation Method for Total Body Irradiation Design and Dosimetry* Proceedings of the 34th Annual ASTRO Meeting San Diego, CA.

D.U. Akyurekli, L.H. Gerig, G.P. Raaphorst and J. Scott (1993) *The Effects of Local Hyperthermia on Normal Porcine Cerebral and Skeletal Muscle Blood Flow*, Forty First Annual Meeting of the Radiation Research Society (Abstract P-02-7), Dallas Texas.

L.H. Gerig, J. Szanto and G.P. Raaphorst (1991) *On the Spatial Resolution of Type T and K Clinical Thermometers*, Proceedings of the World Congress on Medical Physics and

Biomedical Engineering, 9th International Conference on Medical Physics, Japan.

Clive Greenstock

Research: Studying radiation-induced conformational changes in the human genome using time-resolved- and immuno-fluorescence spectroscopy, and investigating the role of DNA synthesis and packaging enzymes in determining radiation response.

Using ESR spectrometry in Biological Dosimetry of human samples and tissue-equivalent surrogate materials, and evaluating its potential for individual dose estimation in radiation accidents and occupational exposures.

Measuring radiation damage to the lymphocyte immuno-surveillance system. Fluorescent monoclonal antibody binding to specific cell surface receptors is used to monitor an early-warning response to radiation and trigger mechanisms involved in cell signalling and adaptation processes.

An immuno-assay technique (ELISA) technique has been set up to measure antioxidant levels in cells and to explore their role in inducible and constitutive radiation protection mechanisms.

Publications:

C.L. Greenstock, R.E.J. Mitchel, A. Trivedi and Y. Xu (1993) *Immunofluorescence studies of low dose radiation effects on human lymphocyte surface markers*, Proc. 4th International Conference on Anticarcinogenesis and Radiation Protection, Plenum Press, New York 217.

C.L. Greenstock and R.P. Whitehouse (1992) *Radiation chemical studies of sensitization by 5-bromouridine-5'-monophosphate* Radiat. Environ. Biophys. 31, 1-9.

C.L. Greenstock and A. Trivedi (1992) *Free radical measurement in bio-organic substances using an electron spin resonance technique*, Proc. Eighth International Radiation Protection association Congress 1 455-458.

A. Trivedi and C.L. Greenstock (1992) *Use of sugars and hair samples for ESR emergency dosimetry*, Appl. Radiat. Isot. 44, 85-90.

A.B. Ross, W.G. Mallard, W.P. Helman, B.H.J. Bielski, G.V. Buxton, D.E. Cabelli, C.L. Greenstock, R.E. Huie and P. Neta (1992) *NDRL-NIST Solution Chemistry Database:- ver. 1*, National Institute of Standards and Technology, Gaithersburg, 34 pp.

A.O.L. Tchen, I. Bonnot, C.L. Greenstock and A. Trivedi (1992) *An investigation of silicone/sucrose pellets: A new development in electron spin resonance (ESR) dosimetry*, Atomic Energy of Canada Limited (AECL) Research Report No. RC-702, 17 pp.

B.P. Smith, K.L. Gale, M. Einspenner, C.L. Greenstock and N.E. Gentner (1992) *Stimulated human fibroblast cell survival/clonogenicity in response to low doses of ionizing radiation*, Proc. International Conference on Low Dose Irradiation and Biological Defense Mechanisms, Elsevier, Amsterdam, 299-302.

C.L. Greenstock and N.E. Gentner (1991) *A review of potential health hazards associated with occupational exposure to beryllium*, Canadian Fusion Fuels Technology Program (CFFTP) Report No. G-9031 26 pp.

D.P. Heller and C.L. Greenstock (1991) *Fluorescence lifetime analysis: A detailed review and optimization of instrument operations and data analysis*, Atomic Energy of Canada Limited (AECL) Report No. AECL-10127, 52 pp.

C.L. Greenstock, N.E. Gentner, K. Gale, B. Smith, D. Adams and J.-A. Walker (1991) *An Investigation of Beryllium Cytotoxicity in Normal and Repair-deficient Cells*, Canadian Fusion Fuels Technology Program (CFFTP) Report No. Co 591, pp 38.

Funding: Supported as a member of AECL Research staff

Candu Owners Group, R&D support	150K
Accelerator Business Unit, Impela dosimetry grant	15K
Atomic Energy Control Board, biolog. dosim. grant	22K
AECL Research H.O., isotope operation/study grant	10K

Boguslaw J. Jarosz
Research: Therapeutic application of ultrasound in hyperthermia of deeply localized tumours. Current research concentrates on improvements to already developed interstitial hyperthermia applicator. Of paramount importance is understanding of interaction of sonic waves with tissue and mode conversion in tissues, projects that have been recently initiated. Also recently research of a multi-applicator waveguided interstitial hyperthermia system for therapy of brain tumours has been started. The latter involves research of laser generated ultrasound.

Publications:
B.J. Jarosz (1992) *Effects of blood flow on temperature elevation in ultrasonic interstitial hyperthermia*, Proc. 14th Ann. Int. Conf. IEEE Eng. Med. Biol. Soc. 14, 344.
B.J. Jarosz (1992) *Effects of inhomogeneities and blood flow on temperature elevation in ultrasonic interstitial hyperthermia*, AAPM/COMP 1992 Ann. Meet., Abstract in Med. Phys. 19, 805.
B.J. Jarosz (1991) *Temperature distribution in interstitial ultrasonic hyperthermia*, Proc. 13th Ann. Int. Conf. IEEE Eng. Med. Biol. Soc., 13 178.
B.J. Jarosz and R.L. Clarke (1991) *Interstitial Ultrasonic Hyperthermia Applicator,* to be published.
B.J. Jarosz (1991) *Ultrasonic surface modes generated by laser pulses on duraluminium,* Ultrasonics, 29, 53.

Funding: Private (Ottawa Civic Hospital Foundation).

Paul Johns
Research: Studying iterative reconstruction techniques to reduce artifacts in computed tomography (CT) by accounting for the polyenergetic nature of the x-ray beam as well as scattered x rays.
Analyzing the effect of system noise and scattered radiation in dual energy x-ray imaging. The results are being applied to mammography.
Investigating the factors controlling the spectral purity and intensity of monoenergetic x rays produced via secondary fluorescence.

Publications:
P.L. Pattee, P.C. Johns and R.J. Chambers (1993) *The Radiation Risk to Patients from Percutaneous Transluminal Coronary Angioplasty*, in press J. Am. College Cardiology.
J.K. Older and P.C. Johns 1993, *Matrix Formulation of Computed Tomogram Reconstruction*, in press Phys. Med. Biol.

Funding: NSERC Operating Grant $15,000.

Norman Klassen
Research: Involved with work to establish absorbed dose standards based on water

calorimetry. One initiative is to extend the work done at 20 MV to ^{60}Co. The other is to examine the radiation chemistry of water in order to resolve anomalies between the experimentally determined H_2O_2 yields, the yields predicted by computer simulation and the temperature rise measured in irradiated water.
Participating in a study of radiation-induced cell death by apoptosis in rat thymocytes. Particular emphasis is placed on initial radiation damage. End points used are cell shrinkage, staining, electron microscopy and gel electrophoresis. Participating in a comparison of the OER of mammalian cell lines at "normal" and "ultra-high" dose rates.

Publications:
N.V. Klassen and C.K. Ross (1991) *Absorbed Dose Calorimetry using Various Aqueous solutions*, Radiat. Phys. Chem., **38**, 95-104.
N.V. Klassen, K.R. Shortt and C.K. Ross (1991) *Calibration of Fricke Dosimetry by Water Calorimetry*, Proc. 7th Tihany Symposium on Radiation Chemistry, pp 543-547.

Funding: Supported as a member of NRC staff.

Alan Mortimer
Research: Studying the way the environment in the immediate vicinity of the cell surface affects what happens to the cell. Ultrasound is known to increase the transport of messenger ions across the cell membrane. Also, the space environment decreases the immune response of cells in suspension. This may be due to reduced convection, leading to reduced surface interaction. Work is underway to study cell surface binding and transport across membranes in simulated micro gravity. Studies are also planned to determine how ultrasound changes the properties of cell membranes thereby affecting wound healing.

Cheng E. Ng
Research: Magnetic Resonance Spectroscopy (MRS) techniques are being investigated for distinguishing drug-resistant from drug-sensitive human ovarian tumour cells perfused in vitro. MRS techniques are also being investigated for monitoring and/or predicting effects of treatment with x-rays, drugs or hyperthermia on the same cells. The goal of these studies is to establish if MRS can play a role in the diagnosis and/or prognosis of cancer.
The effects of drugs which inhibit the ability of human skin cancer cells to repair x-radiation and hyperthermic damage in culture are also being investigated. The aim of these studies is to establish if inhibition of cellular repair can lead to more effective killing of tumour cells.

Publications:
K.A. McGovern, J.S. Schoniger, J.P. Wehrle, C.E. Ng and J.D. Glickson (1993) *Gel-entrapment of perfluorocarbon: A Fluorine-19 NMR spectroscopic method for monitoring oxygen concentrations in cell perfusion systems*. Mag. Res. in Medicine, 29: 196-204.
G.P. Raaphorst, M. Thakar and C.E. Ng (1993) *Thermal radiosensitization in two pairs of CHO wild-type and radiation-sensitive mutants,* in press Int. J. Hyperthermia.
G.P. Raaphorst, D.P. Heller, A.M. Bussey and C.E. Ng (1993) *Thermal radiosensitization by 41 °C hyperthermia during low dose-rate irradiation in human normal and tumour cell lines* in press Int. J. Hyperthermia.
C.E., Ng, A.M. Bussey and G.P. Raaphorst (1993) *Inhibition of potentially lethal and sublethal radiation damage repair by comptothecin and etoposide in human melanoma cell lines*. Submitted.

C.E. Ng, K.A. McGovern, J.P. Wehrle and J.D. Glickson (1992) *^{31}P NMR spectroscopic study of the effect of gamma-irradiation on RIF-1 tumour cells perfused in vitro*, Mag. Res. in Medicine 27 296-309.

Funding: Supported as a Career Scientist with the Ontario Cancer Foundation; Co-investigator on NCIC grant for the study of cellular radiosensitivity, three years (53,000/year);
Co-investigator on NCIC grant for the study of interactions between cisplatin, radiation and hyperthermia, three years, $95,000/year.

Peter Raaphorst, Joanna Cygler and Douglas Salhani

In vitro studies of the role of repair in the radiation resistance of various human tumour cell lines are underway. Hyperthermia is used to cause radiosensitivity and to inhibit repair. Low dose rate measurements are underway, and they show large increases in survival as the dose rate is lowered. The effects of hyperthermia at low dose rates is being evaluated. These data show a large enhancement of radiation sensitivity, which is primarily caused by the presence of hyperthermia during irradiation, blocking systems which repair radiation damage. The response of human glioma cells to very high dose rates is also being studied.

The effect of radiation resistance is also being evaluated. Cell lines expressing radiation sensitivity as well as radiation resistance are being tested for characteristics of this resistance such as increased repair of radiation damage and methods are being investigated to overcome this resistance such as combinations of hyperthermia drugs combined with radiation. In addition, mechanisms of resistance are also being explored and survival curve models are being developed to predict and assess resistance.

The evaluation of patients' radiation sensitivity before treatment is also being investigated. The determination of genetic variation of radiation response can lead to better prescription of dose to individual patients depending on their relative radiation sensitivity.

Hyperthermia in animal model and in the clinic is also being evaluated. To date we have treated 35 patients and have shown that hyperthermia in combination with radiation can provide benefit in superficial tumours. This clinical trial has been completed. In addition, we are evaluating the effect of hyperthermia on blood flow in pigs. The data show that hyperthermia can effect blood flow in muscles, brain and kidney. These data are being analyzed and will contribute to developing a hyperthermia model which can be used in treatment planning in a prediction of thermal dose.

Magnetic resonance spectroscopy is being used to study ^{1}H and ^{31}P in human ovarian carcinoma and rat glioma cells both in vitro and in vivo. It is shown that there are differences in the ^{1}H spectra between cells expressing a normal response and a resistant response to chemotherapeutic agents. Results also show that the stress of cancer therapeutic agents causes changes in the high energy phosphorous metabolites within cells. The effects of hyperthermia, radiation and chemical agents are also being studied.

Various aspects of external beam radiotherapy are being studied. This includes the evaluation of methods for calculating the dose for irregularly shaped fields; the development and implementation of asymmetric arc therapy; the development of a radiosurgery program; the development of a patient position monitor; the evaluation of therapy using asymmetric collimator jaws; the development of dynamic wedges; and the development of algorithms for fitting treatment unit data. A solid state (MOSFET) detector is being evaluated as a clinical dosimeter. High dose rate brachytherapy is also being evaluated.

Publications

T.J. Bichay, M.M. Feeley and G.P. Raaphorst (1992) *A comparison of heat sensitivity, radiosensitivity and PLDR in four human melanoma cell lines*. Melanoma. Research. 2, 63-69.

C.E. Danjo, E. Zakhour, G.P. Raaphorst, L.H Gerig, and S. Grim (1992) Thermalradiotherapy for local, superficial, recurrent cancer. Can. J. Oncol. 2, 57-61.

L.H. Gerig, J. Szanto and G.P. Raaphorst, (1992) *The Clinical Use of Thermocouple thermometry* Fron. Med. Bio. Eng. 4(2): 105-117.

L.H. Gerig, J. Szanto and G.P. Raaphorst, (1992) *On the spatial resolution of clinical thermometers* Med. Phys., 19, 679-684.

G.P. Raaphorst and M.M. Feeley (1992) *A comparison of the pH dependence of recovery of potentially lethal radiation damage in normal and tumour cells of human and rodent origin* Life Sciences, Advances in Oncology, 11: 13-18.

G.P. Raaphorst, M. Thakar and C.E. Ng (1992) *Radiosensitization by hyperthermia in CHO parental cell lines and their radiation sensitive mutants* Proceedings of 6th International Congress of Hyperthermia (Edited by E.W. Gerner), Taylor & Francis, pg. 83.

G.P. Raaphorst, J. Szanto J. Cygler and A. Laewen (1993) *A safe method of analysis for mechanical damage in spherical radioactive sources used in remote afterloading brachytherapy devices.* Medical Physics 20(1): 247-249.

G.P. Raaphorst, M.M. Feeley, C.E. Danjoux, V. Da Silva and L.H. Gerig (1991) *Hyperthermia enhancement of radiation response and inhibition of recovery from radiation damage in human glioma cells* Int. J. Hyperthermia. 7, 629-641.

G.P. Raaphorst and E.I. Azzam (1992) *Comparison of recovery, inhibition and fixation of damage after heating and radiation* J. Thermal Biol. 17, 19-24.

G.P. Raaphorst (1992) *Recovery of sublethal radiation damage and its inhibition by hyperthermia in normal and transformed mouse cells* Int. J. Radiat. Oncol. 22, 1035-1041.

G.P. Raaphorst and E.I. Azzam (1992), *Response of transformed and normal mouse cell lines to anti melanin compounds, hyperthermia and radiation.* Pigment Cell Res. 5(1): 25-3.

M. Soubra, J. Cygler and G. MacKay (1993) *Evaluation of a MOSFET Detector as Radiation Dosimeter* Medical Physics, In press.

J.G. Szekely, G.P. Raaphorst, A.U. Lobreau, S. Delaney and E.I. Azzam (1992) *The effect of colcemid on the heat survival of mitotic V79 Chinese hamster cells* Scanning Microscopy, 6, 177-182.

J. Van Dyk, R. Barnett, J. Cygler and P. Shragge (1993) *Commissioning of Quality Assurance of Treatment Planning computers* - Int. J. Rad. Onc. Biol. Phys., in press.

G.P. Raaphorst, M.M. Feeley, G.L. Chu GL W.C. Dewey (1993), *A comparison of the effect of hyperthermia on DNA polymerase in hamster and human glioma cells* Int. J. Hypertherm. 9, 303-312.

G.P. Raaphorst, M.M. Feeley, G.L. Chu GL W.C. Dewey (1993) *A comparison of hyperthermia enhancement of radiation sensitivity and DNA polymerase inactivation in human glioma cells* Radiat. Res. In press.

D.E. Wilkins, G.P. Raaphorst, J.K. Saunders and I.C.P. Smith (1993) *A new technique for implanting intracranial 9 L tumours in rats* Lab. Animal Sci. In press.

G.P. Raaphorst, D.P. Heller, A. Bussey and C.E. Ng (1993) *Thermal Radiosensitization by 40°C hyperthermia during low dose-rate irradiation in human normal and tumour cell lines* Int. J. Hypertherm. In press.

Funding:

NCIC grant for the study of cellular radiosensitivity, three years - $64,000/year.
NCIC grant for the study of cisplatin in combination with low dose rate

irradiation, three years - $95,000/year.
NIH Grant, Study of hyperthermic and low dose rate irradiation, three years - $128,000/year.
Industrial funding for development of patient positioning monitor system, five years - $500,000
ORCC capital and operating fund - $16,000
$16,000/year, MRC graduate fellowship
$16,000/year, NSERC graduate fellowship

Dave Rogers

Research: Using Monte Carlo techniques to calculate correction factors required for primary radiation standards. Recent examples are the calculation of wall correction factors for ionization chambers used for air kerma standards, and the calculation of the wall effect for Fricke dosimeter vials. These correction factors have a significant impact on several national standards.

Developing more accurate and easily used clinical dosimetry protocols. In this regard, the effect of beam size and beam quality on ionization chamber calibration factors is being calculated. Also, work is underway on a formalism which will use absorbed dose, rather than exposure, calibration factors.

Measuring fundamental data using the NRC linear accelerator. A recent project has accurately measured the bremsstrahlung yield from thick targets as a function of energy and angle and compared the results to Monte Carlo calculations. Another project is underway to measure electron stopping powers which play a fundamental role in radiation dosimetry but have never been measured with an accuracy of better than 5%.

Working on the OMEGA project. This is a collaboration with Rock Mackie's group at the University of Wisconsin to develop a Monte Carlo based code to calculate the dose in a patient undergoing electron beam radiotherapy. We are developing a general purpose code to model radiation beams from clinical accelerators.

Publications:

D.W.O. Rogers, C.K. Ross, K.R. Shortt, N.V. Klassen and A.F. Bielajew (1993) *Towards a Dosimetry System Based on Absorbed-Dose Standards* submitted to IAEA Symposium on Measurement Assurance in Dosimetry, April 1, 1993 (invited paper).

C.K. Ross, K.R. Shortt, D.W.O. Rogers and F. Delaunay (1993) *A test of* TPR_{10}^{20} *as a Beam Quality Specifier for High-Energy Photon Beams*, submitted to IAEA Symposium on Measurement Assurance in Dosimetry, April 1, 1993 (refereed proceedings).

K. Hohlfeld, M. Boutillon, B.M. Coursey, B. Owen and D.W.O. Rogers (1993) *Comparison of primary water absorbed dose standards* (invited paper), submitted to IAEA Symposium on Measurement Assurance in Dosimetry, April 1, 1993.

D.W.O. Rogers (1993) *How Accurately Can EGS4/PRESTA Calculate Ion Chamber Response*, Med. Phys. 20 319-323.

A. Kosunen and D.W.O. Rogers (1993) *Beam Quality Specification for Photon Beam Dosimetry* , Med. Phys. 19 #4.

C.M. Ma, D.W.O. Rogers, K.R. Shortt, C.K. Ross, A.E. Nahum and A.F. Bielajew (1993) *Wall Correction and Absorbed Dose Conversion Factors for Fricke Dosimetry: Monte Carlo Calculations and Measurements*, Med. Phys 20 283-292.

A.F. Bielajew and D.W.O. Rogers (1992) *A standard timing benchmark for EGS4 Monte Carlo Calculations*, Medical Physics 19 303-304.

D.W.O. Rogers and B.A. Faddegon (1992) *Re-evaluation of the total stopping power of polystyrene for 5.3 MeV electrons*, Phys. Med. Biol. 37 969-983.

D.W.O. Rogers (1992) *Calibration of Parallel-Plate Ion Chambers: Resolution of Several Problems by Using Monte Carlo Calculations*, Medical Physics 19 889-899.
A.F. Bielajew and D.W.O. Rogers (1992) *Implications of new correction factors on primary air kerma standards in ^{60}Co beams*, Phys. Med. Biol. 37 1283-1291.
D.W.O. Rogers (1992) *The Advantages of Absorbed Dose Calibration Factors*, Medical Physics 19 1227-1239.
B.A. Faddegon, C.K. Ross and D.W.O. Rogers (1992) *Measurement of Collision Stopping Powers of Graphite, Aluminium and Copper for 10 and 20 MeV electrons*, Phys. Med. Biol. 1561-1571.
B.A. Faddegon and D.W.O. Rogers (1992) *Comparisons of thick-target bremsstrahlung calculations by EGS4 and ITS*, in press, Nucl. Instr. Meth. A.
X.A. Li and D.W.O. Rogers (1992) *Electron Mass Scattering Powers Calculated Using Monte Carlo Simulation* submitted to Med. Phys., Dec.
M. Holmes, Y.T. Mackie, W. Sohn, S.S. Kubsad, P. Reckwerdt, J.S. Kinsella, A.F. Bielajew and D.W.O. Rogers (1992) *The Application of correlated sampling to the computation of electron beam dose distributions in heterogeneous phantoms using the Monte Carlo method*, submitted to Phys. Med. Biol. Sept.
D.W.O. Rogers (1992) *New Dosimetry Standards*, in 'Advances in Radiation Oncology Physics', ed. J. Purdy, Medical Physics Monograph 19 90-110.
D.W.O. Rogers (1992) *Fundamentals of High Energy X-ray and Electron Dosimetry Protocols* in 'Advances in Radiation Oncology Physics', ed. J. Purdy, Medical Physics Monograph 19 181-223 AAPM (New York).

Funding NRC - ongoing operations and capital funds
NSERC - graduate student support of $12.5 k/year
NIH - $100k/year (to Ottawa) for three years for the OMEGA project.

Carl Ross

Research: Using water calorimetry to establish absorbed dose standards for ^{60}Co γ-rays and high energy x-rays. An important consideration in the dissemination of these standards is the specification of beam quality. We are studying various quality specifiers which are either in routine use or have been proposed in the literature.

We have done a series of measurements of high-energy x-ray spectra using a large NaI detector. We are now starting a project to measure electron stopping powers using the same detector. This requires operating our linear accelerator with an average beam current of less than 0.5 electrons per beam pulse.

Publications:

C.K. Ross, K.R. Shortt, D.W.O. Rogers and F. Delaunay (1993) *A test of TPR_{10}^{20} as a Beam Quality Specifier for High-Energy Photon Beams*, submitted to IAEA Symposium on Measurement Assurance in Dosimetry, April 1, 1993 (refereed proceedings).

D.W.O. Rogers, C.K. Ross, K.R. Shortt, N.V. Klassen and A.F. Bielajew (1993) *Towards a Dosimetry System Based on Absorbed-Dose Standards* submitted to IAEA Symposium on Measurement Assurance in Dosimetry, April 1, 1993 (invited paper).

C.M. Ma, D.W.O. Rogers, K.R. Shortt, C.K. Ross, A.E. Nahum and A.F. Bielajew (1992) *Wall Correction and Absorbed Dose Conversion Factors for Fricke Dosimetry: Monte Carlo Calculations and Measurements* in press, Med. Phys. 20 283-292.

I. Janovsky and C.K. Ross (1993) *The IRS Thermoluminescent Dosimetry System*, NRC Report, PIRS-0369.

B.A. Faddegon, C.K. Ross and D.W.O. Rogers (1992) *Measurement of Collision Stopping Powers of Graphite, Aluminium and Copper for 10 and 20 MeV electrons*, Phys. Med. Biol. 1561-1571.

C.K. Ross and K.R. Shortt (1992) *The Effect of Waterproofing Sleeves on Ionization Chamber Response*, Phys. Med. Biol. 37 1403-1411.

Funding: Supported as a member of NRC staff.

Ken Shortt

Research: Involved with the establishment of a primary standard of absorbed dose to water for high energy x-rays. The approach is to use a water-filled calorimeter whose heat defect can be calculated or measured to calibrate a Fricke chemical dosimeter solution. The calibrated solution is placed in small glass vials to determine the dose at a point. The Canadian dose standard has been compared to those of other countries using transfer ionization chambers. A number of perturbations, such as those caused by vial walls and water proofing sleeves are under investigation.

Publications:

K.R. Shortt, C.K. Ross, M. Schneider, K. Hohlfeld, M. Roos and A.-M. Perroche (1993) *A Comparison of Absorbed Dose Standards for High Energy X-rays*, submitted to Phys. Med. Biol.

C.K. Ross, K.R. Shortt, D.W.O. Rogers and F. Delaunay (1993) *A test of* TPR_{10}^{20} *as a Beam Quality Specifier for High-Energy Photon Beams*, submitted to IAEA Symposium on Measurement Assurance in Dosimetry, April 1, 1993 (refereed proceedings).

D.W.O. Rogers, C.K. Ross, K.R. Shortt, N.V. Klassen and A.F. Bielajew (1993) *Towards a Dosimetry System Based on Absorbed-Dose Standards* submitted to IAEA Symposium on Measurement Assurance in Dosimetry, April 1, 1993 (invited paper).

C.M. Ma, D.W.O. Rogers, K.R. Shortt, C.K. Ross, A.E. Nahum and A.F. Bielajew (1992) *Wall Correction and Absorbed Dose Conversion Factors for Fricke Dosimetry: Monte Carlo Calculations and Measurements* in press, Med. Phys. 20 283-292.

C.K. Ross and K.R. Shortt (1992) *The Effect of Waterproofing Sleeves on Ionization Chamber Response*, Phys. Med. Biol. 37 1403-1411.

Funding: Supported as a member of NRC staff.

Tony Waker

Research: The application of microdosimetric methods and counters in radiation protection mixed field dosimetry and the development of low pressure tissue equivalent proportional counters with enhanced sensitivity. Microdosimetry and neutron spectrometry in support of neutron dosimetry for therapy, radiobiology and radiation protection. Criticality accident dosimetry.

Publications:
P.K. Verma and A.J. Waker (1992) *Optimization of the Electric Field Distribution in a Large Volume Tissue Equivalent Proportional Counter* Phys. Med. Biol. 37 10 1837-1846.

D.J. Thomas, A.J. Waker, J.B. Hunt, A.G. Bardell and B.R. More *An Intercomparison of Neutron Field Dosimetry Systems* Rad. Prot. Dosim. 44 No. 1/4 219-222.

A.J. Waker (1992) *Microdosimetry--The Next 25 Years* Editorial, Rad. Prot. Dosim. 42 No. 2 75-76.

A.J. Waker, B. Oldroyd and M. Marco (1992) *The Application of Microdosimetry in Clinical Bone Densitometry Using a Dual-Photon Absorptiometer* Brit. J. Radiol. 65 523-527.

A.J. Waker and M. Marco (1992) *The Application of Microdosimetry to the Metrology of Low Energy X-Rays Used in Mammography* Brit. J. of Radio. 65 258-261.

Funding: Candu Owners Group

11. Kudos

Two graduate students associated with the MPORU have been awarded Medical Research Council scholarships. They are George Ding (supervised by Dave Rogers) and Julia Wallace (supervised by Peter Raaphorst).

MPORU members Jano Szanto and Doug Salhani are now members of the Canadian College of Physicists in Medicine after having successfully passed the written examinations.

Julia Wallace was one of two winners in the Carleton University Faculty of Science Graduate Student Poster Contest. Each winner is awarded free tuition for one term at Carleton.

Paul Johns was one of the CAP lecturers this year and gave talks at Laurentian University, Queen's University and the Royal Military College.

12. In Memory of Jiansu Wei, 1957-1993

On March 15 this year, the MPORU suffered the loss of Jiansu Wei, who died of liver problems apparently caused by an adverse drug reaction.

Jiansu was born on Oct. 14, 1957 to a worker's family in Ziyang in Sichuan province, in the Peoples Republic of China. He went to high school there and in 1977 he entered Chongching University and obtained his B.Sc. degree in Physics in 1982. After a year and a half as a high school teacher, he pursued his graduate study at Sichuan University and obtained his M.Sc in 1985. Then he worked as an assistant lecturer in the Physics Department at the Huadong University of Engineering. A year later, he became a lecturer there.

He came to Canada in 1989 as a graduate student in the Dept. of Physics at the University of Windsor where he worked with Professor Bill Baylis doing theoretical physics. He received his second M.Sc. in August 1991, and published two papers in

theoretical physics; one as the senior author[1] and one about the role of imaginary numbers in physics with the intriguing title "Why i?"[2] To quote from his letters of reference from Windsor, "Mr Wei is a top-notch theoretical physicist who has a deep concern about providing for his small family. We will sorely miss him when he goes to Ottawa".

In the fall of 1991 Jiansu came to Carleton University to study medical physics under my supervision. He was working on the OMEGA project to provide accurate treatment planning for electron beam radiotherapy.

We grew accustomed to Jiansu softly bouncing into our group meetings with a smile on his face. This meant he had either found and corrected a bug in one of our standard computer programs; or he had developed a new general purpose piece of code which could do absolutely everything; or he had a better way to do the entire project and we should throw out three years of work! This always made for interesting meetings and forced us all to be on our toes and to re-examine old assumptions. In other words Jiansu was a first rate physicist who was making a major contribution to the project.

Jiansu was very fast at researching a new topic and would immediately recognize where arguments were weak and try to break them completely and then explore other approaches to the problem. While working on the overall OMEGA project, he had begun work on his own thesis research which was to be on multileaf collimators; and he had already programmed the most sophisticated model yet available. It is a great shame that this work has stopped as suddenly as it had started since I know Jiansu would have made a major contribution to the effectiveness of this new technology for cancer treatment. Jiansu was helping prepare a paper describing the work done so far on the OMEGA project. When published, this paper will be dedicated in memory of Jiansu.

Jiansu placed a great deal of importance on "doing science". However there was more to Jiansu than just science. He was friendly and helpful, he worked very hard, he was excited by ideas and he had a strong sense of what was right. For example, rather than call in sick after his operation for an ulcer late last fall, he had his work marking university assignments brought into the hospital for him to do in his bed!

Jiansu cared deeply for his family. Nothing could stop Jiansu from trying to convince someone about some point of physics - except when he had to leave to pick up his daughter, Lucy, from school or day care. Jiansu's friends are deeply concerned for his family at this time. We share the grief of Qiong Li and Lucy who have lost a dear husband and father. We know we cannot lessen that loss. However, at this difficult time there have been memorial funds established in memory of Jiansu Wei at the NRC, Carleton University and by the Chinese Students and Scholars Association.

I will end by saying how deeply we are going to miss Jiansu. He was a good man, he had a brilliant mind and a very bright future. His friends and colleagues will miss him.

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[1] *Monopoles without strings: a conflict between the one-photon condition and duality invariance,* Jiansu Wei and W.E Baylis, Found. of Phys Lett. 4 (1991) 537-556.

[2] *Why i?* , W.E. Baylis, J. Huschilt and Jiansu Wei, Am. J. Phys. 60 (1992) 788-797.

Dave Rogers
Ionizing Radiation Standards, NRC

13. CVs of New MPORU Members

This year we welcome Tony Waker (AECL) as a new member of the MPORU. Highlights from Tony's CV are given below. The CVs of established members may be found in previous Newsletters.

Anthony J. Waker

Mailing Address: AECL Research
Health Physics Branch
Chalk River Laboratories
Chalk River, Ontario K0J 1J0

Telephone: 613-584-3311 ext. 4754
613-584-4024 (fax)

Current Position: Research Scientist, AECL Research
Associate Professor (part time), Physics
McMaster University

Previous Positions: Lecturer, Medical Physics
University of Leeds, U.K.

Education: PhD - South Bank Polytechnic, London, U.K.
Joint European Research Centre, Ispra, Italy

B.Sc - South Bank Polytechnic, London, U.K.

Sample Publications:

A.J. Waker, B. Oldroyd and M. Marco (1992) *The Application of Microdosimetry in Clinical Bone Densitometry Using a Dual-Photon Absorptiometer* Brit. J. Radiol. 65 523-527.

D.J. Thomas, A.J. Waker, J.B. Hunt, A.G. Bardell and B.R. More *An Intercomparison of Neutron Field Dosimetry Systems* Rad. Prot. Dosim. 44 No. 1/4 219-222.

P.K. Verma and A.J. Waker (1992) *Optimization of the Electric Field Distribution in a Large Volume Tissue Equivalent Proportional Counte*r Phys. Med. Biol. 37 No. 10 1837-1846.

A.J. Waker, M.T. Eivazi and T.T. Williams (1992) *Low Energy X-Ray Dosimetry in Standard Fields Using Low Pressure Proportional Counters* Phys. Med. Biol. 37 No. 6 1231-1243.

H.G. Menzel, H. Schuhmacher, A.J. Waker, Th. Schmitz and L. Lindborg (1989) *Radiation Protection Instruments Based on Proportional Counters - Part II of an International Intercomparison* Rad. Prot. Dosim. 29 No. 1-2 55-68.

A.J. Waker and R. Brown *Application of Cavity Theory to the Discharge of Electrostatic Dust Filters by X-Rays* Int. Jour. of Appl. Rad. and Isotopes Part A 39 No. 7 667-684.