

iCORE RESEARCH

FISCAL 2008



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2008 Research Report



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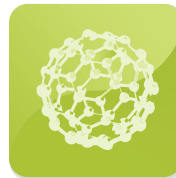
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President's Message

As I reviewed the new form of this iCORE annual research publication, the old adage “Good things come in small packages” came to mind. And it is fitting, not just for this publication, but also for iCORE as a whole.

This fiscal 2008 iCORE Annual Research Report has been re-designed into a smaller and easily digestible package. This year, we are including Executive Summaries from each active iCORE researcher, along with PDF versions of their full research report, and a DVD of many of the research presentations made at our 2008 iCORE Summit. It is our hope that it allows readers to get quickly see the breadth and depth of the iCORE Academy, and then delve further into any area of research interest for a more thorough understanding.

On a larger scale, iCORE is working on a similar re-package. Throughout 2009, we are working with the Ministry of Advanced Education and Technology on making research funding, collaborations and pathways to building on Alberta's economy more accessible, to leverage the good things iCORE does so well. Ten years after iCORE was established by the Government of Alberta to foster an expanding community of exceptional researchers in disciplines related to information and communications technology (ICT), iCORE is now a small agency with 29 Research Chairs in areas as diverse as Medicine, Power Systems, Plant Genomics, and Nanoscale Devices.

Research by the iCORE Academy is not only working on solutions for fundamental ICT solutions; including foundations of quantum computing, scalable



solutions to managing large data sets, and knowledge extraction through intelligent data mining, but are applying those technologies in ways that improve medical diagnoses and treatments, support more efficient management of power distribution grids, and even increase the effectiveness of solar panels. These are pretty impressive accomplishments for a relative handful of researchers working in a few universities in Alberta. Good things... small package.

A handwritten signature in black ink that reads "R. Goebel".

Randy Goebel
President and CEO,
iCORE



About iCORE

The role of the Alberta Informatics Circle of Research Excellence

iCORE was established in October 1999 by the Government of Alberta to foster an expanding community of exceptional researchers who support and grow the ICT sector. This investment stems from a belief that strong fundamental research is at the core of a healthy economic sector, which in turn creates social, cultural and economic advantages for Albertans.

Mission

The mission of the Alberta Informatics Circle of Research Excellence (iCORE) is to attract and grow a critical mass of exceptional researchers in the field of informatics, that is, areas of computer science, electrical and computer engineering, physics, mathematics and other disciplines related to information and communications technology (ICT).

Target areas

As part of the Government of Alberta's strategy to create a globally competitive knowledge-based economic sector, iCORE is directing its support to areas in which Alberta has a chance to develop internationally recognized research teams. It is also focusing on areas in which Alberta companies are active, so that intellectual property and valuable knowledge workers resulting from iCORE's investment will have compelling reasons to stay in Alberta.

Focus on people

iCORE invests in people – the highest caliber research scientists who work on fundamental and applied problems in informatics. Around these leaders, world-class research teams are developed.

The iCORE principle is simple: exceptional people produce exceptional results.

Flagship Grant Programs

Chair and Professor Establishment (CPE) Grants

iCORE Chairs are awarded to exceptional researchers with outstanding research records that place them in the top five percent of their fields. iCORE Professors are mid-career researchers with outstanding potential whose record may not yet justify a Chair position.

Funding research teams may vary in size from a single Chair or Professor working alone to teams with ten or more members. iCORE funds can be used to cover the salaries of chairs, professors, research associates, postdoctoral fellows and graduate students, as well as some research operating and equipment costs. The research itself may range from fundamental to applied.

CPE grants are normally awarded for five years, represent one-half or less of the total budget, and are renewable on a competitive basis.

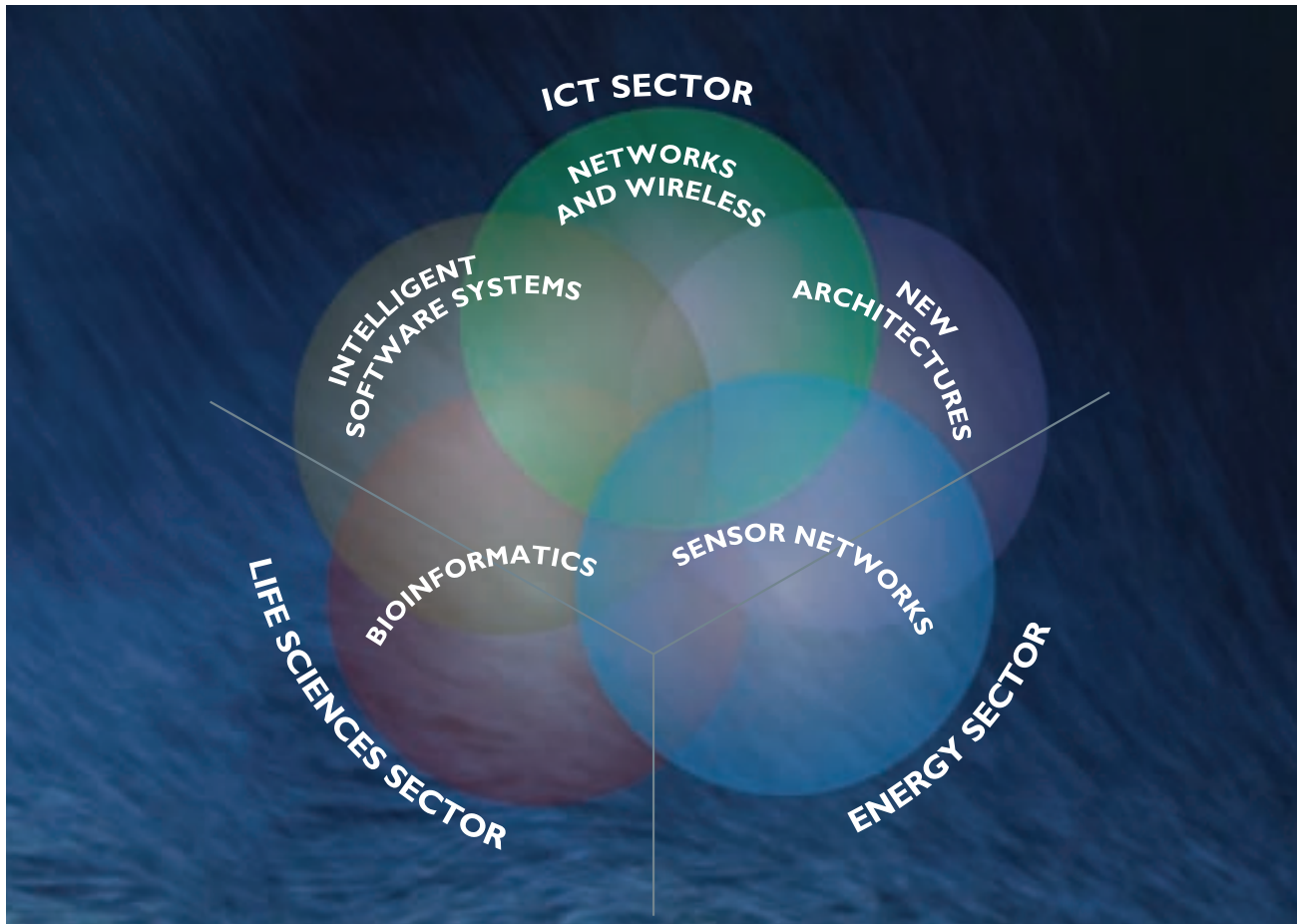
Industry Chair Establishment (ICE) Grants

iCORE Industry Chairs are awarded to researchers undertaking high-caliber, internationally competitive research. Industry Chairs are always developed in conjunction with a sponsor company(s) that has demonstrated a willingness and ability to collaborate closely with the research team, and to exploit proposed research in Alberta. The program is also typically matched with NSERC awards.

Funded research teams may vary in size from one to ten or more members, and may include a Chair, professors, research associates, postdoctoral researchers, graduate students and research staff. The funds may also cover operating and equipment costs.

ICE grants are normally awarded for five years, represent one-third or less of the total budget, and are renewable on a competitive basis.

Clusters



Support programs

Graduate Student Scholarships (GSS)

- Designed to recruit exceptional graduate students in computer science and electrical and computer engineering
- Operates in conjunction with Alberta Ingenuity

Visiting Professor (VP) Grants

- Designed to bring internationally recognized researchers to Alberta for six months to two years to develop partnerships and possibly recruit Chairs or Professors

ICT Strategy Planning and Recruiting (ISPR) Grants

- Designed to support the interaction with potential candidates for major iCORE award programs
- Supports ICT conferences and workshops in Alberta in areas where a Chair or Professor award may be made

Banff Summit

- An annual event that brings together iCORE researchers and their national and international colleagues

iCORE Academy

Networks and Wireless Communication		start date
Wireless Communications	Dr Norman C. Beaulieu	2000-01
Intelligent RF Radio Technology	Dr Fadhel Ghannouchi	2004-05
Wireless Science and Technology	Dr James W. Haslett (now ATIPS)	2002-03
Advanced Technology Information Processing Systems	Dr Graham Jullien	2000-01
High Capacity Digital Communications	Dr Christian Schlegel	2001-02
Broadband Wireless Networks, Protocols, Applications, and Performance	Dr Carey Williamson	2001-02
Wireless Traffic Modelling and Simulation	Dr Carey Williamson	2002-03
New Architectures		
Algorithmic Number Theory and Cryptography	Dr Hugh Williams	2001-02
Nanoengineering ICT Devices	Dr Michael Brett	2000-01
Thin Film Engineering	Dr Michael Brett	2003-04
Nanoscale Physics and Nanomaterials	Dr Mark Freeman	2003-04
Quantum Information Science	Dr Barry Sanders	2003-04
Quantum Cryptography and Communication	Dr Wolfgang Tittel	2005-06
Nanoscale ICT	Dr Robert Wolkow	2002-03
Intelligent Software Systems		
Information Security	Dr Rei Safavi-Naini	2006-07
Advanced Digital Media for Education	Dr Anup Basu	2005-06
Collaborative Virtual Environments	Dr Pierre Boulanger	2004-05
Interactive Technologies	Dr Sheelagh Carpendale and Dr Saul Greenberg	2006-07
Services Systems Management	Dr Eleni Stroulia	2008-09
High Performance Artificial Intelligence	Dr Jonathan Schaeffer	2000-01
Computer Process Control	Dr Sirish Shah	2005-06
Reinforcement Learning and Artificial Intelligence	Dr Rich Sutton	2003-04
Intelligent Sensing Systems	Dr Hong Zhang	2003-04
Bioinformatics		
Biocomplexity and Informatics	Dr Stuart Kauffman	2004-05
Applied Bioinformatics	Dr Christoph Sensen	2004-05
Biosystems Informatics	Dr Gane Ka-Shu Wong	2007-08
Medical Imaging Informatics	Dr Ross Mitchell	2008-09
Sensor Networks		
Wireless Location	Dr Gérard Lachapelle	2000-01
Power Quality	Dr Wilsun Xu	2007-08

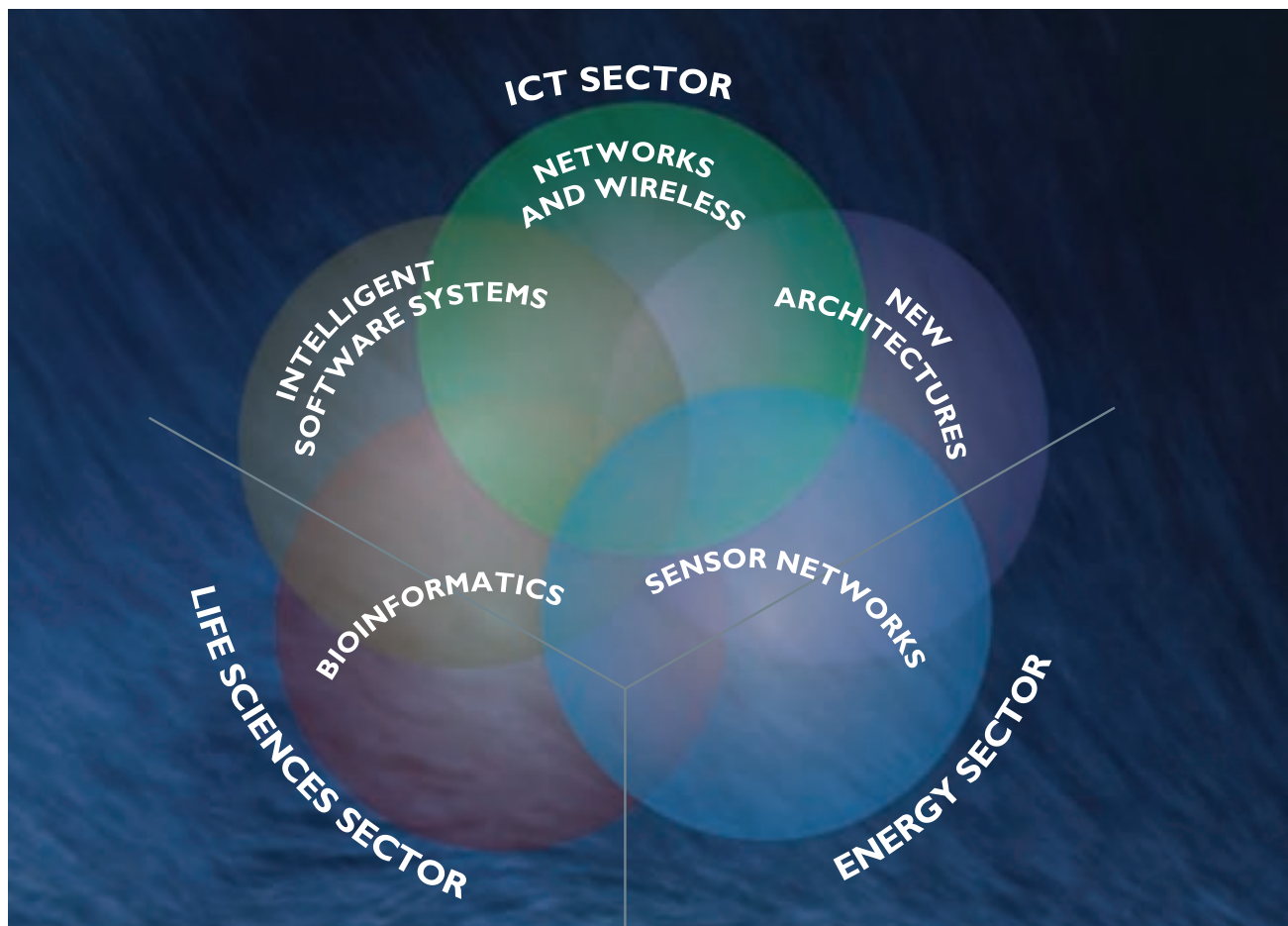
Networks and Wireless Communications

Starting from the recruitment of Dr Graham Jullien in 2001, iCORE's investment in Networks and Wireless Communications has focused on research solutions for tangible problems and applications. As the demands on networks and from wireless applications continue to grow, iCORE Chairs work to find innovative ways of handling the strain while improving performance.

Dr Jullien's Advanced Technology Information

Processing Systems (ATIPS) laboratory has become a knowledge network for biomedical, information security, and other advanced technology applications. iCORE Chair Dr Jim Haslett is now running the ATIPS lab.

Also in 2001, Dr Norman Beaulieu was brought on board to find new ways of maximizing the traffic that can travel on the increasingly limited resources of the wireless spectrum. Though his research focus is the most fundamental aspects



of the science of broadband wireless communications, technology developed by the iCORE Wireless Communications Laboratory is now in use in the Wireless Metropolitan Area Network protocols and elsewhere.

The 2002 addition of Dr Carey Williamson increased the ability of this cluster to tackle the problems of wireless local area networks, Internet traffic classification, and cellular network provisioning. This Chair's industry collaboration with TELUS Mobility applies high-level research solutions to real-world problems.

The newest member of the iCORE Networks and Wireless Communications Cluster, Dr Fadhel Ghannouchi joined the Networks and Wireless Communications Cluster in 2005. His team's recent Green Electronics innovations have made the news and will soon be making cellular technology more environmentally friendly.

These cutting-edge solutions to the problems of today are examples of research meeting the needs of industry and the people of Alberta.



Dr Norman C. Beaulieu



Dr Fadhel Ghannouchi



Dr Graham Jullien

Dr Jim Haslett



Dr Christian Schlegel



Dr Carey Williamson

Networks and Wireless Communications

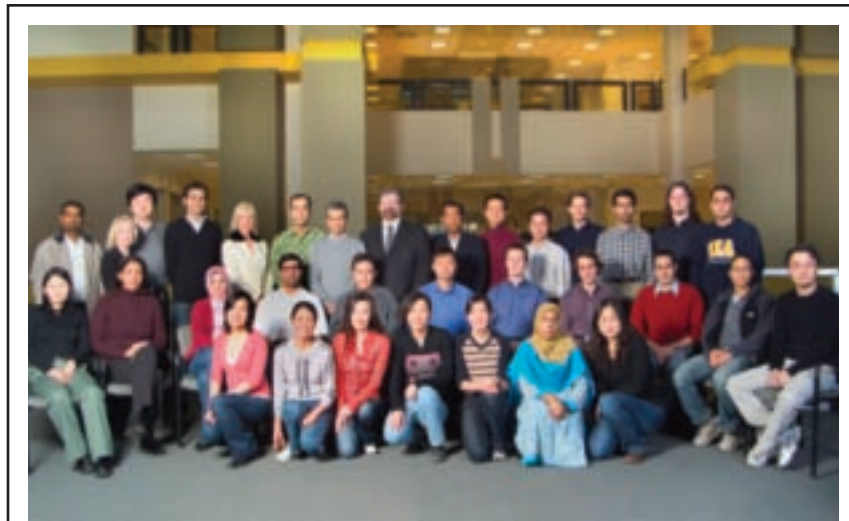


Wireless Communications Lab

The overall goal of the iCORE Wireless Communications Laboratory (iWCL) research program is to create new engineering science and technologies that will lead to high capacities in broadband wireless communication systems at lower cost. Current topics under investigation by the iWCL include ultra-wide bandwidth (UWB) systems, cooperative wireless networks, wireless sensor networks, orthogonal frequency division multiplexing (OFDM) systems, multi-user detection, space-time coding, multiple input multiple output (MIMO) systems, wireless channel modelling, and synchronization.

Successful research collaborations have resulted in journal papers, conference papers, patent applications, and technology licensing. New graduates trained in the iWCL have secured industry and teaching positions. In terms of intellectual property, the iWCL applied for six patents in the reporting period, on technologies for UWB, MIMO, pilot symbol assisted modulation (PSAM), and low density parity check codes (LDPC).

In 2008, the Chair published 24 refereed journal papers, all in leading international journals. A



Dr Beaulieu's Research Team, Members of the Wireless Communications Lab

further 25 refereed journal papers were awaiting publication or were accepted in the reporting period, again all in leading international journals. In addition, 30 conference papers were presented by the iCORE Chair and his research trainees.

In this reporting year, Professor Beaulieu was appointed an IEEE Distinguished Lecturer and was listed in the MARQUIS publications Who's Who in American Education, Who's Who in America, and Who's Who in the World. Dr Beaulieu was selected to appear on Thomson Scientific's ISIHighlyCited.com. He is one of only seven researchers at the

University of Alberta, and one of only five researchers in Electrical and Computer Engineering in Canada so honoured. Additionally, he is one of only two researchers in communications in Canada to ever have been listed on ISIHighlyCited.com. He was also awarded the most prestigious award for technical achievement of the IEEE Communications Society, the Edwin Howard Armstrong Achievement Award, for "outstanding contributions to the analysis, design, and modeling of wireless communication systems."

The Chair's outreach activities included revising an encyclopedia article for eight to ten-year-olds

Dr Norman C. Beaulieu



Ultra-wide bandwidth wireless (UWB) is an overlay technology that will replace cables and wires by enabling users to send data at hundreds of megabytes per second



iCORE researchers (left to right) Norman Beaulieu, Bo Hu, Hua Shao, and Somasundaram Niranjayan have published papers in international journals and conferences and filed patents on novel technologies for UWB.

and giving seminars on intellectual property to new faculty members.

In consequence of the achievements, awards, recognition, and growth of the first ninety-one months, the iCORE Wireless Communications Laboratory is now renowned in the international communications research community and is increasing international and national awareness of Alberta, iCORE, and the University of Alberta ⑦



Location: University of Alberta

Department: Electrical and Computer Engineering

Team Members: 56

Website: <http://www.ualberta.cac/~iwd>

Biography: Dr Norman C Beaulieu has been an iCORE Chair since 2001. He received his PhD degree from the University of British Columbia. He was Associate Head of Electrical and Computer Engineering at Queen's University before joining the Department of Electrical and Computer Engineering at the University of Alberta in 2000.

In 2006, Dr Beaulieu won the J Gordin Kaplan Award for Excellence in Research, the most prestigious award at the University of Alberta. He also won the ASTEC Outstanding Leadership in Alberta Technology Award, and was elected fellow of the Canadian Academy of Engineering. He has been featured in a Time Magazine article. In 1999, Beaulieu won one of four NSERC E. W. R. Steacie Memorial Fellowships, Canada's top prize for all areas of scientific research, and was elected Fellow of the IEEE ⑦

Networks and Wireless Communications

COLLABORATIONS – DR BEAULIEU

<i>Participants</i>	<i>Nature of Collaboration</i>
Provincial Collaborations	
R. Carruthers, University Technologies International, Calgary, AB	1 International conference paper accepted 1 International conference paper presented
Dr P. Tan, TELUS, Edmonton, AB	2 Accepted journal papers 1 Published journal paper 3 Submitted journal papers 1 International conference paper presented 2 National conference papers presented
Faculty of Engineering, MINT Program	Funding assistance
TEC Edmonton	Financial assistance
ECE Dept., U. of Alberta	Financial assistance and IT assistance
M. Ardakani, U. of Alberta	Funding assistance
C. Tellambura, U. of Alberta	Funding assistance
S. Vorobyov, U. of Alberta	Funding assistance
A. Fapojuwo, U. of Calgary	Funding assistance
ECE Graduate Students and Postdoctoral Fellow	Graduate Students' Seminar Series (14 seminar presentations)
Kim Ito, TEC Edmonton	TEC Student Entrepreneur Program to discuss student involvement in the program and how it might benefit some students

Dr Anup Basu & Lihang Ying, Computer Science, U. of Alberta	Collaborative research in ad hoc wireless networks
2007 iCORE Summit	Chair of breakout session on Network and Wireless
Dr Eric Manning, Chair of iCORE's ICT Research Advisory Committee (IRAC)	To evaluate the impact on host departments of iCORE Chair Program
Dr M. Ardakani Dr C Tellambura Dr S. Vorobyov	Joint NSERC Strategic Grant Application (successful)
Dr J. Neilsen, U. of Calgary	UWB research proposal discussion
ECE Department, U. of Calgary	External examiner, final doctoral examination of Saeed Khalesehosseni
National Collaborations	
Dr M.O. Damen, U. of Waterloo	1 Accepted journal paper
Dr J. Cheng, UBC Okanagan	1 Accepted journal paper 1 Published journal paper 1 International conference paper accepted
Dr K.E. Baddour, Communications Research Centre (CRC), Ottawa	1 Accepted journal paper
Dept. of Mathematics & Statistics, Queen's University, Queen's Communications Group	Dr N.C. Beaulieu, Adjunct Professor
Canadian Society of Information Theory (CSIT)	President

Networks and Wireless Communications

Mr. S. Szyskowicz, Carleton University	Invited seminar series speaker Collaborative research on lognormal sums
Business, Research Advisory Council for the Centre for Communications and Information Technology, Ontario Centres of Excellence	Appointed member
Canadian Society of Information Theory (CSIT) Workshop (CWIT 2007), Edmonton, AB, June 6-8, 2007	General Chair (one of two)
Dr R. Schober, UBC	Joint NSERC Strategic Grant Application (successful)
ECE Department, UBC	External examiner, final doctoral oral exam of Christopher Snow
International Collaborations	
Dr J. Fiorina, Supélec, Paris, France	1 Accepted journal paper
Dr Y. Chen, University of Warwick, UK	3 Accepted journal papers 5 Published journal papers 5 Submitted journal papers 3 International conference papers accepted 2 International conference papers presented
Dr S.J. Lee, Electronics & Telecommunications Research Institute (ETRI), Korea	3 Accepted journal papers 1 Submitted journal paper 3 International conference papers presented

Dr Y. G. Kim, University of Seoul	2 Accepted journal papers 2 Submitted journal papers 2 International conference papers accepted 2 International conference papers presented
Dr Z. Du, Huawei Technologies, a leading telecommunications equipment manufacturer	2 Accepted journal papers 1 Published journal paper
Dr B. Hu, Schlumberger Cambridge Research, Cambridge, UK	2 Accepted journal papers 2 Published journal papers 1 Submitted journal paper 2 International conference papers
Dr S. Haghani, University of Southern Alabama	3 Published journal papers 1 Submitted journal paper 1 International conference paper accepted 3 International conference papers presented
W.Li, ALTERA Corp., California	1 Accepted journal paper
J. Li and D. X.-D. Zhang, Tsinghua University	1 Published journal paper
Dr J. Zhu, Anhui University	1 Accepted journal paper
K. Mahdavian and O. Taheri, Isfahan University	1 International conference paper accepted
Dr J.R. Barry, School of ECE, Georgia Institute of Technology	Invited external examiner

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Dr M.-S. Alouini, ECE Department, U. of Minnesota	Invited external examiner
Dr Hsiao-Hwa Chen, National Sun Yat Sen University, Taiwan	Invited seminar series speaker
Dr Hsiao-Hwa Chen, National Sun Yat Sen University, Taiwan	Invited seminar series speaker
Dr Liuqing Yang, University of Florida, Gainesville	Invited seminar series speaker
Dr M.Z. Win, Massachusetts Institute of Technology	Invited seminar series speaker
Radio Communications Committee (RCC), IEEE Communications Society	RCC Technical Recognition Award committee member RCC Outstanding Service Award committee member
IEEE Transactions on Communications	Editor for Wireless Communication Theory
Security and Communication Networks	Senior Editor
IEEE International Conference on Ultra- Wideband ICUWB 2009	Chair, Technical Program Committee
IEEE International Conference on Communications (ICC 2008)	Senior Co-Chair, Communication Theory Technical Symposium

10th International Symposium on Spread Spectrum Techniques and Applications (ISSSTA 2008)	Technical Program Committee Member
ChinaCom2008 Signal Processing for Communications Symposium	Technical Program Committee Member
The 10th International Symposium on Wireless Personal Multimedia Communications (WPMC 2007)	Technical Program Committee Member
IEEE GLOBECOM 2007 Conference (GLOBECOM 2007)	Technical Program Committee Member
2007 IEEE 66th Vehicular Technology Conference (VTC 2007 Fall)	Technical Program Committee Member
2007 IEEE International Conference on Intelligent Signal Processing and Communication Systems (ISPACS07)	Technical Program Committee Member
24th Queen's Biennial Symposium on Communications	Technical Program Committee Member
Mathematical Reviews (MR) Editorial Board	Editor-Reviewer

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1st International Conference on Cognitive Radio Oriented Wire-less Networks and Communi-cations (CrownCom 2007)	Technical Program Committee Member
IEEE Wireless Communications & Networking Conference (WCNC 2007)	Technical Program Committee Member
IEEE Asia Pacific Operations Centre	Invited 2008 IEEE ComSoc Distinguished Lecturer – Asia Pacific
Harvard University	Invited Seminar Speaker
IEEE International Conference on Communications (ICC 2009)	Technical Program Committee Member
The 11th International Symposium on Wireless Personal Multimedia Communications (WPMC 2008)	Technical Program Committee Member
2007 IEEE 67th Vehicular Technology Conference (VTC 2008 Fall)	Technical Program Committee Member
Industry Collaborations	
Dr X. Zhang, NORTEL, Ottawa, Ontario	3 Published journal papers 2 Submitted journal papers 2 International conference papers presented
Dr K. Sivanesan, NORTEL, Richardson, Texas	1 Published journal paper

Strategic Wireless Solutions, Inc., Plant City, Florida	Consulting Agreement on Space-Time Codes
Klegg Electronics, Inc., UTEK Corporation	Discussion of licensing of the “Antenna Selection Methods for Alamouti MIMO Systems” technology from the U.of Alberta

COLLABORATIONS – DR TELLAMBURA

<i>Participants</i>	<i>Nature of Collaboration</i>
Provincial Collaborations	
Dr S. Vorobyov	Joint supervision of Phan Tran Khoa, M.Sc. Candidate
Industrial Collaborations	
Bell Canada	Contributor to their NSERC Strategic Grant Application (successful)
Sierra Wireless	Contributor to their NSERC Strategic Grant Application (successful)

COLLABORATIONS – DR ARDAKANI

<i>Participants</i>	<i>Nature of Collaboration</i>
Provincial Collaborations	
Dr N. C. Beaulieu Dr C. Tellambura Dr S. Vorobyov	Joint NSERC Strategic Grant Application (successful)
National Collaborations	
Dr R. Schober (UBC)	Joint NSERC Strategic Grant Application (successful)
Benjamin Smith, Wei Yu, Frank R. Kschischang (U. of Toronto)	Joint search on complexity optimization of LDPC codes
International Collaborations	
Pirouz Zarrinkhat, Airvana Inc., Boston, USA	Contributor to their NSERC Strategic Grant Application (successful)

Networks and Wireless Communications

INTELLECTUAL PROPERTY

<i>Applicants</i>	<i>Status</i>	<i>Title</i>
N.C. Beaulieu and H. Shao	US and International Patents Application, filed March 7, 2008	"A Zonal UWB Receiver and Method"
N.C. Beaulieu and S. Niranjan	US and Canadian Provisional Patent Application filed October 18, 2007	"A Myriad Filter Detector for Multiuser Communication"
N.C. Beaulieu and Z. Du	US and International Patents Application, filed August 31, 2007	"Decision-Feedback Detection for Block Differential Space-Time Modulation"
N.C. Beaulieu	US and International Patents Application, filed August 23, 2007	"System and Method for Receiving Time-Hopping UWB Signals"
N.C. Beaulieu and Y.G. Kim	US and Canadian Provisional Patent Application, filed August 21, 2007	"Hybrid Message Decoders for LDPC Codes"
N.C. Beaulieu	US and Canadian Provisional Patent Application, filed May 31, 2007	"Decorrelating Pre-Processor for Receiver Antenna Diversity"
N.C. Beaulieu and H. Shao	US and Canadian Provisional Patent Application, filed May 4, 2007	"A Novel P-Order Metric UWB Receiver Structure with Improved Performance in Multiple Access Interference"
N.C. Beaulieu	US and Canadian Provisional Patent Application, filed May 2, 2007	"UWB Receiver Designs Based on a Gaussian-Laplacian Noise-Plus-MAI Model"
N.C. Beaulieu and Y. Chen	US and International Patents Application, filed April 12, 2007	"Pilot Symbol Assisted Modulation Signal Processing Systems and Methods"

N.C. Beaulieu	Threaded Algebraic Space-Time Constellations and Threaded Algebraic Space-Time Code Construction Methodology	TEC Edmonton licensed this technology to an American corporation, and receives royalties for usage based on the number of units the technology is installed in. There is also a minimum royalty per year to be paid regardless of the number of unit installations. The legal agreement provides for profit sharing with TEC Edmonton if the licensee licences the technology to other companies.
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Networks and Wireless Communications



Intelligent RF Radio Technology

The trends in communication networks are toward ubiquitous, distributed, and cooperative networks, which will also be required to support the large demand for mobility and high-throughput specifications within the environment of multi-standard communications. This adds up to severe linearity requirements for wireless and satellite communications' mobile and fixed terminals accompanied, in most cases, with high direct current power consumption resulting in very low power efficiency. Accordingly, future radio systems will need to be designed to meet all the aforementioned critical capabilities, as well as to be less energy hungry and more environmental friendly, or "green." The mission of the Intelligent RF Radio Laboratory (iRadio Lab) is to develop new knowledge and innovative enabling technologies pertinent to intelligent and green radio systems and related applications that are valuable to our partners and sponsors and to train highly qualified personnel in radio frequency (RF) and wireless communications science and technology.

This laboratory is devoted to advanced research and development (R&D) activities relevant to intelligent and green RF radio technolo-



Members of Dr Ghannouchi's Research Team, the iRadio Lab

gies applicable to broadband wireless and satellite communication systems. The research program of iRadio Lab is concerned with RF and microwave devices, circuits and systems; adaptive digital signal processing (DSP); modeling of device and systems; linearization and hardware impairment compensation concepts; multiple-input multiple-output (MIMO) systems; software-hardware implementation and integration issues; and other related applications.

The iRadio Lab was founded in May 2005 and it is already staffed with more than twenty graduate students and talented researchers, recruited worldwide. The main space dedicated to the iRadio Lab in the University of Calgary's ICT building is being used as

offices for graduate students and research staff, as well as the main instrumentation, simulation, and design area. An auxiliary space in the Engineering building, used for printed circuit boards fabrication and circuit prototyping, was recently completed; and, the development of the fabrication process is under way. The iRadio Lab facilities are supported by a number of computer aided design (CAD) based software tools, test benches, and rapid prototyping setups.

Leading-edge research, development, testing, validation, and evaluation of new concepts and architectures relevant to software-defined and software-enabled RF radio activities are being conducted in collaboration with the RF

Dr Fadhel Ghannouchi

and wireless communications industries and government R&D agencies. Despite its recent creation, the iRadio Lab has succeeded in the initiation of close formal collaborations with several national and international academic institutions, industry partners, and government agencies. Ten non-disclosure agreements to access proprietary information and technologies have been signed to support these collaborations.

The innovative and applications-oriented R&D activities being carried out at iRadio Lab have led to more than fifty refereed journal and conference papers, a Patent Cooperation Treaty (PCT) patent application, a US patent application, and two provisional patent applications. One distinguished speaker has been invited to give a public talk at the University of Calgary. Graduate students from iRadio Lab won second and third places in a worldwide competition on the design of highly efficient power amplifiers, which took place in June 2007 in Hawaii at the International Microwave Symposium (IMS 2007). These designed green RF amplifiers achieved a benchmark, in terms of power-added efficiency of over 80%. In addition, a team of six iRadio Lab graduate students qualified for the finals of the Software Defined Radio Challenge 2008, an international competition, taking place in Washington in November 2008. The iRadio Lab team is the only Canadian and non-US team among the six selected teams.

In 2008, iRadio Lab has been successful in securing substantial funding: \$165K from the Natural Sciences and Engineering Research Council of Canada (NSERC), \$63K from TRLabs, and \$135K from industry. These monies supplement the \$30K, \$20K, and \$120K yearly averages provided by iCORE, the Canada Research Chairs (CRC) Program and the University of Calgary, respectively, over a five-year period. In addition, in-kind contributions and equipment donations and loans in the amount of about \$120K from Industry partners and \$100K of in-kind contributions from the University of Calgary have been obtained during the reporting period ⑥



Location: University of Calgary

Department: Electrical and Computer Engineering

Team Members: 30

Website: <http://www.iradio.ucalgary.ca>

Biography: Dr Fadhel Ghannouchi has been an iCORE chair since 2005. He received his BEng in 1983, his MSc in 1984, and his PhD in 1987 from the University of, Montréal, Quebec. He is a professor, researcher, and engineer.

As a CEO, he guided the development of an innovative line of products for the satellite communications market., which is now manufactured by Mitec Telecom and sold worldwide. Dr Ghannouchi is a recognized member of a network of influential people in academia, as well as in the RF, microwave, digital signal processing, wireless and satellite communications sectors in Canada, the US, Japan, and Europe. He has provided consulting services to a number of microwave and wireless communications companies ⑥

Networks and Wireless Communications

COLLABORATIONS

<i>Participants</i>	<i>Nature of Collaboration</i>
National Collaborations	
École Polytechnique Montréal Dr K. Wu Dr R. Malhame Dr A. Cevdet	Collaboration with the Poly-Grames Research Center (Dr K. Wu) concerns the access to advanced printed circuit board (PCB) fabrication facilities by the iRadio Lab team. Moreover, three graduate students from École Polytechnique Montréal are currently supervised by Dr Ghannouchi.
Focus Microwaves, Canada Dr C. Tsironis	Focus Microwaves is sponsoring the ongoing NSERC Collaborative Research and Development Grant (CRD) (2007-2009) and providing privileged technical support for our activities related to the load-pull characterization of active devices. (Lead contact person: Dr F. Ghannouchi)
Nanowave Technologies, Canada Dr A. Rahal	Dr Ghannouchi has been collaborating with Nanowave Technologies since 2006, within a NSERC CRD project. The ongoing collaboration involves an NSERC strategic research project related to the development of GaN based switching-mode amplifiers for satellite and avionic applications. (Lead contact person: Dr F. Ghannouchi).
Nortel Networks, Canada T. Dashin	The collaboration with Nortel Networks, Calgary Division, was initiated last year. Nortel Networks is currently supporting an NSERC strategic project related to the development of GaN based switching-mode power amplifiers. (Lead contact person: Dr F. Ghannouchi)
Rockwell Collins, Government Systems, USA Dr G. Hegazi	Collaboration on LINC transmitter design. (Lead contact person: Dr F. Ghannouchi)
Powerwave Technologies, USA B. Vassilakis	The collaboration with Powerwave Technologies was initiated last year. This collaboration is aimed at the modeling and linearization of Powerwave's commercial power amplifiers. (Lead contact person: Dr F. Ghannouchi)
Freescall, USA J. Wood	Freescall is providing LDMOS-based devices and high-efficiency PA evaluation boards of their products to be used as devices under test for the ongoing research topic related to the design of high-efficiency Doherty power amplifiers. (Lead contact person: Dr Boumaiza)
Nitronex Corporation, USA P. Rajagopal	The collaboration with Nitronex was initiated last year. It covers the support of an NSERC strategic grant, as well as privileged access to Nitronex's GaN device technology. (Lead contact person: Dr Ghannouchi)

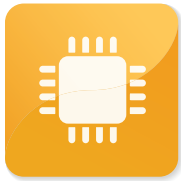
RFHIC Corporation, Korea	RFHIC, Korea is providing the iRadio Lab with privileged access to their GaN transistor products for characterization, modeling and application to the design of wideband RF power amplifiers. (Lead contact person: Dr Boumaiza)
Altera, USA	Altera Corporation is providing the iRadio Lab with FPGA boards from their university program. (Lead contact person: Dr F. Ghannouchi)
Analog Devices, USA	Analog Devices is providing the iRadio Lab with DSP boards and circuits from their university program. (Lead contact person: Dr F. Ghannouchi)
Industry Collaborations	
TRLabs, Canada Dr R. Davis	Concerns the development of an antenna selection algorithm for MIMO systems and RF front-end design for MIMO radio systems (Lead contact person: Dr Ghannouchi)
Canadian Space Agency, Canada Mr. G. Brassard	In the frame of a NSERC Collaborative Research and Development Grant (CRD) (2007-2009), this collaboration aims at the development of GaN based innovative Doherty power amplifiers intended for CSA's quicksat program. The ongoing collaboration covered the co-supervision of a master thesis of a CSA engineer (Lead contact person: Dr Ghannouchi)
Focus Microwaves, Canada Dr C. Tsironis	Focus Microwaves is sponsoring the ongoing NSERC Collaborative Research and Development Grant (CRD) (2007-2009), and providing privileged technical support for activities related to the load-pull characterization of active devices (Lead contact person: Dr Ghannouchi)
Nanowave Technologies, Canada Dr A. Rahal	Collaborating with Nanowave Technologies since 2006 within a NSERC CRD project, the ongoing collaboration involves an NSERC strategic research project related to the development of GaN based switching mode amplifiers for satellite and avionic applications. (Lead contact person: Dr Ghannouchi)
Nortel Networks, Canada T. Dashin	Initiated this year, Nortel's technical staff assisted with the two-day course organized by the iRadio Lab. Recently, Nortel Networks supported an NSERC strategic grant application (Lead contact person: Dr Ghannouchi)
Agilent Technologies, USA A. Amini	This work concerns the co-simulation and optimization of WiMAX transmitters within Agilent's Advanced Design System (ADS) software. For this purpose, privileged access to Agilent's ADS WiMAX library was granted to the iRadio Lab (Lead contact person: Dr Boumaiza)

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INTELLECTUAL PROPERTY

<i>Applicants</i>	<i>Title/Name</i>	<i>Status</i>
Applied for through UTI this year	Mode-Multiplexing LINC Transmitters for Wireless Transmitters	US provisional patent application, Feb. 2008
Applied for this year	All-Digital Multi-standard Transmitter Architecture using Sigma-Delta Modulators	PCT patent application, Feb. 2008
Applied for this year through UTI	Methods and Apparatuses for Providing Digital Baseband Predistortion	US patent application, Dec. 2007
Applied for this year	Multi-standard Transmitter using Sigma-Delta Modulator	US provisional patent application, Nov. 2007
US patent # 7,035,345, April 2006.	“Adaptive Predistortion Device and Method Using Digital Receiver”	Granted

Networks and Wireless Communications



Advanced Technology Information Processing Systems

The Advanced Technology Information Processing Systems (ATIPS) laboratory conducts research into advanced and emerging technologies for use in solving a variety of information processing tasks. Their team of over 50 personnel continues to address a range of major initiatives including biomedical microsystems, information security, multimedia processing, hardware/software co-design and advanced imaging technologies. These complementary disciplines form the backbone of a concerted effort to develop new and exciting solutions to some of science's most challenging problems.

The 2007–08 year saw significant progress in new initiatives, including the completion and formal opening of the Advanced Micro/Nanosystems Integration Facility.

Additionally, ATIPS has seen the beginnings of a transition in leadership. After 39 years researching and developing new technologies for information processing systems, Dr Graham Jullien has announced his retirement. His leadership has been invaluable to the growth and success of ATIPS Labs and has helped to maintain a strong focus on our core mission to explore and exploit advanced and emerging technologies for high performance information processing systems.

As the ATIPS lab enters its eighth year of operation, the directorship passes to ATIPS's closest collaborator over the years, Dr James Haslett. Prior to undertaking an iCORE/NSERC/TRLabs Industry Research Chair, Dr Haslett was a key part of the ATIPS leadership and it was Dr Haslett who brought Dr Jullien to Alberta. Always a close collaborator of the ATIPS team, Dr

Haslett is uniquely placed to assume the leadership of the ATIPS group in an almost seamless fashion and yet his return also brings considerable new opportunities in radio frequency and wireless development, including radio astronomy, power management for biomedical microsystems and smart array antennas.

In ATIPS's seventh year of operation, an outstanding team of academics, senior researchers and graduate students continue to fulfil ATIPS's core mission by developing significant new technologies for advanced information processing systems, which this year includes a best-in-class FPGA implementation of the point-multiplication problem in elliptic curve cryptography; the successful ergonomic trialling and continued development of the wireless "band-aid" sensor platform, the development of an advanced shielded multi-electrode array design for interfacing brain neurons with silicon chips that improves field control for guided neuron growth, the acceptance for publication of the first papers to come from our new quantum-enabled communications collaboration with iCORE Chair Dr Wolfgang Tittel and the design of an integrated CMOS imager with depth perception, based on a innovative optical element and design using ATIPS's own CAMSIM software.



Dr Jullien with members of his research team

Dr Graham Jullien

ATIPS members received numerous awards this year, in recognition of research excellence. Dr Wael Badawy received the 2008 Achievement Award from the International Security Conference, for his team's work on video analytics for security applications. Dr Badawy also won the 2007 Westlink Commercialization Award for "Automated microscope system: Reducing analysis time and cost with high quality," together with his student Mostafa Amer. Incoming ATIPS director Dr Jim Haslett was appointed a "University Professor" by the University of Calgary, as part of their University Professorships program to promote the recruitment and retention of top researchers. Joshua Nakaska won third place in the Student Paper Competition held at the prestigious 2007 IEEE International Microwave Symposium (IMS) in Honolulu, Hawaii, for his paper entitled "2 GHz Automatically Tuned Q-Enhanced CMOS Bandpass Filter." Andrew Macpherson and Robert Randall were each awarded the Analog Devices Inc. "Outstanding Student IC Designer Award," presented by Analog Devices at the IEEE International Solid State Circuits Conference.

The ATIPS team contributed 11 journal papers, 28 refereed conference papers, three book chapters, one contribution to international standards and five invited talks. In 2008, ATIPS Labs also graduated seven PhD and four Master's candidates and ATIPS senior team members have also chaired and organized a number of major conferences and conference sessions and accepted positions on a number of advisory and directorial boards.

Finally, ATIPS represents the University of Calgary's portal to the services of CMC Microsystems, with dozens of integrated circuit designs fabricated using tools running on our server. ATIPS's workstations and servers continue to host a growing number of University of Calgary users, addressing a broad range of integrated circuit and microsystems design needs ⑥



Location: University of Calgary

Department: Electrical and Computer Engineering

Team Members: 56

Website: <http://www.atips.ca/people/jullien>

Biography: Dr Graham Jullien has been an iCORE Chair since 2001. He came to the University of Calgary from the University of Windsor and currently directs the Advanced Technology Information Processing Systems (ATIPS) Laboratory. He also co-founded the Very Large Scale Integration (VLSI) Research Group in 1985.

Dr Graham Jullien has worked in VLSI research for the past 15 years and has 20 years of extensive experience in leading group research projects. He is a world-class researcher in digital signal processing (DSP) architectures and algorithms for high speed signal processing and high performance, low power systems. He covers novel and innovative work on architectures, algorithms, arithmetic systems, and on VLSI circuit implementation down to the transistor level design ⑥

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COLLABORATIONS

<i>Participants</i>	<i>Nature of Collaboration</i>
Provincial Collaborations	
<p>The Centre for Information Security and Cryptography (CISaC)</p> <p>Department of Mathematics, University of Calgary</p> <p>H. Williams, R. Scheidler, V.S. Dimitrov, G.A. Jullien, M. Jacobsen</p>	<p>Prof. Hugh Williams, iCORE Chair in Cryptography, established CISaC in 2003 to bring together a multidisciplinary group with a shared interest in cryptography and quantum computing. Drs Dimitrov, Jullien, Imbert, and O'Neill are members of this centre and Dr Dimitrov also sits on the board of CISaC as the Engineering Representative. A joint strategic grant between CISaC and the ATIPS Lab is presently in its final year and opportunities for further collaboration are being investigated.</p>
<p>Department of Chemistry, University of Calgary</p> <p>V. Birss, G. Jullien</p>	<p>We have jointly investigated instrumentation techniques for nano-biosensors and their integration with our low-power SoC bio-platform. A key part of this collaboration is our work on implantable glucose monitors.</p>
<p>Calgary Laboratory for Information Assurance and Security (CLIAS)</p> <p>H. Williams, R. Scheidler, V.S. Dimitrov, G.A. Jullien, B. Sanders, W. Tittel, R. Safavi-Naini, C. O'Neill</p>	<p>Growing out of our collaboration with iCORE chairs Drs Hugh Williams and Barry Sanders, this collaboration is supporting the promotion of a major initiative in the field of Information Assurance and Security (IAS).</p> <p>Under the principal guidance of Drs Williams and Safavi-Naini, this collaborative effort has nurtured close ties with the Calgary Police service investigating issues associated with Cybercrime.</p>
<p>Hotchkiss Brain Institute and the Faculty of Medicine, University of Calgary</p> <p>N. Syed, D. Zochodne, G. Jullien, R. Midha, V. Verge (Saskatoon), T. Gordon (Edmonton), M. Chan (Edmonton),</p>	<p>ATIPS is taking a prominent role in programs at the Hotchkiss Brain Institute such as the Spinal Cord and Nerve Regeneration project. The Institute is focussed on the discovery and development of new and improved ways to detect, prevent, and treat neurological and mental health conditions.</p> <p>This team has been successful in attaining a \$2.25M CIHR Regenerative Medicine and Nanomedicine grant entitled Dynamic manipulation of nerve regeneration: An electronic-axon interface. The Regenerative Medicine and Nanomedicine Initiative is one of the four main CIHR large initiatives with the fundamental goal of the development of meaningful multi-disciplinary research approaches to regenerative medicine and nanomedicine.</p>

<p>Centre for Bioengineering Research and Education (CBRE)</p> <p>J. Ronksy, C. Hunter, J. Haslett, C. Dalton, C. O'Neill</p>	<p>The establishment of the Centre for Bioengineering Research and Education (CBRE) took place in November of 2003. Bioengineering is rapidly expanding and growing in importance provincially, nationally and internationally. The CBRE is a unique multidisciplinary collaboration between the faculties of Engineering, Medicine, and Kinesiology.</p> <p>Together with Drs Ronksy and Hunter of the CBRE, Drs Haslett, Dalton, and O'Neill are exploring opportunities for collaboration.</p>
<p>Calgary Health Region, Faculty of Medicine, Computer Science, RFIC Group University of Calgary</p> <p>J. Conly, W. Ghali, B. Bayliss, J. W. Haslett, W. Badawy, S. Carpendale, I. Finvers C. O'Neill et al.</p>	<p>ATIPS is supporting the Medical Ward of the 21st Century program, W21C. This is a highly multi-disciplinary program that includes staff from Calgary Health Region and the Faculties of Medicine, Engineering, and Computer Science (U of C). Drs. Haslett and O'Neill are members of the steering committee.</p> <p>Drs. Haslett, and Badawy are part of the team investigating the development of wireless monitoring devices for in-situ real-time vital sign measurements and video analytics for improving patient safety. ATIPS is also supporting W21C through the Advanced Micro/nanosystems Integration Facility.</p>
<p>Institute for Quantum Information Science, (IQIS) University of Calgary</p> <p>B. Sanders, G.A. Jullien, W. Tittel</p> <p>V. Dimitrov</p> <p>C. Dalton</p>	<p>ATIPS continues to nurture collaborations with new iCORE / General Dynamics Industrial Chair Wolfgang Tittel. Jointly supervised graduate student Philip Chan is spearheading the collaboration through investigating Quantum Key Distribution (QKD) for cryptographic systems and discussions have begun between Dr Tittel and Dr Vassil Dimitrov (ATIPS) on addressing the quantum error correction problem. AMIF has also been consulting with Dr Tittel's work on quantum memory – helping to design a thin-film electrode for a key component.</p>
National Collaborations	
<p>RCIM Laboratory faculty, University of Windsor</p> <p>G. Jullien, V. Dimitrov, M. Ahmadi, R. Muscedere</p>	<p>We have a formal association with the Research Centre for Integrated Microsystems and are currently collaborating on an NSERC CRD grant sponsored by Gennum Corporation. G. Jullien currently co-supervises a PhD student at RCIM and we continue to collaborate on implementations of application-optimized arithmetic schemes. Dr Jullien is also an Adjunct Professor at Windsor.</p>

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<p>NRC Dominion Radio Astrophysical Observatory (DRAO) Penticton R. Taylor, P. Dewdney, J. Halsett, B Veidt, L. Belostotski</p>	<p>Designing the front-end ultra low noise amplifiers and signal chain components for a proposed next generation radio telescope, the International Square Kilometer Array (SKA). This research effort involves 17 countries, and researchers and industrial companies around the world. The LNA team at University of Calgary, led by Jim Haslett and Leonid Belostotski, has achieved world record ultra-low-noise wideband LNA designs.</p> <p>NRC has awarded a five-and-a-half year contract to Dr Haslett, which began January 1, 2007</p> <p>Jim Haslett is also a Principal Investigator on a national Research Network proposal for the Canadian Square Kilometer Array Consortium (CSKAC)</p>
<p>University of British Columbia G. Jullien, K. Walus</p>	<p>Former ATIPS researcher Konrad Walus is now an assistant professor at UBC and continues to collaborate with ATIPS on QCA structures and the QCADesigner tool.</p>
<p>CMC Microsystems G. Jullien, J. Haslett, C. Dalton, C. O'Neill, other ATIPS Laboratory members and senior Faculty from the Schulich School of Engineering Other Canadian university participants in the SOCRN</p>	<p>CMC provides microsystem design tools, fabrication, and information services to 44 Canadian Universities, and Colleges. Dr Jullien has been a member of CMC since 1985 and became a member of the Board of Directors in 1989, serving as vice-chairman in 1993. He was one of 10 principal researchers in the System-on-Chip Research Network, funded by a \$40M CFI grant. Drs. Badawy and Jullien were lead clients for the IP blocks that were purchased from the CFI funds, and the IP-block authoring suite developed by the Technical Advisory Committee. The ATIPS Secure SoC laboratory was set up in the CCIT building to support this work and to handle commercial IP blocks in the development of SoC platforms.</p> <p>ATIPS Labs has been a lead member in the ongoing discussions regarding the proposed CMC West initiative that would see CMC establish a base in Western Canada and expand its brokering of microsystems services and capabilities.</p>
International Collaborations	
<p>Laboratoire de l'Informatique du Parallelisme (ENS) Lyon J.-M. Muller, G. Jullien, J-L. Beauchat, A. Tisserand</p>	<p>We have a standing research exchange agreement with LIP to promote collaboration in graduate training and research that includes providing short-term research internships and collaborative research projects with supervision at both institutions.</p>

<p>Laboratoire d'Informatique, de Robotique et de Microélectronique de Montpellier, France G. Jullien, V. Dimitrov, L. Imbert, J-C. Bajard, V. Berthé, M. Robert, H. Williams,</p>	<p>ATIPS has a long research association with LIRMM/CNRS focussing on computer arithmetic, cryptography, and fault tolerance. This collaboration has resulted in the submission of five research papers in the past year and a research exchange agreement has been signed on the same basis as that described below with LIP in Lyon</p> <p>Drs Laurent Imbert (ATIPS/LIRMM) and Mike Jacobson (Computer Science - UoC), have received a \$10K travel grant from the French embassy in Canada to support international collaboration on hyper-elliptic curve cryptography and Dr Imbert has just returned to Calgary on secondment to further this collaboration. Other senior investigators will include Drs V. Dimitrov, R. Scheidler, H. Williams, and J-C Bajard. In furthering this collaboration, Dr G. Jullien also visited Montpellier in April 2008.</p>
<p>GE Healthcare/Global Research E. Cannon, J. Ronsky, M. Okoniewski, C. O'Neill, C. Dalton, et al.</p>	<p>Dr C. O'Neill was part of the Shulich School of Engineering team that hosted GE Healthcare in Kananaskis in March and, together with Dr C. Dalton and the wider Schulich team, has continued to investigate opportunities for collaborative research and development.</p>
<p>Graduate School in Electronics, Telecommunication and Automation (GETA) Helsinki University of Technology V. Dimitrov, G. Jullien, I. Hartimo</p>	<p>Dr V.S. Dimitrov has strong ties with GETA, and was a consultant there from 1997-2000 on digital signal processing, number theoretic techniques and cryptography. Dr Dimitrov has also taught short courses at GETA since 1998. Dr Jullien has also participated in two of these courses and ATIPS has an active student exchange agreement with GETA that facilitates research collaborations with other Finnish universities associated with GETA and includes students taking credited graduate courses.</p> <p>This team recently completed the FPGA design of the point multiplication algorithm over Koblitz curves that is widely regarded as "best-in-class."</p>

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Industry Collaborations	
<p>Genum Corporation Burlington, ON G. Jullien, V.S. Dimitrov, W. Badawy O. Yadid-Pecht</p>	<p>Genum have been the industrial sponsor on our Joint University of Calgary/University of Windsor NSERC Collaborative Research and Development grant providing cash and in-kind support matched by NSERC. The CRD program is investigating</p> <ol style="list-style-type: none"> 1. The optimization of arithmetic structures based on the data representation, 2. The development of streaming data architectures, and 3. Special processing modules and circuit techniques. <p>Dr Jullien has been working with Genum for over ten years. Collaborative projects have included broadcast quality video signal processing systems and completely-in-canal hearing instrument processors. Genum has provided support worth over \$700,000 (including matching funds) since 1994.</p>
<p>DALSA Corp., Waterloo, ON Eindhoven, Netherlands G. Jullien, O. Yadid-Pecht, J. Roberts, G. Ingram, C. Flood, M. Miethig</p>	<p>Dr Jullien has a long-term research interaction with DALSA Inc. and helped pioneer the concept of in-camera defect detection in 1990 with DALSA's Dr J. Roberts. This idea, patented in 1995, has resulted in sales exceeding \$20M over the past decade. Related research has been supported by Micronet with matching funds from DALSA totalling approximately \$500,000.</p> <p>The DALSA sponsored digital watermarking NSERC I2I, led by Dr O. Yadid-Pecht, has just concluded this year and DALSA have expressed an interest in continuing to explore the technology through their Eindhoven research division.</p>
<p>Neurosilicon Calgary, AB G. Jullien N. Syed</p>	<p>University of Calgary spin-off Neurosilicon is developing technology and services to create, operate and market neuron to silicon interfaces. ATIPS Labs has been working very closely with the growing company and a number of our researchers have taken positions (full/part time) helping to develop world-leading optical and electronic interfaces for stimulation and recording of brain neuron activity.</p>
<p>PackagingOne Waterloo, ON G. Jullien</p>	<p>Following initial discussions regarding packaging for microsystems, Graham Jullien is a member of the advisory board of Ontario-based PackagingOne Corporation</p>

<p>Intelliview Technologies Inc. Calgary, AB W. Badawy</p>	<p>ATIPS's spin-off Smart Camera, under the leadership of Dr Wael Badawy, is continuing to develop technologies in collaboration with ATIPS Labs.</p> <p>In addition to the City of Calgary project, Smart Camera has been awarded \$110K from the AIF Industrial Associateship program and has signed a sole manufacture agreement with Toronto Microelectronics Corporation.</p>
<p>Xilinx Inc. W. Badawy</p>	<p>ATIPS research team members under the guidance of Dr Wael Badawy have been given the opportunity to undertake a six-month internship with Xilinx working on FPGA platform design and gaining invaluable skills and on-the-job experience.</p>

INTELLECTUALPROPERTY

<i>Applicants</i>	<i>Title/Name</i>	<i>Status</i>
J. Haslett, I. Finvers, G. Jullien	"Bandage with Sensors" United States Patent Application No. 11/681,628	Submitted April 27th, 2007
J. Haslett, I. Finvers, G. Jullien	"Bandage with Sensors" Canadian Patent Application No. 2583034	Published September 3rd, 2007
A. Yousif, J.W. Haslett	"Time to Digital Converter", US non-provisional patent No. 11/853,446	Filed September 11, 2007
H. Gomaa, W. Badawy	"Analyzing a Segment of Video" United States Patent Application No. 11/945,979	Submitted November 27th, 2007
H. Gomaa, W. Badawy	"Analyzing a Segment of Video" Canadian Patent Application No. 2,620,517	Submitted February 6th, 2008
W. Badawy, M. Shehata, M. Shah Pervez, J. Cai, A. Radmanesh, T. Burr	"Detection of Environmental Conditions in a Sequence of Images" Canadian Patent Application No. 2549797	Published November 30th, 2007

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High-Capacity Digital Communications



Dr Schlegel and his research team

The iCORE High-Capacity Digital Communications (HCDC) laboratory completed its sixth successful year of operation in December 2007. HCDC is supported primarily by iCORE with strong leveraged support from NSERC, CFI, AIF, CMC, ASRA, and local and international industry. The laboratory's focus is on digital information transmission theory and systems, information transfer and distribution, data networks, data integrity and security, as well as prototyping of low-power integrated circuits.

The reliable and resource-efficient transmission of information, particularly over wireless media, is a key economic and social driver in the information age. Research into efficient information transport provides the technological basis for future expansions of all

forms of information networks, and is the primary technical expertise of the HCDC group. The laboratory's engagements span all levels of data communications, from high-level network organization and management to systems research and implementation with supporting research in circuits theory and silicon-based prototyping (VLSI and FPGA based circuits). HCDC's recent reorientation into the three core areas of: (i) Systems Theory and Techniques, (ii) Microsystems Implementations, and (iii) Networking and Data Management has been further consolidated with increased joint activities with the Department of Computing Science and with the VLSI Design and Test Laboratory in the Department of Electrical and Computer Engineering. The group has built a very active

exchange with industry at various levels of cooperation, support, and know-how transfer. In particular, the team is engaged with L3 Communications, PMC Sierra, Telus, Aquantia Corporation, Intel, HP, Lyrtech, Spartan Controls, Elpro Technologies, Honeywell, and Ukalta.

In this past year, the HCDC laboratory concentrated on expanding its research activities into the wireless networking arena, with strong support from system research. They have built a suite of wireless channel emulators to be utilized in its proposed novel virtual Network Emulator for Wireless Artificially Generated Environments (NEWAGE). These modules form the core business of Ukalta, a start-up venture organized by students from HCDC and the Department's VLSI group. On the systems research side, further progress has been made on implementation oriented iterative demodulators—a major research theme the HCDC team presented at a number of technical meetings. An FPGA prototype of this work is currently being pursued by one of the students. On the networking side, a key PhD thesis on the

Dr Christian Schlegel

promise and limitations of ad hoc networking is nearing completion and three new PhD students have taken up topics in sensor and information networking, and work has been ramping up again on inter-symbol interference mitigation for cable channels and multiple antenna communications in anticipation of a major collaboration with Telus corporation. This work will also have strong impact on mesh networking research, which is expected to intensify with the emergence of meshed 802.11 WiFi networks and the emergence of cellular femtocells. As every year, the team's research findings were disseminated in a series of journal and conference publications.

HCDC has also taken its "good citizen" mandate seriously by organizing several key events for students. Primarily, they successfully completed their second Western Canadian Summer School on Information and Communication Theory and are well on track for this year's third Summer School. They also organized and conducted a Wireless Camp for University of Alberta students to introduce them to the technical wonders and career opportunities in the communications field. Due to the large demand, the camp was held a second time this past February, this time with industry participation and financial support.

The HCDC laboratory's recent research results have been presented in a variety of technical meetings. Professor Schlegel has toured North America as IEEE Distinguished Lecturer for the Circuits and Systems Society. Among his destinations were Northeastern University in Boston, the Public Safety Communications Summit in Washington DC, the University of Utah, and the University of British Columbia where he taught a three-part lecture series on iterative processing. Professor Schlegel continued to serve the technical community as Editor for the IEEE Transactions on Communications, and Professor Gaudet serves as Associate Editor for the IEEE Transactions on Circuits and Systems II: Express Briefs, and as Digest Editor for the IEEE International Solid-State Circuits Conference ⑦



Location: University of Alberta

Department: Electrical and Computer Engineering

Team Members: 35

Website: <http://www.ee.ualberta.ca/HCDC>

Biography: Dr Christian Schlegel has been an iCORE Chair since 2002. He received his first engineering degree from the Federal Institute of Technology in Zürich, Switzerland, in 1984, and his masters and doctorate degrees in electrical engineering from the University of Notre Dame in Indiana, in 1986 and 1989, respectively.

Dr Schlegel is an associate editor for coding theory and techniques for the IEEE Transactions on Communications, and served as the technical co-chair of the IEEE Information Theory Workshop 2001 in Australia. He is a senior member of the IEEE Information Theory and Communication Societies. In 1997, he received a National Science Foundation Career Award and, in 2001, a Canada Research Chair ⑦

Networks and Wireless Communications

COLLABORATIONS

<i>Participants</i>	<i>Nature of Collaboration</i>
Provincial Collaborations	
Telus Corporation	We have recently managed to attract major funding from this company with the assistance of iCORE's economic development team. A kick-off meeting of the project suite to be addressed under this collaboration was held this March with Dr Vanja Subotic, Senior Research Scientist with Telus. This project will also provide research topics for students supervised by Professor Nowrouzian, an expert in adaptive signal processing.
Local Industry, Alberta	We have forged connections with Spartan Controls, Elpro Technologies, and Honeywell on educational initiatives. These companies have actively participated in our wireless camp and also provided funding for the event.
National Collaborations	
University of British Columbia	Collaboration exists with Professors Schober and Lampe at the Department of Electrical and Computer Engineering at the University of British Columbia. Apart from exchanges of students, Professor Schlegel spent several months of sabbatical time at UBC where he held a video-taped lecture series on iterative methods in signal processing.
International Collaborations	
L3 Communications, Salt Lake City, Utah	This company has had a long-standing liaison with Dr Schlegel and is currently supporting hardware oriented research efforts by having funded Dr Zachary Bagley's thesis work under Professor Schlegel. L3 engineers are also currently discussing collaboration on channel emulation, including discussions on licensing Ukalta's emulation cores.
Tohoku University, Japan	Collaborations exist with Professor Hanyu at the Research Institution for Electrical Communication at Tohoku University in Sendai, Japan. Prof. Hanyu and his associates were recently awarded an International Centre of Excellence from the Japanese Government, to support international collaboration. Prof. Gaudet was invited to speak at the inaugural workshop, held in Maui in February 2008. Also, Dr Tomohiro Takahashi, a graduate of Tohoku University, visited the HCDC Laboratory in 2007. Prof. Gaudet will visit Tohoku University as part of his sabbatical in 2008-2009.

Télécom-Bretagne, France	Collaborations exist with Professors Lahuec, Séguin, and Jézéquel in the Electronics Department at Télécom-Bretagne, known as the birthplace of Turbo Codes. In 2007, Mr Jorge Perez, a PhD Candidate from Télécom-Bretagne, visited the HCDC Laboratory, and participated in the design of two CMOS integrated circuits that are currently undergoing testing. Prof. Gaudet has been invited to visit Télécom-Bretagne in January 2009.
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INTELLECTUAL PROPERTY

<i>Applicants</i>	<i>Title/Name</i>	<i>Status</i>
Dr Amirhossein Alimohammad, Mr Saeed Fouladi Fard, Dr Bruce F. Cockburn, and Dr Christian B. Schlegel	US Provisional Patent No. 60/888,630 filed February 7, 2008, PCT serial Number 2006045. Signal Filtering and Filter Design Techniques	On February 7, 2007 the HCDC Laboratory filed a provisional patent application with the US patent office (USPTO).
Dr Vincent Gaudet, Dr Bruce Cockburn, Dr Christian B. Schlegel, Dr Stephen Bates, Mr Paul Goud, Mr Robert Hang, Dr Sheryl Howard and Mr Anthony Rapley.	US Provisional Patent No. 60/570,901 filed May 14, 2004 (expired), PCT Serial Number PCT/CA2005/000731 Publication Number WO 2005/112272 converted US Utility, filed May 13, 2005, Serial Number 11/569,017 (active)	Bit-Serial Method and Apparatus for Decoding Low Density Parity Check Codes
Dr Christian B. Schlegel, and Dr Christopher Winstead	Low-Voltage CMOS Circuits for Analog Decoders	On March 23, 2004 the HCDC Laboratory filed a provisional patent application with the US Patent and Trade Office (USPTO). US Provisional Patent No. 60/544,191 filed Feb 13, 2004, converted to US Utility, filed Feb 10, 2005, Serial No. 11/056,063 (active)

Networks and Wireless Communications



Broadband Wireless Networks, Protocols, Applications & Performance Wireless Traffic Modeling

Dr Carey Williamson is the iCORE Chair in Broadband Wireless Networks, Protocols, Applications, and Performance and the NSERC/iCORE/TELUS Mobility Industry Research Chair (IRC) in Wireless Internet Traffic Modeling. In 2008, he completed Year 2 of his renewed five-year term in this position and completed Year 4 of 5 of his IRC. Combined, Dr Williamson leads a research team of approximately 20 people with interests in broadband wireless networks, Internet technologies, and network performance. Much of the research has an experimental flavour, with an applied focus on industrially relevant network and protocol performance issues.

Highlights from Fiscal 2008 include:

- Leading an active research team involving three faculty members, six research staff, and 16 students (eight PhD, eight MSc)
- Managing a team that collective-

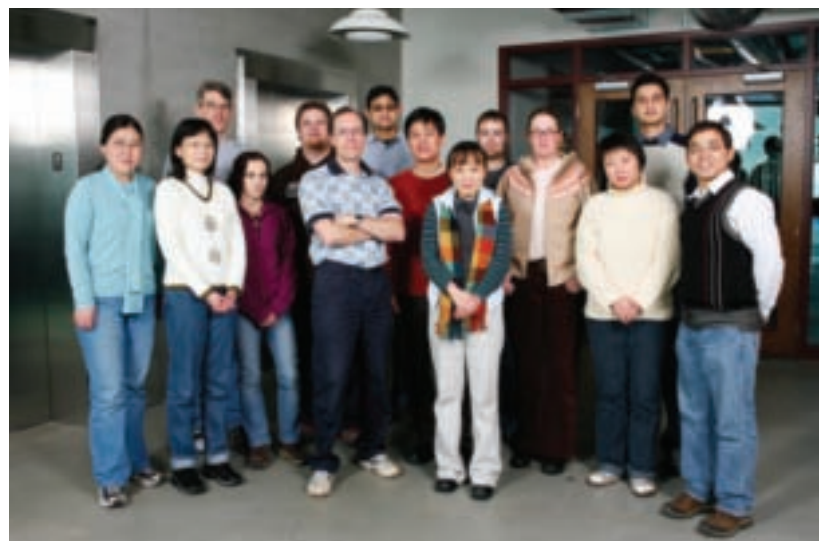
ly produced 31 published and/or accepted research publications (nine journal, 22 conference), with 17 more papers (eight journal, nine conference) currently submitted and under review

- Serving as General Chair for a highly-successful major international conference (WWW 2007)

The Chair's primary objectives in

the past year were research and renewal. The Chair was able to fill several of the holes on its research team. At the faculty level, they were able to hire replacements for the staff members lost, and now have sufficient personnel to achieve their goals.

The coming year's objectives include completing the IRC program, undertaking a new



Dr Williamson with his research team

Dr Carey Williamson

initiative on Internet security, recruiting a new crop of graduate students, and fulfilling several new service obligations.

Other initiatives include an Interneted Systems Security Network (ISSNet) collaborative research initiative. The mandate of ISSNet is to conduct advanced research on network security and develop the next generation of expertise required to protect Canada's critical Internet information infrastructure. The Chair has three new service obligations in the year ahead as well, as Chair of ACM SIGMETRICS; Program Co-Chair for the 16th International Symposium on the Modeling, Analysis, and Simulation of Computer and Telecommunication Systems (IEEE/ACM MASCOTS 2008); and as General Chair for the 7th ACM Workshop on Hot Topics in Networks (HotNets-VII) at the University of Calgary in October 2008.

The NSERC/iCORE/TELUS Mobility Industry Research Chair comes to an end in March 2009. The research directions in the final year of the IRC are the same as those outlined in the original proposal. Year 5 will explore the architecture and services for next-generation, packet-based wireless and cellular networks. Near the end they will also provide TELUS Mobility recommendations on how to migrate their network infrastructure to a packet-based IP network, and how to integrate with other wireless technologies. Deliverables will include a final report to NSERC, an internal report to TELUS Mobility, and a suite of software tools for TELUS Mobility. The Wireless Internet Traffic Modeling tools will facilitate the evaluation and comparison of proposed network architectures, protocols, applications, and services ⑦



Location: University of Calgary

Department: Computer Science

Team Members: 20

Website: <http://www.cpsc.ucalgary.ca/~carey>

Biography: Dr Carey Williamson has been an iCORE Chair since 2002. He received his PhD from Stanford University in 1992.

He is considered one of the “rising stars” of computer networks research. He is noted for demonstrating the usefulness of loss-load curves as a network congestion control mechanism, and a unique protocol supporting IP multicast for mobile hosts.

He has been voted “Professor of the Year” by Computer Science undergraduate students four times, and won the Master Teacher award at the University of Saskatchewan Fall Convocation in October 2000 ⑦

Networks and Wireless Communications

COLLABORATIONS

<i>Participants</i>	<i>Nature of Collaboration</i>
Institutional Collaborations	
CISaC	Member Organized by iCORE Chair Hugh Williams
Provincial Collaborations	
WestGrid, Cybera	Member/Registered User Long-term plans for file storage are being explored.
National Collaborations	
NSERC	At the national level, I was a co-applicant on a successful proposal for a Strategic Network on Internet Security. The initiative is led by Paul van Oorschot at Carleton University and John McHugh at Dalhousie University. The project involves about 15 researchers from a dozen institutions across Canada. This national collaboration effort has been approximately two years in the making. A funding award of \$1.0M per year for 5 years was announced by NSERC in December 2007. The paperwork is underway to negotiate the inter-institutional agreements and intellectual property agreements between the participating institutions. Funds transfer and research activity are expected to start in September 2008.
U of C, U of S, CFI	My other multi-institutional partnership involves the CFI-funded Experimental Laboratory for Internet Systems and Applications (ELISA), shared by the University of Calgary and the University of Saskatchewan. We are currently in Year 7 of this 1-year CFI project, due to many administrative difficulties at the University of Calgary, particularly with Research Services and financial accounting. In addition, I am still waiting for the three-year award (2005-2007) of CFI Institutional Operating Funds (IOF) to appear in an account at the University of Calgary. We have fully spent all of this money, even though it has not arrived yet. We have had ongoing technical difficulties with the primary file server in the ELISA lab. These problems have disrupted some of our data collection and analysis activities. A new network monitor was purchased and installed this year. We are planning to use UCIT and/or WestGrid resources to provide dependable backup of our data.

International Collaborations	
WWW 2007	My major international activity this year involved the World Wide Web Conference, which took place in Banff in May 2007. I was one of the General Chairs for this conference. Planning for this large conference consumed enormous amounts of my time and energy for the past 2 years (e.g., conference calls, budget planning, Web site, marketing, registration, e-mail queries, invitation letters, and more). The total budget for the conference was approximately \$1.0M, with about \$800K from registration fees, and \$200K from the corporate sponsorship program. Fortunately, the event was a huge success, attracting 982 attendees to the conference in Banff. A small surplus of approximately \$65K was generated from the conference. These surplus funds have been targeted to graduate student scholarship support at the University of Calgary.
IW3C2	I have now completed my third and final year as an ex officio member of the International World Wide Web Conferences Steering Committee (IW3C2). In October 2007, I attended an IW3C2 meeting in Madrid, to conduct a site visit of the facilities for the 18th International World Wide Web Conference (WWW2009). I also gave a 1-hour presentation and submitted my final report on WWW2007 in Banff (available upon request).
IEEE	Served on the Program Committee for several different conferences this year, including IEEE LCN 2007, IEEE WLN 2007, IEEE WONS 2008, PAM 2008, and SimuTools 2008
IIT Delhi, Dr S. Dharmaraja	Dr Dharmaraja spent two months in Calgary during Summer 2007 to work with Dr Williamson, Hongxia Sun, Jingxiang Luo, and Mingwei Gong. One paper has been published to date, with two more in preparation
Industry Collaborations	
TELUS Mobility	<p>Part of the NSERC/TELUS/iCORE Industry Research Chair in Wireless Internet Traffic Modeling</p> <p>Work with Hongxia Sun, Yujing Wu, Jingxiang Luo and Dr Williamson continues to emphasize modeling Voice-over-IP (VoIP) and Quality of Service (QoS) mechanisms in EV-DO networks. Hongxia and Yujing have developed an extensive EVDO simulation environment, including application-layer traffic models, scheduling algorithms, Quality of Service (QoS) mechanisms, and physical-layer wireless interference models. As requested by TELUS Mobility, Hongxia's EV-DO simulator is currently being rewritten to model HSDPA (High Speed Downlink Packet Access) networks to facilitate our planned work in 2008.</p>

New Architectures

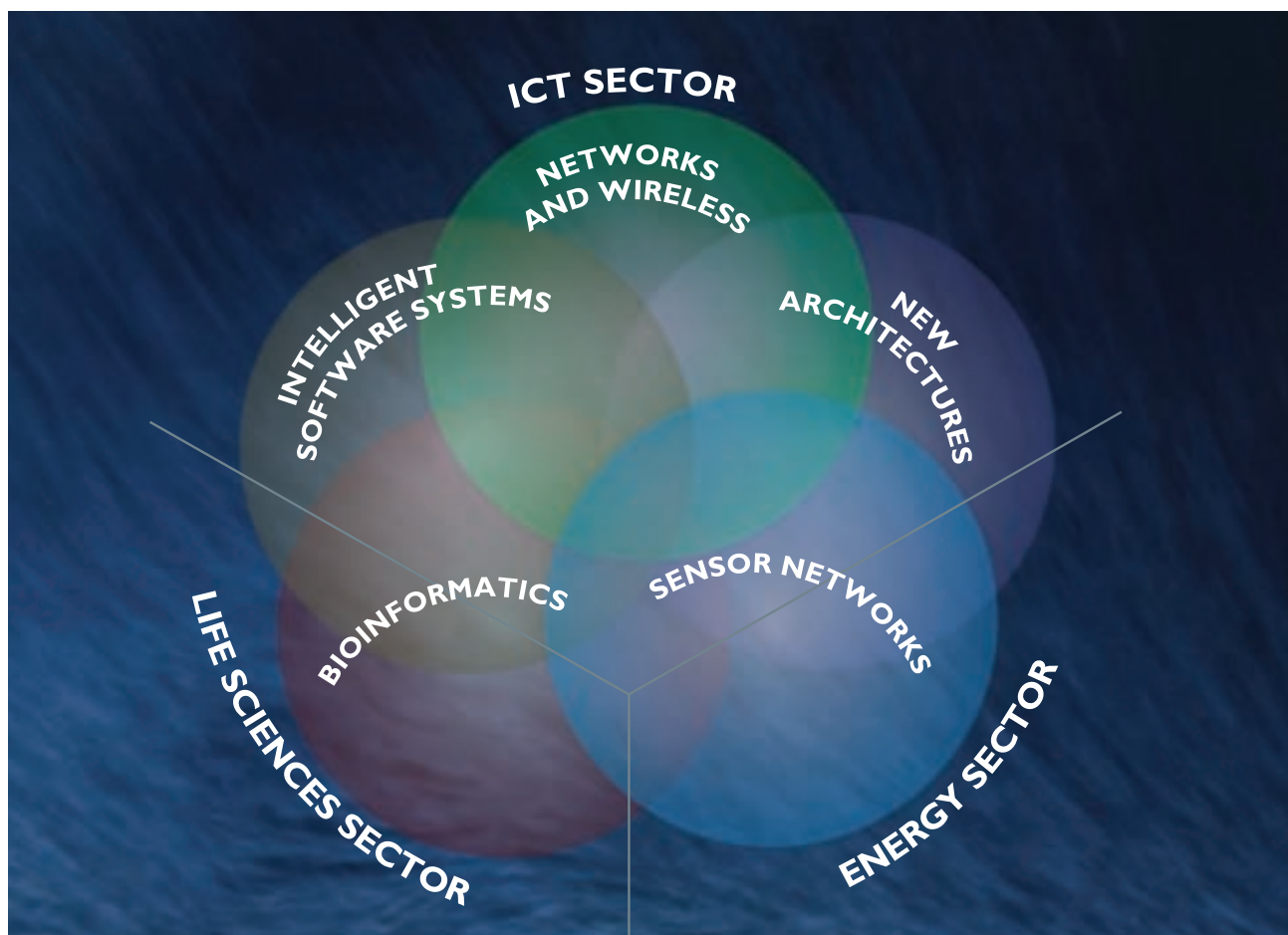
iCORE researchers are investigating a wide range of new architectures, resulting in applications as diverse as information security to nanoscale materials for solar panels.

In 2001, iCORE recruited Drs Brett and Freeman to explore the fundamental aspects of physics at the nanoscale. This research evolved into greater collaborations at the National Institute for Nanotechnology (NINT) and an iCORE Industry Chair when Dr Brett teamed up with industry

partner Micralyne to create the Nanoengineered ICT Devices group.

2002 iCORE recruit Dr Hugh Williams works in Algorithmic Number Theory and Cryptography, and as cryptography emerged as a very important high-growth area in communications security, iCORE also recruited Dr Barry Sanders in the area of Quantum Information Science.

Dr Sanders was instrumental in the recruit-



ment of Dr Wolfgang Tittel in 2006. Dr Tittel's work in quantum cryptography and communication is being co-funded by industry partner General Dynamics; providing a path to commercialization.

As the researchers in our New Architectures cluster continue to collaborate with their peers, and build partnerships with industry, this foundational research, has paved the way for new clusters: researching Cryptography/ Number Theory/Quantum Cryptography/ Information Security and researching Nanoscale Physics & Materials/ Nano ICT/ Nano Devices.



Dr Hugh Williams



Dr Michael Brett



Dr Mark Freeman



Dr Barry Sanders



Dr Wolfgang Tittel



Algorithmic Number Theory and Cryptography

ICANTC, the iCORE Chair in Algorithmic Number Theory and Cryptography, is focused on research and training excellence in cryptology and computer security. The group was originally mandated to conduct research in fundamental algorithmic number theory and mathematical cryptography, although over the years the scope has broadened to include applied research into information assurance and security. ICANTC, through the Centre for Information Security and Cryptography (CISaC), maintains

a strong membership cluster that includes academics in a variety of disciplines as well as professionals from the public and private sectors. Its vision is to be an internationally recognized research and education centre conducting multidisciplinary research into all aspects of information protection while building and maintaining strong linkages with industry and the community.

During Fiscal Year 2008, ICANTC has continued to expand as it builds on the public's increasing

recognition of the need for better information security technologies and policies. Part of this growth includes developing information security initiatives that can diversify Alberta's economy and create intellectual capital, commercialization, and career opportunities within the province.

ICANTC's success has been augmented with the addition of a new iCORE Chair in Information Security and is further complemented by the appointment of the iCORE/General Dynamics Canada Industrial Research Chair in Quantum Cryptography and Communication. This added expertise has bolstered the University of Calgary's and ICANTC/CISaC's strength in information security. As a result, CISaC is being restructured to reflect this partnership and its website, www.cisac.ucalgary.ca, has been revised to reflect this additional expertise.

CISaC's Management Board continues its efforts to create a business plan to direct and promote its activities. The January 29, 2008 revision of the university's policies regarding centres and institutes is now being integrated into this



Dr Williams with his research team

Dr Hugh Williams

effort. A planning committee has been established and most of the work will be completed by the end of 2008.

Vassil Dimitrov, Michael Jacobson Jr. and Renate Scheidler have stepped down from the management board and have been replaced by Abraham Fapojuwo, Mark Bauer, and John Aycok. Abraham Fapajuwo is an Associate Professor in the Department of Electrical & Computer Engineering and together with new members Marina Gavrilova and Ken Barker from the Department of Computer Science, University of Calgary; Dennis Tracz, Information Security Officer, University of Calgary; and Douglas Stephen, Senior Security Architect, University of Calgary, the total number of members and affiliates has increased to 37.

In addition, Dr Hugh Williams is working closely with the newly formed Global Centre for Securing Cyberspace (GCSC) to assist them in establishing this centre in Calgary. GCSC's mission is to provide a strategic national approach within a secure environment to address the rapidly increasing social and economic impact of e-crime.

Along with these significant changes and initiatives, in the past year the ICANTC research team published or submitted for publication over 60 research articles and gave over 40 presentations in Calgary and around the world. ICANTC researchers were principal investigators on personal research grants totaling over \$700,000 annually.

In the coming year, ICANTC will continue to conduct both planned and opportunity-driven research, remaining relevant, innovative, and committed to training highly qualified individuals with the skills to protect the privacy and information security of Albertans and Canadians ⑦



Location: University of Calgary

Department: Mathematics and Statistics

Team Members: 32

Website: <http://math.ucalgary.ca/~williams>

Biography: Dr Hugh Williams has been an iCORE Chair since 2002. He received his BSc in 1966, his MSc in 1967, and his PhD in 1969 all from the University of Waterloo. He was an Associate Dean at the University of Manitoba, and an Adjunct Professor at the University of Waterloo. Dr Williams has a strong international reputation for his work in cryptography and number theory and is considered the top academic in this field in Canada.

Dr Williams was one of the first researchers to use modern mathematical techniques for securing and authenticating communication. He is the recipient of numerous awards including a Killam Fellowship, an Australian Research Council IREX grant, prestigious NSERC awards, and a MITACS award (held jointly with Alfred Menezes). He is also an associate editor of *Mathematics of Computation* ⑦

New Architectures

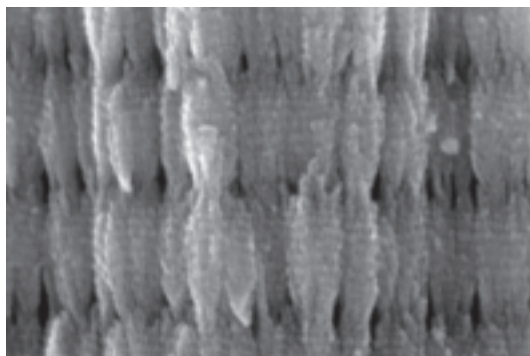
COLLABORATIONS

<i>Participants</i>	<i>Nature of Collaboration</i>
Provincial Collaborations	
ATIPS; University of Calgary	Work continues to develop with OnSite Systems Inc. a strategic Joint Information and Communications Technology (ICT) initiative to perform research into demonstration-standard implementations of the AES cryptographic protocols for OnSite's SONET/SDH add-drop multiplexer (ADM) equipment.
CLIAS Initiative	This initiative has expanded to include the new iCORE Industrial Chair in Quantum Cryptography and Communication and the new iCORE Chair in Information Security. CLIAS will now be able to offer a full spectrum of services pertaining to the increasingly important area of information security.
Global Centre for Securing Cyberspace (GCSC)	Dr Hugh Williams is assisting GCSC with this centre in Calgary. GCSC's mission is to provide a strategic national approach within a secure environment to address the rapidly increasing social and economic impact of e-crime.
International Collaborations	
Ruhr-University, Bochum, Germany	ICANTC has established a formal exchange agreement through the Horst-Goertz Institute in the Faculty of Engineering

New Architectures



Nanoengineered ICT Devices Thin Film Engineering



A cross-sectional image of an optical filter device fabricated of titania, showing layers of high and low refractive index. The height of this image is approximately 500 nm

The programs of the iCORE Professorship and Industry Chair held by Dr Michael Brett continue to play an instrumental role in the growth of nanotechnology and nanofabrication research and training in Alberta. Key leadership initiatives have included the continued expansion and operation of the University of Alberta Micromachining and Nanofabrication Facility (NanoFab), cross-appointment as Group Leader in Engineered Materials for Energy at the NRC National Institute of Nanotechnology in Edmonton, and establishment of the BSc

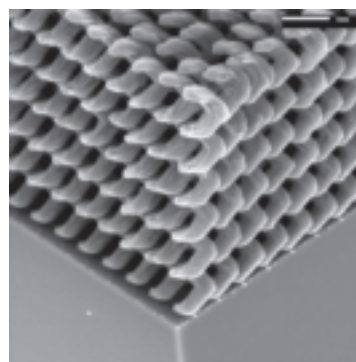
program in Engineering Physics: Nanoengineering Option.

The research program has involved development of nanostructured thin film materials and study of their device applications in the fields of sensors, photonics, energy, and nanobiotechnol-

ogy. Industry sponsorship by Micralyne and international collaboration with Philips Research (Netherlands) has provided a strong commercial perspective. A team of significant size and excellence has been assembled, at its core comprising three professors, seven research associates, and 19 graduate students, with 14 of the students recognized by major scholarships from Alberta Ingenuity or NSERC. Several of the research trainees have or will take their skills to the growing local Alberta nanotechnology industry. Initiatives such as the new Engineering Physics:

Nanoengineering Option will help ensure a steady supply of highly qualified personnel for this field.

Brett has continued to work to support the NanoFab in its growth to a user base of over 900 researchers. This facility is now seen as the best of its kind in Canada, and by attracting users from six provinces defines Alberta as the focal point for nanotechnology processing. Funds from iCORE are used to support personnel that develop nanofabrication processes critical to many users. Such personnel include Stephanie Bozic, who has trained hundreds of researchers from a diversity of fields in micro- and nanopatterning



An image of silicon square spiral photonic crystals, viewed obliquely (seen in Physics Today)

Dr Michael Brett

processes. Most recently Brett has been the principal investigator for a successful application to the Alberta Science and Research Investments Program, which will provide \$2M for enhanced patterning processes to better fabricate micro- and nano-devices, with matching contributions from NRC NINT. NSERC has contributed operating funding totalling over \$1M for a five-year period.



Members of Dr Brett's research team

Brett's cross-appointment to NINT has provided new research opportunities through collaborations and access to a significant arsenal of equipment. A significant new research thrust in energy fields has been initiated. In collaboration with Dr Jillian Buriak, development of nanostructured photovoltaics devices is underway with a team of approximately 10 researchers. Other new projects include the use of nanostructured films as electrode materials for energy storage, and as energy scavenging coatings. The nanofabrication facilities and collegial environment of NINT and the University of Alberta, in conjunction with iCORE funding and top personnel, provide an ideal breeding ground for innovation in development of these new devices ⑦



Location: University of Alberta

Department: Electrical and Computer Engineering

Team Members: 29

Website: <http://www.ece.ualberta.ca/~glad>

Biography: Dr. Michael Brett has been an iCORE Professor since 2001. He received his BSc in 1979 from Queen's University and his MSc and PhD from the University of British Columbia in 1981 and 1985 respectively. Dr Brett played a central role in creation and expansion of the University of Alberta NanoFab, one of the top open-access micro/nanofabrication facilities in North America. He was awarded the 2003 ASTech Award for Outstanding Leadership in Alberta Technology, the 2004 APEGGA Excellence in Education Award, and in 2007 was awarded the University Cup — the highest honour the University of Alberta can bestow on a member of its academic staff.

Dr. Brett is known for his authorship of the thin film growth simulator SIMBAD, which was marketed worldwide for use in integrated circuit modelling. Dr. Brett and his research group also invented the Glancing Angle Deposition (GLAD) process, for fabricating nanoscale architectures in thin film coatings ⑦

New Architectures

COLLABORATIONS

<i>Participants</i>	<i>Nature of Collaboration</i>
Provincial Collaborations	
Dr W. Finlay, U OF A Mech Eng	Fabrication of nanoengineered aerosol particles
Dr R. Fedosejevs, Dr Y. Tsui; U OF A Elect. Comp. Eng	Optical characterization of nanostructures
Dr K. Westra, U OF A Elect. Comp. Eng	Nanostructured inorganic materials
Dr M. McDermott, U OF A Chemistry/ NINT	SPR devices for sensing
Dr D.J. Harrison, U OF A Chemistry/ NINT	Microfluidic devices
Dr J. Veinot, U OF A Chemistry	Sensor devices and organic materials
Dr A. Kovalenko, NINT	Optical theory and modelling
National Collaborations	
Dr L. Whitehead, UBC Physics	Reflective display devices
Dr J. Tunney, NRC - ICPET	Sensor devices
Dr T Smy, Carleton University	Nanostructure growth modelling
Dr J. Dahn, Dalhousie University	Nanostructured materials
International Collaborations	
Dr D Broer, Philips Research Corp., Netherlands	Study of nanostructured liquid crystal devices
Dr K. Bastiaansen, Tech. Univ.of Eindhoven, Netherlands	Polymer nanostructures and devices
Dr G. Morloch, Univ. Hohenheim, Stuttgart	Thin layer chromatography
Matthias Thommes, QU of Antachrome, USA	Porous material characterization

INTELLECTUAL PROPERTY

<i>Patents</i>	<i>Description</i>	<i>Status</i>
DE 69808653, EP1007754B(UK), EP1007754B(FR)	Glancing Angle Deposition of Thin Films	granted prior to this year
	Method of Depositing Shadow Sculpted Thin Films	granted prior to this year
	Glancing Angle Deposition with Controlled Porosity	granted prior to this year
	Shadow Sculpted Thin Films	granted prior to this year
	Optical Device	granted prior to this year
	Capped Porous Thin Films	granted prior to this year
	Glancing Angle Deposition of Thin Films	granted prior to this year
	Shadow Sculpted Thin Films	Granted, July 24, 2007
	Glancing Angle Deposition of Thin Films	Granted, Nov 13, 2007
	Capped Porous Thin Films	Under review
	Glancing Angle Deposition of Thin Films	Under review
	Transparent Conductive Film with a Large Birefringence	Filed Sept 23, 2005
	Transparent Conductive Film with a Large Birefringence	Filed Sept 22, 2006
60/740,901#60/740,901#60/740,901#60/740,901	Organic Luminescent Chiral Device	Filed Nov 30, 2005
	Organic Luminescent Chiral Device	Filed Nov 29, 2006
#61/028,111#61/028,111#61/028,111	Photovoltaic device	Filed Feb 12, 2008
Spinout Companies		
Chiral TF Devices	In a holding mode	

New Architectures



Nanoscale Physics and Nanomaterials

This is the most exciting time in history to be working on the science and applications of materials, thanks to the phenomenal feedback loop between nanoscience and nanotechnology. It is the mission of the iCORE Centre for Nanoscale Physics and Nanomaterials Research (CoreNano) led by Dr Mark Freeman, to be an integral component of the local nanoscale science and technology community and a source of exceptionally trained personnel for the Alberta nanotechnology research cluster.

The CoreNano group stresses fundamental aspects of physics

at the nanoscale, in effort both to exploit and to accelerate the feedback between nanoscience and nanotechnology. Their primary focus is on nonequilibrium physical properties of nanosystems relevant to future ICT. Nonequilibrium properties ultimately underlie the operation of all active devices and also pose some of the most interesting questions for current study.

CoreNano funds are used to support personnel at all stages of development, from undergraduates through postdoctoral fellows, in the acquisition of skills critical to international competitiveness in the high-tech sector. The activities

of many of the personnel receive complementary support from other sources, particularly scholarships and fellowships. Twenty-three graduate students, eight postdoctoral fellows, and seven undergraduate students have been supported in part by CoreNano during this reporting period. Nine trainees from the past seven years are now employed in the local Alberta nanotech industry. In addition, seven undergraduates who worked with the CoreNano team have gone on to graduate studies in Alberta.

Additionally, these funds have supported this year's notable achievements, such as the creation of a new patterning technology for light-emitting silicon nanocrystals. This work made the inside cover of the journal *Advanced Materials* and was the Editor's Choice in Science.

CoreNano engaged in outreach work, as well, including preparation of the experimental component of the western Canada High School Physics Olympiad and nanotechnology tours for physics students and professors from the Augustana campus of the University of Alberta. Dr Freeman



Dr Freeman's research team

Dr Mark Freeman

participated in the Canadian Institute for Advanced Research's 25th anniversary "Next Big Question" public debates in Calgary, on behalf of the nanoelectronics program, and presented a public lecture on history of nanomagnetism to the Royal Society of Canada.



Dr Freeman (right) and one of his team members, working in the lab

CoreNano continued to strive for tangible results, and to that end, now has two patents awarded and two provisional patent applications for material coatings and diodes compatible with the require manufacturing processes. Also pursuant to this goal, CoreNano members published several papers this year, on topics such as the strange physical properties of materials on a nano scale ⑦



Location: University of Alberta

Department: Physics

Team Members: 29

Website: <http://laser.phys.ualberta.ca/~freeman>

Biography: Dr Mark Freeman has been an iCORE Chair since 2001. He completed his PhD at Cornell University in 1988, his MSc at Cornell University in 1984, and his BSc (Honours) at the University of Alberta in 1981. He is considered one of the top nanotechnology researchers worldwide and is internationally recognized for his work on state-of-the-art imaging of magnetic phenomena in the solid state.

Dr Freeman is the recipient of numerous awards and honors, including IBM's Invention Achievement Award, the Martha Cook Piper Research Award and NSERC's E.W.R. Steacie Fellowship. He is also an Associate of the new Canadian Institute for Advanced Research Nanoelectronics Program ⑦

New Architectures

COLLABORATIONS

<i>Participants</i>	<i>Nature of Collaboration</i>
Provincial Collaborations	
U of A: ECE Dr K Westra	Advanced e-beam lithography
U of A: Physics and Chemistry Dr R Tykwinski Dr R Wolkow	Molecular conductors
U of A: Chemistry Dr R Tykwinski	Organic materials
U of A: Physics Dr R Sydora	Micromagnetic modeling
U of A: Chemistry Dr J. Veinot	Silicon nanocrystals
U of A: Electrical and Computer Engineering Dr R DeCorby	Developing rare-earth-doped silicon nanocluster glasses as possible waveguide amplifiers.
National Collaborations	
McGill University Dr P Grütter	Magnetic nanostructures
INRS/Univ of Quebec Dr T Ozaki, RM Dotti	Extreme terahertz sources and applications
University of Manitoba Dr D Thomson	Dielectric measurements on single cells
NINT Dr M Malac	Electron holography
NINT Dr W Hiebert	Nanomechanics

NINT Dr Ken Bosnick	Ultrafast dynamics in nanowires and carbon nanotubes
Brock University Dr A. Knigavko	High temperature superconductors
McMaster Dr J Carbotte	High temperature superconductors
UBC Dr Tom Tiedje	GaAs nitrides and bismides
Queen's Dr B Gooding	High temperature superconductors
Simon Fraser University Dr B Heinrich	Dynamic coupling in magnetic multilayers
International Collaborations	
Cal Tech Dr M Roukes	NEMS interferometry
La Sapienza, Rome Dr L Benfatto	High temperature superconductors: optics
La Sapienza, Rome Dr E Cappeluti	Spin-Hall effect, high temperature superconductors
University of Geneva Dr F Carbone Dr AB Kuzmenko Dr HJA. Molegraaf Dr E van Heumen Dr J Teyssier Dr V Lukovac Dr D van der Marel	High temperature superconductors: optical properties
Rutgers Dr K Haule Dr G Kotliar	High temperature superconductors: optics and dynamical mean field theory
Lausanne, Dresden Dr C Grimaldi	Spin-Hall Effect

New Architectures

University of Bristol Dr I Manners	Direct-written organometallic nanomagnets
Chinese University of Hong Kong Dr Q Li	Advanced electron microscopy
Institut für Laser und Plasma-physik, Univ Duisburg-Essen Dr M Horn von-Hoegen	Dynamics of electrons in nanostructures
Seagate, Pittsburgh Dr Xiaobin Zhu	Magnetization dynamics
University of Massachusetts Amherst Dr BV Svistunov Dr NV Prokof'ev	Supersolid phase of helium
ETH Zurich Dr Matthias Troyer	Supersolid phase of helium
Industry Collaborations	
Norcada Dr Yuebin Ning Mr Graham McKinnon	Nanomechanics
Applied Nanotools Dr Mirwais Aktary	Electron beam lithography
Micralyne and TR Labs, Edmonton Dr R DeCorby Dr C Haugen	Silicon nanoclusters for microphotonics (NSERC Strategic Program)
University of Nizhniy Novgorod Dr VA Burdov	Theory of silicon nanocrystals

INTELLECTUAL PROPERTY

<i>Patent</i>	<i>Title/Name</i>	<i>Status</i>
US 5,451,863	Fiber optic probe	awarded prior to this year
US 5,663,652	Magneto-optic current sensor	awarded prior to this year
US Provisional Patent No. 60/941,010, by C. Hessel, A. Meldrum, and J. Veinot, TECEdmonton reference 2007006.	nc-SiO ₂ coatings and direct lithographic patterning thereof”	
US Provisional Patent No. 60/971,136, by S. Kuai and A. Meldrum, TEC Edmonton Reference 2007033	Light emitting silicon diode compatible with ULSI processing temperatures and monolithic silicon integration	

New Architectures



Quantum Information Science

Quantum information science is an interdisciplinary field comprising computer scientists, physicists, mathematicians, and engineers who aim to revolutionize communication and computation by exploiting the remarkable quantum aspects of nature. The goal of this revolution is to create quantum devices that can perform tasks that are thought to be impossible without quantum devices, which quantum information researchers refer to as classical communication and classical computation.

The University of Calgary's Institute for Quantum Information Science (IQIS) is an interdisci-

plinary centre addressing a wide spectrum of quantum information research areas. Led by Dr Barry Sanders, there are seven faculty members in experimental and theoretical physics, computer science and mathematics, including one Canada Research Chair, one iCORE Professor and one GDC/iCORE/NSERC Industrial Research Chair. The Institute's goals are to conduct leading research in key theoretical and experimental topics of quantum information science, to provide excellent education, training, and outreach in quantum information and to foster linkage between the Institute and other partners.

The Institute has the dual objective of applying quantum physics to produce revolutionary advances in information and communication science and technology and to advance understanding and methods in quantum physics by applying breakthroughs in quantum information research. The Institute and its members are partners in NSERC's Innovation Platform QuantumWorks, the Canadian Institute for Advanced Research (CIFAR), the Canadian National Centres of Excellence in Mathematics for Industrial Technology and Complex Systems (MITACS), and the Australian Centre of Excellence for Quantum Computer Technology.



Dr Sanders and his research team

In Fiscal Year 2008, the most exciting results include IQIS's theoretical proposal for implementing quantum walks in superconducting circuit quantum electrodynamics in collaboration with Blais at l'Université de Sherbrooke, experimental storage and retrieval of squeezed light from a Rubidium-gas quantum memory, a proposal for a "loop-hole-free" Bell inequality violation using ultracold atoms manipulated by laser tweezers in collaboration with Raizen at the University of Texas at Austin, the discovery with Whaley and Karasik at the

Dr Barry Sanders

University of California at Berkeley that noisy environments can incoherently generate coherence and a complete solution to the Gaussian quantum marginal problem with Eisert and Rudolph of Imperial College London and Tyc of Masaryk University in the Czech Republic. These discoveries contribute significantly to the theoretical and experimental march forward towards full understanding and ultimately exploitation of quantum information science.

Next year, much of the research focus will be on highly efficient and practical authentication and long-distance communication in quantum key distribution based on the joint patents by Sanders and Beals of the University of California at Berkeley, a full theory for quantum simulation on small-scale quantum computers, efficient protocols for characterizing quantum states and quantum processes, new and improved optical quantum gates with applications to quantum cryptography, and the commencement of theoretical work on quantum nanoscience as it pertains to quantum information processing ⑦



Location: University of Calgary

Department: Institute for Quantum Information Science

Team Members: 57

Website: <http://www.iqis.org>

Biography: Dr Barry Sanders has been an iCORE Professor since 2003 and an iCORE Chair since 2008. He obtained his BSc from the University of Calgary and his PhD from the University of London (Imperial College). He had been a post-doctoral research fellow at the Australian National University, the University of Waikato, and the University of Queensland. He joined Macquarie University in 1991, where he conducted research in quantum optics and quantum informatics, and served as Head of the Department of Physics for six years ⑦

New Architectures

COLLABORATIONS

<i>Institution</i>		<i>Nature of Collaboration</i>
Provincial Collaborations		
University of Calgary	Wolfgang Tittel	Academic
National Institute for Nanotechnology	Robert Wolkow	Academic
National Collaborations		
Wilfrid Laurier University	Shohini Ghose	Academic
University of Toronto	René Stock	Academic
Université de Sherbrooke	Alexandre Blais	Academic
International Collaborations		
Masaryk University, Czech Republic	Tomáš Tyc	Academic
University of California at Berkeley, USA	K. Birgitta Whaley, Raisa Karasik, T. Beals	Academic research and student/faculty exchange
University of New Mexico, USA	Ivan H. Deutsch, Paul M. Alsing	Academic
University of Sydney, Australia	Stephen D. Bartlett	Academic collaboration on joint research
University of Texas, USA	Mark G. Raizen	Academic
Institute of Physics, Chinese Academy of Sciences, China	Peng Han, Kui-Juan Jin, Yueliang Zhou, Hui-bin Lu, Guo-zhen Yang	Academic
Macquarie University, Australia	Peter G. Brooke, James D. Cresser, Dominic W. Berry	Academic

New Architectures



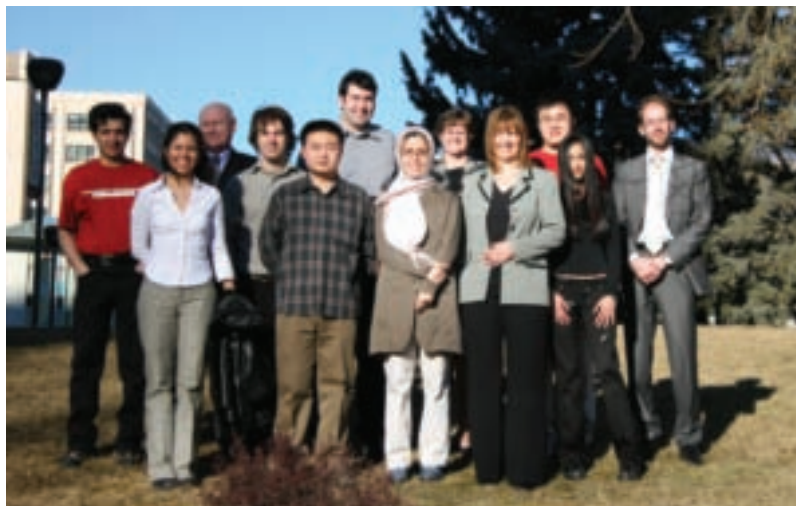
Quantum Cryptography and Communication

The academic employment of Dr Wolfgang Tittel at the University of Calgary commenced on July 1, 2006. Since then, the establishment of the new Quantum Cryptography and Communication Laboratory (QC2Lab) has expanded the Institute for Quantum Information Science (IQIS), whose focus has been on theoretical and fundamental experimental research, into applied research backed by industry. Through partnership with General Dynamics Canada (GDC) and based on support from the Southern Alberta Institute for Technology (SAIT), the research program targets the important interfacing of the world-class academic research with the demands of society for provable secure communication systems, and is indispensable given the strategic importance of self-sufficiency in information security. It will lead to pioneering advances in practical quantum cryptography (QC), and to significant benefits for Albertan and Canadian society and industry, the U of C, and SAIT.

Quantum information science is concerned with revolutionary implications of quantum devices

and systems to information and communication science and technology. Although the field is still in an embryonic stage and implementations are difficult, the advance of experimental capabilities coupled with new technologies are bringing us closer each day to actual realizations. In particular, the tremendous progress in the information-theoretically secure distribution of quantum keys during the last decade underlines the expectations that secure communication, invincible to future technological or algorithmic im-

provements, can be achieved. Yet, Canada cannot rely on importing working QC systems due to trade restrictions, nor can imported technology be fully trusted because of the risk of “backdoor” information leakage. Furthermore, current quantum key distribution (QKD) systems suffer from small key rates and limited distance, and the integration into networks is still in development. In short, investigation into QC systems that can be made in Canada is indispensable.



Dr Tittel's research team at the Institute for Quantum Information Science

Dr Wolfgang Tittel

The research program targets the building of fibre-based point-to-point QC systems for up to 50 km distance with unprecedented key rates, and integration into classical communication infrastructure and networks. It also targets the development of quantum relay and repeater technology to extend QC across Alberta and ultimately across the nation. This includes novel techniques for rendering photonic quantum communication primitives practical, plus hitherto unrealized means for efficient and reversible transfer of quantum information between photons and atoms for temporal storage (i.e. quantum memory).

After having set up the requisite infrastructure in terms of laboratories, equipment, highly qualified personnel, and collaborative linkage during the first year, the second year of Dr Tittel's employment at the U of C was primarily devoted to starting research into the four pillars: point-to-point quantum key distribution, quantum networks, quantum relays, and quantum memory. A large variety of novel, highly versatile tools has been developed, and provides a sound basis for implementing complex applications of quantum cryptography and communication theory. Furthermore, a dedicated dark fibre cable, connecting Dr Tittel's Laboratories at the U of C and SAIT has been established and will serve as a test-bed for assessing QC systems in a real-world environment ⑦



Location: University of Calgary

Department: Physics and Astronomy

Team Members: 17

Website: <http://www.iqis.org/people/home/wtittel>

Biography: Dr Wolfgang Tittel has been an iCORE Chair since 2006. He studied Physics at the University of Frankfurt in Germany, was a PhD student at the University of Geneva/GAP Optique (Switzerland) and completed his post-doctoral at the University of Aarhus (Denmark) and again at GAP Optique, before being recruited by iCORE.

Along with collaborations with his present Quantum Memory group that continues on in Geneva, Dr Tittel brings with him existing collaborative connections with the Institute for Quantum Computing (Waterloo, Canada), research groups at the Lund Institute of Technology (Sweden), the University of Nice (France), and the University of Paderborn (Germany) ⑦

New Architectures

COLLABORATIONS

<i>Participants</i>	<i>Nature of Collaboration</i>
Provincial Collaborations	
Mr. Hosier, Southern Alberta Institute of Technology	Extension of telecommunication and network architectures from the classical to the quantum domain
Dr Sanders, University of Calgary, Institute for Quantum Information Science (IQIS)	Studies of long-distance quantum communication assuming realistic technology
Dr Jullien, University of Calgary, Advanced Technology Information Processing Systems (ATIPS) Laboratory	Fast classical post-processing for quantum cryptography
Dr Williams, University of Calgary, Department of Mathematics and Statistics	Optimization of error correction for Quantum Cryptography
Dr Marzlin, University of Calgary, Institute for Quantum Information Science (IQIS)	Quantum Memory (theoretical investigations)
National Collaborations	
Dr Godbout, Polytechnique Montréal, Département de génie physique	Sources of entanglement for quantum relays

International Collaborations	
Dr Moiseev, Zavoisky Kazan Physical Technical Institute of the Russian Academy of Sciences	Quantum Memory (theoretical investigations)
Dr Gisin, University of Geneva, Group of Applied Physics, Switzerland	Quantum Memory (experimental investigations)
Dr Guillot-Noel, ENS de Chimie de Paris , France	Quantum Memory (spectroscopy)
Drs Le Gouet and Chanelière, Laboratoire Aimé Cotton, CNRS Paris, France	Quantum Memory (experimental investigations)
Dr Sohler, University of Paderborn, Group of Applied Physics, Germany	Quantum Memory (material development)

Intelligent Software Systems

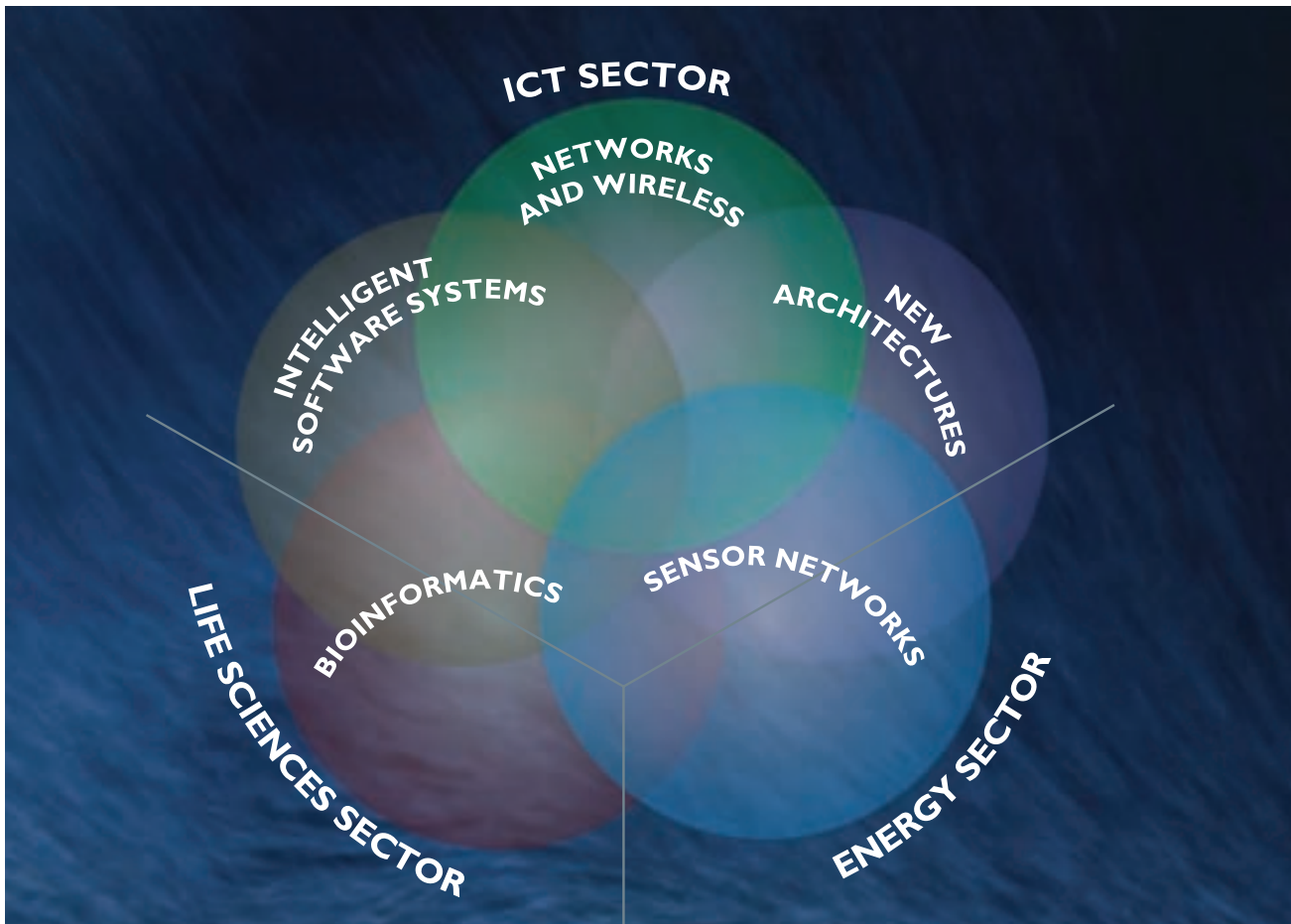
iCORE researchers are working on Intelligent Software Systems providing solutions ranging from decision optimization to collaborative learning. Their research is moving from theoretical to experimental, developing work that is garnering the attention of world-class companies.

This cluster got its start in 2001 with the recruitment of top-level Artificial Intelligence researcher Dr Jonathan Schaeffer, followed by the 2003 addition of Dr Robert Wolkow and his Nanoscale

Information and Communication Technologies group.

In 2004, iCORE recruited another AI researcher, Dr Richard Sutton, and Intelligent Sensing Systems researcher Dr Hong Zhang, whose Industry Chair is in partnership with industry leaders Syncrude and Matrikon.

Dr Pierre Boulanger, in 2005, brought his expertise in Collaborative Virtual Environments to his



industrial partner TRILabs, as they work jointly to bring people closer together, virtually, to save time and money.

Providing tools to the oil and gas sector since 2006, Dr Sirish Shah's Suncor and Matrikon Industry Chair is researching advanced process control algorithms, essential to remaining competitive in a world with ever-growing energy demand.

The newest iCORE Chairs in the Intelligent Software Systems cluster, brought onboard in 2007, are Dr Rei Safavi-Naini and Drs Sheelagh Carpendale and Saul Greenberg. Dr Safavi-Naini's Information Security is one step closer to practical application through work with Canadian police on multimedia and cyber security. Drs Carpendale and Greenberg are in industrial partnership with SMART Technologies, creating the next generation of smart tabletop interactive computers.

As the researchers in Intelligent Software Systems cluster continue their work, their collaborations are strengthening research clusters in: Cryptography/ Number Theory/Quantum Cryptography/ Information Security, and Nanoscale Physics & Materials/ Nano ICT/ Nano Devices, Collaboration/Visualization/Interaction.



Dr Rei Safavi-Naini



Dr Robert Wolkow



Dr Anup Basu



Dr Pierre Boulanger



Dr Sheelagh Carpendale

Dr Saul Greenberg



Dr Jonathan Schaeffer



Dr Sirish Shah



Dr Richard Sutton



Dr Hong Zhang

Intelligent Software Systems



Information Security

The iCORE Chair in Information Security in the Department of Computer Science, University of Calgary, is a research group directly led by Dr Safavi-Naini, including research staff and students who are directly funded by iCORE, and also academic staff within the Department of Computer Science whose research aligns with the research direction of the iCORE Information Security Lab (iCIS Lab) and have joined the Lab since its inception.

The Chair's area of expertise is information security. Her current areas of investigation are information theoretic security, provable security, wireless and sensor security, and privacy-enhancing technologies. This covers highly theoretical research in finding fundamental limits of security systems, as well as developing application-driven security systems with guaranteed assurance for their performance.

The iCORE Chair in Information

Security was officially launched on October 17, 2007. The launch provided an excellent opportunity to introduce the Lab and its vision to the wider community and demonstrate some of the research that is currently underway. A number of media events including radio and television interviews followed the launch.

Over the period last year, members of iCIS Lab made significant contributions to world-class security



Dr Safavi-Naini and her research team

Dr Rei Safavi-Naini

research and education, and successfully worked towards building linkages with industry and community. These are evidenced by research output, industry and community support for industry collaborative projects, and numerous media and community interviews and talks delivered by members of iCIS Lab.

The iCIS Lab hosted 18 national and international visitors who presented their research and delivered talks on a wide range of security topics, including at the iCIS Security Seminars. The Chair was also part of the winning bid to host the 3rd International Conference on Information Theoretic Security (ICITS 2008) in Calgary.

Additionally, members of the iCIS Lab have published or are awaiting publication of six papers in refereed journals, have published in 21 referred conference proceedings, and even published a book on Image Pattern Recognition.

In the next year, the Chair plans to move forward with continued research and to help the iCIS Lab provide an environment for others to do research into information security, to foster ties to industry, and to become a centre for information security and privacy in Alberta ⑦



Location: University of Calgary

Department: Computer Science

Team Members: 21

Website: <http://pages.cpsc.ucalgary.ca/~rei>

Biography: Dr Rei Safavi-Naini has been an iCORE Chair since 2007. She received her PhD in Electrical and Computer Engineering - Coding Theory from the University of Waterloo, Canada, after completing her BSc and MSc in Electrical Engineering at the University of Tehran, Iran.

Before joining the University of Calgary in 2007, Dr Safavi-Naini was a Professor of Computer Science in the Faculty of Informatics. She was also the Director of the Telecommunication and Information Technology Research Institute (TITR) and the Centre for Information Security (at the University of Wollongong, Australia). She has served on the program committees of major conferences in cryptology and information security including CRYPTO, EUROCRYPT, ASIACRYPT, and ACM CCS ⑦

Intelligent Software Systems

COLLABORATIONS

<i>Participants</i>	<i>Nature of Collaboration</i>
Institutional Collaborations	
CISaC	Member
QIS (Dr Sanders, Dr Tittel)	Research collaboration
Broadband Wireless Network (Drs Williamson, Ghaderi)	Research collaboration (Sensor security)
Advance Database System Lab (Dr Ken Barker)	Research collaboration (Privacy systems)
Biometric Technologies Lab (Dr Gavrilova)	Research collaboration (Biometric systems)
AI Research Laboratory (Dr Denzinger)	Research collaboration (Privacy systems)
National Collaborations	
University of Waterloo, CrySP	Co-applicants, MITACS funded project
International Collaborations	
ICITS 2008	Program Chair Steering Committee
MITACS-INRIA Initiative France-Canada	Student exchange Research Collaboration PC Member

Intelligent Software Systems



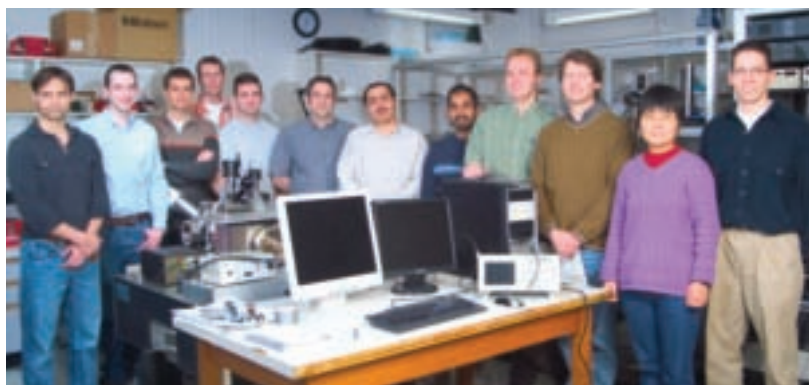
Nanoscale Information and Communication Technologies

The Molecular Scale Devices Group (MSDG) uses scanning tunneling microscopy (STM) and advanced quantum mechanical computation, together with expertise in condensed matter physics, surface chemical physics, organic synthesis, and instrument engineering to gain a detailed understanding of and atom-scale control over hybrid silicon-molecule structures. The knowledge gained in this venture will underpin revolutionary devices capable of new function and miniscule power consumption that will be fabricated—and later disassembled—using “green” processes. While initially nanoscience researchers face a great array

of formidable challenges, the brain-like computational power and sensing functions created will more than repay the investment. In the past five years, the MSDG has made great progress towards realizing its goals. Funding from iCORE, together with comparable resources from the National Institute for Nanotechnology (NINT) and other sources have allowed the MSDG to assemble a tremendous team and state-of-the-art facilities that place us among the world's leaders.

The MSDG's involvement in the study of molecules as devices began 20 years ago. Some of the group members' early work helped define

the concepts and methods that opened up a new field. One indication of our standing in the area is given by citation statistics; three of the MSDG's early papers have collectively been cited over 950 times; a more recent article, proposing hybrid silicon-organic molecular structures as a foundation for molecular devices, has been cited over 300 times, placing it in the top 1% of articles in the field. An MSDG paper published in *Nature* on sensing individual molecules has been cited 135 times and another paper in *Nature* on self-forming molecular nanostructures on silicon has been cited 254 times. The average citation rate of the team's 25 most cited papers is 95.



Dr Wolkow with his research team

The MSDG has substantially advanced their ability to control multi-molecular nanostructure fabrication on silicon. Moving beyond linear structures, they have succeeded in directing growing structures to turn and continue to grow at a right angle. They have developed further atom-scale surface structural controls, as well. The MSDG has given their first demonstration of dopant-dependent molecular structural growth. These are significant steps toward

Dr Robert Wolkow

general control over silicon-based molecular nano-structure and properties.

The MSDG has continued to build on their recent development of the sharpest, most stable electron-emitting object made by man. Collaborative development with an industry partner continues and commercialization appears likely in the coming year.

They have designed a remarkable new instrument based upon the extraordinary electron emission properties of their sharp tips and it is now being built at the university of Alberta and NINT. This instrument has revolutionary potential – it is predicted to yield atom-resolved, element-specific, 3D images of nano-objects.

A lithography effort aimed at bridging the many orders of magnitude size difference separating nano-objects and the macro world has advanced substantially. This effort will transition nanoscale entities from the rarified laboratory environment into the real world.

Theoretical and experimental studies of nanoscale electrical contacts have also advanced substantially. The MSDG's first two students at U of A have graduated with expertise in this area. Together, these advances move the team closer to completed proto-devices.

Finally, a new development is being pursued collaboratively with the group of iCORE Chair Barry Sanders. They are exploring possible new routes to constructing a solid-state quantum computer ②



Location: University of Alberta

Department: Condensed Matter Physics

Team Members: 14

Website: <http://nanoscale.phys.ualberta.ca>

Biography: Dr Robert Wolkow has been an iCORE Chair since 2003. He received his BSc Honours from the University of Waterloo in 1982 and his PhD from the University of Toronto in 1987. Dr Wolkow has received awards for outstanding achievement from almost every institution at which he has worked. He became a fellow of the Academy of Science of the Royal Society of Canada in 2000, and he became a member of the Canadian Institute for Advanced Research nanoelectronics program in 2002.

Dr Wolkow has been recruited to Alberta from Ottawa, where he was leader of the Molecular Interfaces Program at the Steacie Institute for Molecular Sciences. At that time he was also adjunct professor of chemistry at the University of Ottawa and adjunct professor of physics at McGill University ②

Intelligent Software Systems

COLLABORATIONS

<i>Participants</i>	<i>Nature of Collaboration</i>
Provincial Collaborations	
Prof. Mark Freeman, Physics, U of A	A joint effort exploring ultra fast scanned probe microscopy – Mark brings time-resolved scanned probe and magnetism expertise. They successfully raised over 3M\$ to drive this project
Prof. Frank Hegmann, Physics, U of A	The same joint effort as above to explore ultra fast scanned probe methods, Frank brings ultra fast laser expertise and he led the effort to gain substantial CFI and related funding for the team
National Collaborations	
Prof. George Kirczenow, Physics, Simon Fraser University	Coupled experimental-theoretical electrical transport study of hybrid silicon-molecule structures. One paper published, two written and near ready to be submitted
Prof. Qiao Sun, Electrical Engineering, University of Calgary	They continue to jointly designing new instrument noise isolation techniques
K. U. Ingold, Steacie Institute for Molecular sciences, NRC	They regularly discuss their projects with Keith Ingold, one of Canada's greatest living scientists. Over the last decade his expertise with radicals has several times led to powerful insights
International Collaborations	
Prof. Werner Hofer, Physics, Liverpool	Theoretical study of molecule-silicon electronic properties – a coauthor on their recent Nature publication. Werner's theoretical approaches compliment ours (Gino's)
Yukihiro Shimoi from AIST in Japan	Theoretical exploration of new inter-organic molecule conduction mechanisms

INTELLECTUAL PROPERTY

<i>Title/Name</i>	<i>Status</i>
Molecular transistor	Provisional, progressing to patented status
Nano-tip	Provisional, progressing to patented status
Electron localization	New application initiated

Intelligent Software Systems



Advanced Digital Media for Education

Computer games, animations, cartoons, and videos are traditionally only forms of entertainment, but recently educators have explored the use of multimedia for innovative testing. Rather than traditional pen-and-paper tests, the iCORE/Gautam Rao Industry Research Chair in Advanced Digital Media for Education (ADME) is researching alternative methods of using video and graphics for more effective methods of testing. The ADME team uses a variety of multimedia types in their tests to determine which are the most effective. As well, the team

investigates how games can be used to interactively test concepts, in part by designing questions for a chemistry test with interactive multimedia, suggesting approaches for automatically adjusting the difficulty level of interactive questions, and proposing strategies for giving partial marks for incorrect answers.

The importance of this research is highlighted by the interest from other research communities. In 2007–08, the ADME iCORE Chair was invited to give presentations at the University of Ottawa

Multimedia Communications Research Lab and at the Institute of Computer Science of the Foundation for Research and Technology, Hellas, the latter with team member Dr Irene Cheng. Dr Cheng was also Chair of the 2007 International Symposium on Visual Computing. Also among the team's accomplishments for this year are having published 14 refereed conference proceedings and the software licensing deal they are currently negotiating with Castle Rock Research, which they anticipate will bring in another revenue stream.



DrBasu's research examines the effects of data loss on a model with photorealistic textures

Dr Anup Basu

The research they have conducted thus far sheds more light on new methods to test different cognitive skills, such as those used in understanding music or using multimedia interfaces. The team also constantly evaluates the effectiveness of their working model and implements additional solutions, such as a method for estimating the difficulty level of a mathematical item type using Item Response Theory (IRT). The ADME team evaluated the effectiveness of the multimedia item types through extensive testing on students. All of these implementations have been developed by members of the ADME research group and will be refined as more data is collected.

As the team analyzes this data over the next year, the Chair will continue to explore these projects while trying to answer the resulting new questions, such as how to precisely measure the effectiveness of multimedia in adaptive testing; how to automatically grade responses to multimedia-based questions, such as how to evaluate the accuracy of a sketched map; how to use graphics to effectively simulate laboratory tests; how to use multimedia and haptics to create more engaging testing environments for the visually impaired; and many more 🕒



Location: University of Alberta

Department: Computer Science

Team Members: 39

Website: <http://www.cs.ualberta.ca/~anup>

Biography: Dr Anup Basu has been an iCORE Chair since 2006. He received his BSc in Math & Statistics from the Indian Statistical Institute (Calcutta) in 1980, his ME in Computer Science from the Indian Statistical Institute (Calcutta) in 1983, and his PhD in Computing Science from the University of Maryland in 1990.

He has worked on various aspects of online multimedia with special emphasis on human perception. He has developed leadership in industrial research over the last decade by leading several industry-university projects as well as assisting in the formation of start-up companies. His work has been recognized by Hewlett-Packard, and resulted in one of the only funding of a multimedia educational curriculum in Canada, to the University of Alberta 🕒

Intelligent Software Systems

COLLABORATIONS

<i>Participants</i>	<i>Nature of Collaboration</i>
Provincial Collaborations	
Profs Terry Anderson and his group Athabasca University	Educational Multimedia
International Collaborations	
Prof Guido Cortelazzo Padova, Italy	Robust multimedia transmission
Prof Claudio Silva University of Utah	Graphics & Visualization
Prof Kostas Daniilidis University Penn, USA	Segmentation
Prof Jianbo Shi University Penn, USA	Multimedia communication with packet loss
Prof Satish Tripathi SUNY Buffalo, USA	Networks
Industry Collaborations	
Castle Rock Research	Industrial Prototyping & Commercialization
Tom Malzbender HP Labs, Palo Alto	Advanced 3D Imaging Techniques

INTELLECTUAL PROPERTY

<i>Nature</i>	<i>Title/Name</i>	<i>Status</i>
Software licensing agreement	Multimedia Adaptive Testing	In negotiations

Intelligent Software Systems



Collaborative Virtual Environments

One of the hottest topics in Virtual Reality research is in the field of Collaborative Virtual Environments (CVE). The idea behind CVE is very simple; a simulated world runs on several computer systems, each running a compatible CVE application. The computers are connected over a network and people using those computers are able to interact and collaborate in real-time, sharing the same virtual world. Some tele-immersive CVE systems recognize the presence and movements of individuals and objects, process those images, and then project them in realistic, multiple, geographically-distributed virtual

environments where individuals can interact with each other and with computer-generated models.

The Collaborative Virtual Environments group, led by Dr Pierre Boulanger, is comprised of researchers from a broad variety of backgrounds, but one of the major strengths of the team is the collaborations with researchers in other areas, such as medical imaging specialists and industrial manufacturing designers. In 2007 the CVE group successfully finalized two main projects financed by this Chair and by HP Labs, the Government of Alberta, and Precarn.

In December 2007, the CVE group finished the plan initiated in 2006 in collaboration with HP Labs in Palo Alto, California. This project consisted of developing, with Hewlett Packard, the next generation of video-conferencing systems, based on the CVE group's tele-immersive technology. The technology developed during this project will be included in their new Halo system, one of the first commercial telepresence systems. The project addresses the problem of the automatic and efficient segmentation of a foreground layer from a natural scene that is robust to changes in ambient lighting. The research group's aim is to segment the foreground object from the natural background in real time without user interaction even in the presence of changes in ambient lighting, which occur frequently. This is of key importance for HP to reduce the cost of Halo systems, as a large part of the real cost of installing such a system consists of the modifications that must be made to the room itself in order to create a uniform background between Halo stations, which creates a sense of a common virtual room. HP financed this project with a contribution of \$65K and



Dr Boulanger and his research team

Dr Pierre Boulanger

the Government of Alberta matched the funding with a contribution of \$155K. The project is now finished to both parties' satisfaction. The CVE group plans in 2008 to continue the work with HP Labs and to expand its activities as part of a larger two-year, \$1.2M project that would also include TRILabs, WED, Government of Alberta, Telus, and Cybera.

In 2006, the CVE group started a Precarn industrial project of \$1.1M, working with Creaform 3D and Camoplast to develop a new deformable part inspection system. This project finished successfully in December 31, 2007. With the help of Laval University 3D Vision Group, CVE developed a prototype system for those two companies, which is capable of performing dimensional inspection on deformed parts. This has the potential to revolutionize dimensional inspection in industry, as inspection of such parts currently requires a lengthy fixturing process that is very costly and slow. In 2007, the team finished and delivered the code to Creaform 3D and they are now in the process of integrating this software in their new product. In 2008, CVE plans to continue to collaborate with Creaform 3D to improve the speed and accuracy of the software. In addition, last year Airbus expressed interest in applying this new technology to the inspection of composite material parts from the Airbus 380. Creaform is now working directly with them to deliver in 2009 a prototype inspection system. In 2007, the Department of Radiology and Diagnostic Imaging invested \$1.5M into the chair to develop the first immersive Cave Automatic Visualization Environment in Canada for the visualization of real-time CT and MRI data. This is quite a scientific challenge, as real-time CT can produce data at rates in the order of 64 GB/s. This is a key contribution to the Chair, as collaborative visualization of large datasets is of prime importance for the medical community. To spearhead this collaboration, Prof Boulanger was nominated as the scientific director of the new Servier Virtual Heart Center that will be opened at the Mazankowski Heart Institute in 2009 ⑦



Location: University of Alberta

Department: Computer Science

Team Members: 18

Website: <http://www.cs.ualberta.ca/people/profile.php?who=96297>

Biography: Dr Pierre Boulanger has been an iCORE Chair since 2005. He received his Masters from Laval University in Engineering Physics. He received his Ph.D. in Electrical Engineering from the University of Montreal. He worked for 18 years at the National Research Council of Canada as a senior research officer. He is an adjunct scientist and principal investigator for new media at TRILabs and at the Banff Centre. In 2004, Dr Boulanger was awarded an iCORE Industry chair in Collaborative Virtual Environment. He is the founder of the Canadian Virtualized Reality Systems Working Group and the Director of the Advanced Man Machine Interface Laboratory. On the commercial side, Dr Boulanger is the president of PROTEUS Consulting Inc., an Alberta-based consulting firm specialized in Virtual Reality Applications ⑦

Intelligent Software Systems

COLLABORATIONS

<i>Participants</i>	<i>Nature of Collaboration</i>
Provincial Collaborations	
Prof. Richard Levy, UofC	Collaborator in CRDN and Canarie MLP Projects
Maria Lantin, Banff Centre	VR for the ARTS
Dr. Carlos Flores Mir, Dentistry, UofA	Medical Imaging
Dr. Michelle Norga, Radiology Dept., UofA	Medical Imaging
Dr. Paul Major, Dentistry, UofA	Medical Imaging
Dr. John Wolfaardt, COMPRU	Surgeon
National Collaborations	
Prof. Jeremy Cooperstock, EE, McGill University	Collaboration on the Tele-Immersion Project
Prof. Patrick Hebert, EE, Laval University (Passed six months of sabbatical leave in the laboratory)	Collaboration of the 3D Part Inspection Project
Prof. Trevor Hall, Photonics Group, University of Ottawa	Collaboration of the Canarie's HAVE Project
Prof. Nicolas D. Georganas, DISCOVER Lab, University of Ottawa	Collaboration of the Canarie's HAVE Project
Brian Corrie, SFU	Collaborator for WestGrid and Canarie's MLP Project

International Collaborations	
Prof. Patrick Bourdot, LIMSI Lab, CNRS, Orsay, France	Multi-modal Interfaces
Prof. Claude Lurgeau, Ecole des Mines de Paris, France	3D Image Processing
Prof. Tanneguy Redarce, INSA, Lyon, France	3D Imaging and Medical Trainer
Prof. Jason Leigh, EVL Lab, University of Illinois, USA	GLVF Project
Prof. Manuel Garcia, EAFIT University, Medellin, Colombia	Virtual Wind Tunnel Project

Intelligent Software Systems



Interactive Technologies

Modern society demands that people manage, communicate, and interact with digital information and digital devices at an ever-increasing pace. The problem is not with the information itself, but rather with its sheer volume and the unwieldy ways now provided to present, exchange, view, and interact with it. The iCORE/SMART Technologies Co-Chairs, Drs Sheelagh Carpendale and Saul Greenberg, attack this problem, with the overall objective to:

Design, develop and evaluate interactive technologies so that they support the everyday-world practices of how people view,

represent, manage, and interact with information and how they collaborate with it.

This broad objective is realized by two interrelated research themes. First, interactive visualization investigates the possibilities the digital world affords for people's exploration of dense and complex information spaces. The overall goal of an effective interactive visualization is to promote comprehension by providing people with appropriate interactive technologies and digital displays that help them transform information into knowledge. Second, embodied interaction considers how

the technology that displays this information can be designed as a truly integral part of the real world environment. The overall goal is to create new interactive displays and computational devices that fit, support, and participate in – rather than ignore – the everyday-world social practices of people and their surrounding environment. Both themes are tightly intertwined: Interactive visualization considers the fundamental nature of information and how people can effectively interact with it through technology, while embodied interaction considers how these technologies manifest themselves in ways that exploit the everyday practices and routines of people.



The Interactive Tabletop enables new forms of collaboration

Achievements for Fiscal Year 2008 are considerable. Academically, the Chairs published 28 conference papers and six journal papers, most in concert with graduate students. As an offshoot of the Art/Science Partnership, and with hardware donated by SMART Technologies, the research team produced a digital table that has been installed at the Glenbow Museum in Calgary to facilitate interactive learning about Emily Carr.

In terms of grants, they have successfully applied for a match-

Drs Sheelagh Carpendale & Saul Greenberg

ing NSERC Industrial Chair to the iCORE Chair, and iCORE has added a further match leading to a total Chair endowment of \$2M. Part of this money will be applied to a new hire, and they are currently interviewing several very strong candidates. Extra to their other continuing grants, the Chair received the matching NSERC Industrial Chair and an NSERC Research Tools and Instruments Grant for \$90,747 for a Vicon Motion Capture setup; this equipment has now been purchased and is in place. With the Chair's industrial partner, they are continually engaged in discussions over research projects. They continue to attract our strongest graduates as employees.

Now that the NSERC IRC has been accepted, the Chair is actively looking to hire a new Assistant Professor into the group. The search is in progress and interviews with excellent candidates are planned for early 2009. Additionally, they have hired two Post Doctoral Fellows, with a third to come on staff in mid-2009.

From a research perspective, the Co-Chairs are following the plan they outlined in their initial proposal, and they expect no major deviations in the coming year. Several new students will be arriving in the fall, and they will be invited to join projects already in motion ⑦



Location: University of Calgary

Department: Computer Science

Team Members: 28

Website: <http://grouplab.cpsc.ucalgary.ca>
<http://innovis.cpsc.ucalgary.ca>

Biography: Dr Sheelagh Carpendale has been an iCORE Chair since 2007. She is director of the University of Calgary's Innovations in Visualization Interactions Laboratory and an Associate Professor of Computer Science. She specializes in the development of large table displays for group interaction, as well as visualization of a variety of complex relationships (including genetic information, oil exploration data, and hospital workflow information).

Dr Saul Greenberg has been an iCORE Chair since 2007. While he is a computer scientist by training, the work by Saul and his talented students typifies the cross-discipline aspects of Human Computer Interaction, Computer Supported Cooperative Work, and Ubiquitous Computing. He and his crew are well known for their development of designs based on observations of social phenomena, and toolkits for prototyping novel interfaces. He holds a University Professorship, received the CHCCS Achievement award, and was elected to the ACM CHI Academy for his contributions to the field ⑦

Intelligent Software Systems

COLLABORATIONS

<i>Participants</i>	<i>Nature of Collaboration</i>
Provincial Collaborations	
University of Calgary Faculty of Fine Arts	Carpendale on hiring committee for the new interdisciplinary CRC position in New Media and Creative Practices
University of Calgary Department of Art	Carpendale is working towards the development of interdisciplinary programs and as part of this has run the pilot Art/Com. Sci. interdisciplinary course, Annie Tat is an Interdisciplinary MSc student, Supervisor Carpendale, Co-supervisor P. Woodrow
University of Calgary EVDS	Ron Wardell of EVDS is a member of Carpendale's PhD student C. Tang's committee.
University of Calgary Department of Physics	As part of the pilot Art/Com. Sci. interdisciplinary course, two students under Carpendale's supervision (M. Tobiasz, A. Henderson) are visualizing Astro-physics data. Collaborator Russ Taylor
University of Calgary Departments of Radiology and Clinical Neurosciences	Dr. J. Ross Mitchell is working with MSc student E. Penner of visualizing his medical (brain scan) data.
Banff Centre for the Arts Banff New Media Institute	Carpendale is working towards the development of interdisciplinary programs and as part of this has run the pilot Art/Com. Sci. interdisciplinary course. 2 weeks of this course were held as intensives at the Banff centre (first week in Sept. and first week in Jan.) CAe will be held at Banff Centre and collaboration around this is on going. Banff Centre has been very generous in reducing costs for this conference. Carpendale is involved with helping Banff replace their senior research (M. Lantin)
Alberta College of Art & Design	Carpendale is working towards the development of interdisciplinary programs and as part of this has run the pilot Art/Com. Sci. interdisciplinary course – this initiative is joint with ACAD. 3 ACAD students are attending the pilot course. Most of the final projects will result as installations in the ACAD end of year show (opening April 27th)

Ward of the 21st Century	Carpendale – Member of the Steering Committee Carpendale two active research projects on W21C
University of Calgary Faculty of Communication & Culture	Dr. Edna Einsiedel was a member of Saul's MSc student Kimberly Tee's committee.
University of Calgary Faculty of Communication & Culture	Dr. Maria Bakardijieva was a member of Saul's MSc student Stephanie Smale's committee.
University of Calgary Faculty of Communication & Culture	Dr. Patrick Feng was a member of Saul's PhD student Edward Tse's committee.
National Collaborations	
University of British Columbia	Carpendale paid for UBC PhD student A.Tang to spend two weeks in ilab to work on a research project with PhD student P. Neumann. Greenberg performed joint research with Tang leading to accepted publication.
University of Toronto	Both Greenberg and Carpendale associated via NECTAR, including joint publications. Carpendale co-supervising UofT PhD student
University of Saskatchewan	Both Greenberg and Carpendale associated via NECTAR, including joint publications.
University of Victoria	Carpendale has invited Prof. A. Gooch to be a member of PhD candidate Neumann's committee Carpendale co-chair of CAe with Brian Wyvill
International Collaborations	
University of Magdeberg, Germany	Regular research student exchange
University of Queensland, Australia	Research Visitor, Stephen Viller
Mitsubishi Electric Research Lab	Dr. Chia Shen was a member of Saul's PhD student Edward Tse's committee.

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Adapx Inc.	Dr. Philip Cohen was a member of Saul's PhD student Edward Tse's committee.
Industry Collaborations	
Autodesk	Student Internships
Intel	Student Internships
Microsoft Research, Redmond	Student Internships
Mitsubishi Electric Research Laboratories, Boston	Student Internships, PhD Committee member
Smart Technologies	Sponsor

INTELLECTUAL PROPERTY

<i>Patents</i>	<i>Title/Name</i>	<i>Status</i>
With Smart Technologies, Inc.	Various intellectual property	Relased primarily into the public domain

Intelligent Software Systems



High Performance Artificial Intelligence

The High-Performance Artificial Intelligence Systems (HPAIS) research group, led by Dr Jonathan Schaeffer, specializes in artificial intelligence research—investigating new technologies for creating “intelligent” behaviour in a computer. Although their research spans many areas of artificial intelligence—including search, machine learning, and heuristic knowledge—historically they have used games to demonstrate the ideas. Fundamental problems in artificial intelligence are being

investigated in the context of computer programs that play chess, checkers, Go, and poker. Many of their game-playing programs have achieved a high level of performance and have challenged the best human players in the world.

Although the HPAIS team’s reputation was initially made by applying its work to classic board and card games, the major focus of the group is in addressing the challenges of the commercial games industry. Commercial

games (or, more precisely, interactive entertainment) are a mature industry that had over \$35B in sales worldwide in 2007. They work extensively with BioWare, an Edmonton-based company that is the world leader in role-playing games.

In Fiscal Year 2008, the HPAIS group realized two of the major objectives identified in its initial iCORE proposal from 2001: solving checkers and achieving success against the top human players in a



Dr Schaeffer and his research team

Dr Jonathan Schaeffer

man versus machine poker challenge.

In terms of research, the HPAIS group published 35 articles in referred journals or conference proceedings. They have also been invited to give 30 different presentations at universities and institutes all over the world.

The HPAIS team is also developing intellectual property with real-world applications. In conjunction with Edmonton's BioWare, the group has written and implemented an innovative new pathfinding algorithm for computer games. Based on the success of this project, the team will continue to seek collaboration with industry and with other researchers, such as in the case of the WestGrid project, which brings together 13 universities, the Banff Centre, and TRIUMF, Canada's National Laboratory for Particle and Nuclear Physics, all working together to build shared high-performance computing infrastructure to service researchers 📍



Location: University of Alberta

Department: Computer Science

Team Members: 38

Website: <http://www.cs.ualberta.ca/~jonathan>

Biography: Dr Jonathan Schaeffer has been an iCORE Chair since 2001. He is recognized as a world authority in artificial intelligence applied to computer games. He developed Chinook, the first program to win a human world championship in any game. He has received an NSERC E.W.R. Steacie fellowship in 1997 for his influential games-related research.

Dr Schaeffer is one of few Canadians named a Fellow of the American Association for Artificial Intelligence. He contributes substantially to the development of information technology both in Alberta and across the country. He sits on the board of directors of the company BioTools and the national organization for high performance computing in Canada 📍

Intelligent Software Systems

COLLABORATIONS

<i>Participants</i>	<i>Nature of Collaboration</i>
Provincial Collaborations	
Alberta Ingenuity Centre for Machine Learning (AICML)	This research centre was formed five years ago, with Jonathan Schaeffer as one of the co-principal investigators. AICML is working with a number of industrial partners
WestGrid	This is a multi-institutional initiative (University of Alberta, University of British Columbia, University of Calgary, University of Lethbridge, Simon Fraser University, TRIUMF, The Banff Centre, University of Victoria, University of Manitoba, University of Saskatchewan, University of Regina, Brandon University, University of Winnipeg, University of Northern British Columbia, Athabasca University) and multi-disciplinary initiative
National Collaborations	
DS Engineering (Toronto)	A civil engineering firm. They are providing the civil engineering expertise and data they need to do the research
International Collaborations	
IKAT at the University of Maastricht (The Netherlands)	Strong research ties with the HPAIS group including annual visits and graduate student exchanges
BioWare (commercial games research)	Continues to actively engage the Chair

Intelligent Software Systems



Computer Process Control

The main objective of the NSERC/Matrikon/Suncor/iCORE Industry Research Chair in Computer Process Control, led by Dr Sirish Shah, is to continue the development and evaluation of tools, based on fundamental multivariate statistical temporal and spectral techniques, for effective process and performance monitoring strategies, such as developing strategies that help to do preventative abnormal process detection and diagnosis. An equally important objective is to demonstrate the utility of these tools in the Canadian process industry. The end goal is to develop practical tools that industrial personnel can use for knowledge discovery from process data and use them effectively towards process and performance monitoring.

The key feature of this Industry Research Chair project with NSERC and iCORE support is the tripartite partnership between the University of Alberta, Suncor, and Matrikon. This synergistic partnership has not only allowed this Chair to develop ideas from fundamental theory but also evaluate and validate the utility of such ideas on real industrial processes relatively quickly. For example, the research team has developed theoretical methods, for topics listed

below, for which they have already evaluated the utility of these techniques via industrial applications:

- Detection of process nonlinearity using higher order statistics and the use of these methods to detect and quantify valve stiction, nonlinearity in cyclo-stationary vibration signal data from rotating machines such as pumps and gearboxes. These methods have been successfully evaluated on several industrial data sets including data from AT Plastics, Celanese Inc., and Suncor Energy
- Development of bounds for control relevant on-line model validation criteria based on robust stability conditions. These conditions are based on process data and have been validated on simulated examples as well as on industrial data sets from Suncor Energy and benchmark data sets from Eastman Chemicals (USA) and Mitsubishi Chemicals (Japan)
- Theoretical development of the idea of an identification method based on partial correlations analysis that allows one to detect which specific element of the transfer matrix is significantly out of date and subsequent estimation of that specific element. This technique has been validated on Suncor's MPC application for the control of the Kerosene Hydrotreater Unit and the Naptha Hydrotreater Unit
- The detection and isolation of plant-wide oscillations has been investigated from several fronts and has given us a unique insight into temporal and spectral analysis of process data. We have also developed the new concept of the Adjacency and Reachability Matrices that takes



Dr Shah and his research team

Dr Sirish Shah

process flowsheet and control configurations into account. This method complements the data-based approach very well and provides a fool-proof method of oscillation diagnosis. All of these methods have been successfully validated on industrial benchmark data sets from Eastman Chemicals and Mitsubishi Chemicals

- Development of an interface level sensor using a particle filter application on a transformed image. This is a unique application that has already been applied to measure the froth bitumen and middlings interface in a separation cell at Suncor Extraction.

The Chair will continue to work on the development of multivariate statistical techniques for black-box and grey-box time series modeling, process monitoring and fault diagnostics; image based soft sensing and state estimation techniques; development of model identification, state estimation and control techniques for regularly and irregularly sampled multi-rate multivariable systems; development and evaluation of tools for monitoring of constrained model predictive controllers with industrial evaluation; development of tools using spectral and temporal methods for monitoring cyclo-stationary data as obtained from rotating machineries; and the demonstration of the application of these tools in industry ⑦



Location: University of Alberta

Department: Chemical and Materials Engineering

Team Members: 33

Website: <http://www.ualberta.ca/~slshah>

Biography: Dr Sirish Shah has been an iCORE Chair since 2006. He received his BSc in control engineering from Leeds University in 1971, his MSc in automatic control from UMIST, Manchester in 1972, and his PhD in process control (chemical engineering) from the University of Alberta in 1976.

Since 2001, Dr Shah has worked to establish a centre of research excellence in Intelligent Systems and Control. He has held visiting appointments at Oxford University and Balliol College as a Science and Engineering Research Council fellow, United Kingdom, from 1985-86; at Kumamoto University Japan as a senior research fellow of the Japan Society for the Promotion of Science in 1994; and at the University of Newcastle, Australia, in 2004 ⑦

Intelligent Software Systems

COLLABORATIONS

<i>Participants</i>	<i>Nature of Collaboration</i>
International Collaborations	
Dr A. Tangirala (Faculty member at IIT-Madras)	Collaborative work on non-negative matrix factorization (NMF) for data analysis in the spectral domain)
Dr Deyun Xiao (Faculty member at Tsinghua University, China)	Identification of process models from irregularly sampled data
Dr L.Samavedham (National University of Singapore)	Process analytics and health informatics for personalized ‘point-of-care’ medicine.
Professor N. Thornhill (Imperial College, UK)	Detection of process nonlinearities using higher order statistics
Industry Collaborations	
Dr R. Patwardhan (Matrikon); Dr R. Kadali and T. Hrycay (Suncor Energy)	Part of the IRC partnership between Matrikon and Suncor for process and performance monitoring.

INTELLECTUAL PROPERTY

<i>Parties</i>	<i>Title/Name</i>	<i>Status</i>
Suncor Energy	Image based softsensor	Under evaluation
Professor Z. Iwai	A method for tuning PID loops using adaptive control	Patent filed
	Development of a Matlab based toolbox: DVAtool	In development

Intelligent Software Systems



Reinforcement Learning and Artificial Intelligence

A vast number of problems of economic and scientific interest involve sequences of actions where the effect of one action influences the expected utility of subsequent actions. These sequential decision problems include such diverse applications as inventory management, the control of robots and industrial processes, playing backgammon, and planning under uncertainty, all of which are made

more challenging because of their sequential and stochastic aspects. Many problems in robotics and artificial intelligence are also of this nature, as indeed are most of the decision-making and planning problems faced by people and animals in their daily lives. Reinforcement learning is a new body of theory and techniques for solving sequential decision problems, based on classical methods

such as dynamic programming and inspired by animal learning theory, which enables larger and more diverse problems to be solved.

The objectives of the reinforcement learning and artificial intelligence (RLAI) research program, led by Dr Richard Sutton, are to create new methods for reinforcement learning that remove some of



Dr Sutton with his research team

Dr Richard Sutton

the limitations on its widespread application, and to develop reinforcement learning as a model of intelligence that could approach human abilities. These objectives are pursued through mathematics, computational experiments, the development of robotic systems, and through the development and testing of computational models of natural learning processes.

The research team consists of about 50 members, 30 of whom are graduate students and, of those, 15 of whom are recipients of major scholarships. The output of the research program has remained strong, with 32 papers published or accepted for publication in highly-refereed archival venues during the reporting period. Seven PhD and four MSc students graduated in that same period.

The primary focus of the research program has been on how intelligent machines represent their knowledge of the world. The key question is how to organize the knowledge such that it can be verified, learned, and used autonomously without continual tending by human experts. This project has pursued an unusual approach in which knowledge is expressed in terms of the machines' sensors and actuators, thereby enabling it to be compared directly to experiential data. Substantial further progress was made this year toward formalizing the core learning algorithms and developing planning algorithms.

Highlights of the research program this year include participating in the development of the world's best program for computer Go and creating the software for the next generation of scientific competitions in reinforcement learning. Over 140 teams from around the world have registered and downloaded our software in the run-up to the competition and workshop held in July in Helsinki, Finland 🌐



Location: University of Alberta

Department: Computing Science

Team Members: 50+

Website: <http://rlai.cs.ualberta.ca/RLAI/ualberta.html>

Biography: Dr Richard Sutton has been an iCORE Chair since 2003. He received his BA in psychology from Stanford University in 1978, and his MSc and PhD in computer science from the University of Massachusetts in 1980 and 1984. He worked for nine years at GTE Laboratories in Waltham as principal investigator of their connectionist machine-learning project, spent three years at the University of Massachusetts in Amherst as a research scientist in the computer science department, and spent four years at AT&T Labs in New Jersey.

Dr Sutton is the author of the original paper on temporal-difference learning and, with Andrew Barto, of the textbook *Reinforcement Learning: An Introduction* 🌐

Intelligent Software Systems

COLLABORATIONS

<i>Participants</i>	<i>Nature of Collaboration</i>
Provincial Collaborations	
Alberta Ingenuity Center for Machine Learning	R. Sutton, D. Schuurmans, Cs. Szepesvari and M. Bowling are among the eight principle investigators for this center at the U. of Alberta. Total annual funding for AICML is \$2M
National Collaborations	
Doina Precup, McGill University Prakash Panangaden, McGill University Yoshua Bengio, U. Montreal Shie Mannor, McGill University	NSERC Collaborative Research and Development Grants-Project, “Learning and prediction in high-dimensional stochastic domains,” with Nortel Networks, Bell Canada, to R. Sutton and the listed collaborators \$186,523 total (Sept 1/06 – Aug 31/09)
Jonathan Schaeffer, Robert Holte, Duane Szafron, and Michael Buro University of Alberta	NSERC Strategic Grant, “Intelligent Agents for Interactive Entertainment” to M. Bowling, and D. Schuurmans, and the listed collaborators \$480K total (Oct 1/04-Sept 30/07).
Yoshua Bengio, McGill Hugh Chipman, U. Waterloo Christian Leger, U. Montréal William Welch, U. British Columbia Jim Ramsay, McGill Mu Zhu, U. Waterloo	MITACS grant “Statistical Learning of Complex Data with Complex Distributions” to D. Schuurmans, and the listed collaborators \$59K to D. Schuurmans (Apr 1/05-Mar 31/09)
International Collaborations	
Shalabh Bhatnagar, Indian Institute of Science, Bangalore	Joint research with R. Sutton, M. Ghavamzadeh, and M. Lee on actor-critic RL algorithms
Sylvain Gelly, University of Paris South	Joint research with D. Silver on the use of RL in Computer Go

Jean-Yves Audibert, CERTIS, France	Joint research with Cs. Szepesvari on variance estimation in bandit problems.
Remi Munos, INRIA, Lille, France	Joint research with Cs. Szepesvari on batch reinforcement learning
Peter Auer, Ronald Ortner, University of Leoben, Austria	Joint research with Cs. Szepesvari on efficient exploration
Andras Antos, MTA SZTAKI, Hungary	Joint research with Cs. Szepesvari on statistical machine learning
E. James Kehoe, University of New South Wales, Australia	Joint research with R. Sutton, E. Ludvig, E. Verbeek and J. Neufeld on the relationship between reinforcement learning and learning in animals
Industry Collaborations	
Michael James, Toyota Motor Corporation	With R. Sutton and M. Shahamiri exploring the use of reinforcement learning technology for improving the fuel efficiency of gas-electric hybrid cars

Intelligent Software Systems



Intelligent Sensing Systems

Dr Hong Zhang's research in Fiscal 2008 has been productive in terms of both working closely with the industrial sponsors to demonstrate the value of their research and contributing novel ideas and algorithms to the literature in image processing. The past year has also brought the chair's research program near the end of its first five-year term, and the plan is being made to continue this successful university-industry collaboration beyond the iCORE ICE chair mandate.

The long-term direction of the Chair's research program is to push the scientific envelope of information and communications technologies and apply these technologies to the optimization of the performance of oil sands mining operations. The team studies sensor-processing algorithms for monitoring the various stages of oil sand mining, and the research will lead to objective performance models of the mining components as well as the entire mining process. These performance models will enable the industry to improve the performance of its mining process by maximizing the throughput, while minimizing the rejects and its environmental impact.

A key performance indicator of the mining process is the size of the oil sand ore as it progresses through the ore sizing and delivery pipeline. On that basis, the Chair's research focuses on two areas that are fundamental for objectively evaluating a mining process: (a) reliable sensor processing algorithms for ore size measurement under variable environmental conditions and, with the help of the size information, (b) statistical modeling of a system and its components with respect to their performance metrics.

Their approach to a comprehensive framework for the oil sand size analysis has been primarily based on the use of grayscale intensity images, captured in the

mine by existing video cameras and transmitted to the university laboratory. The grayscale images can be analyzed as individual frames or a motion sequence. The research team's methodology typically begins with an examination of existing image analysis techniques and algorithms that have proved their success in other domains, and then tailoring them for specific applications. Their research was developed at the Centre for Intelligent Mining Systems (CIMS), with close interaction with the industry partner Syncrude, and with technology transfer mechanism assistance from Matrikon.

Achievements in the last year include:

- Successful participation in the evaluation of the pilot at-face slurry technology (INBIT) by providing industrial partner Syncrude with reliable software to measure ore size online
- Development of a new image processing algorithm for detecting large lumps that provides a level of performance comparable to that of a human observer



Dr Zhang with his research team

Dr Hong Zhang

- Testing and developing application software for a video server technology that brings live video from the oil sand mine to the research laboratory using off-the-shelf internet technologies
- Theoretical investigation of fundamental issues in automatic feature extraction and active contour techniques for image segmentation algorithms
- Completion of several MSc theses with the graduates all currently working in Alberta and making contributions to its economy.

This Chair's five-year mandate is nearing its end, and so the team will be revisiting one of the major application areas of the measurement technology. Working closely with industry partner Syncrude, the Chair will take the ore size measurement project closer to field tests. At the same time, the CIMS research staff will be working in parallel to further improve the measurement software, which uses a multi-scale and multi-threshold segmentation algorithm and has already demonstrated an approximately 25% improvement over previous versions of the software.

The Chair plans to continue the work initiated with iCORE funding by working even more closely with Syncrude and their researchers to enhance and improve the CIMS image analysis software.

The new mandate will include investigation of other problems that both are of interest to the oil sand extraction industry and can motivate interesting and challenging academic research. Dr Zhang is confident that the university-industry partnership that has been established through the first ICE term will continue to produce successes for many years 🍀



Location: University of Alberta

Department: Computing Science

Team Members: 16

Website: <http://www.cs.ualberta.ca/~zhang>

Biography: Dr Hong Zhang has been an iCORE Chair since 2004. He received his PhD from Purdue University (Indiana) and his BSc from Northeastern University (China).

He is a tenured full professor in the Department of Computing Science in the Faculty of Science at the University of Alberta, and the Director of CIMS. He has published extensively on robotics and machine sensing, and served as the program chair of major international conferences in the area. He has served as the Program Chair of the 2005 IEEE/RSJ International Conference on Robotics and Intelligent Systems. He currently chairs the technical committee on Robotics and Manufacturing Automation of the IEEE Systems, Man, and Cybernetics (SMC) Society, and is an associate editor of the IEEE Transactions on SMC 🍀

Intelligent Software Systems

COLLABORATIONS

<i>Participants</i>	<i>Nature of Collaboration</i>
Provincial Collaborations	
University of Alberta Joerg Sander, Russ Greiner	Joint student supervision
International Collaborations	
Northeast Univeristy (China) Tianyou Chai	Research exchange
Indian Statistical Institute (India) Dipti Prasad Mukherjee	Research exchange
University of Virginia (US) Scott Acton	Research exchange
Industry Collaborations	
Syncrude Canada Ron Kube, Jim Kresta, Ian Parsons	Chair sponsor and technology user
Matrikon Mark Polak, David Shook	Chair sponsor and technology transfer

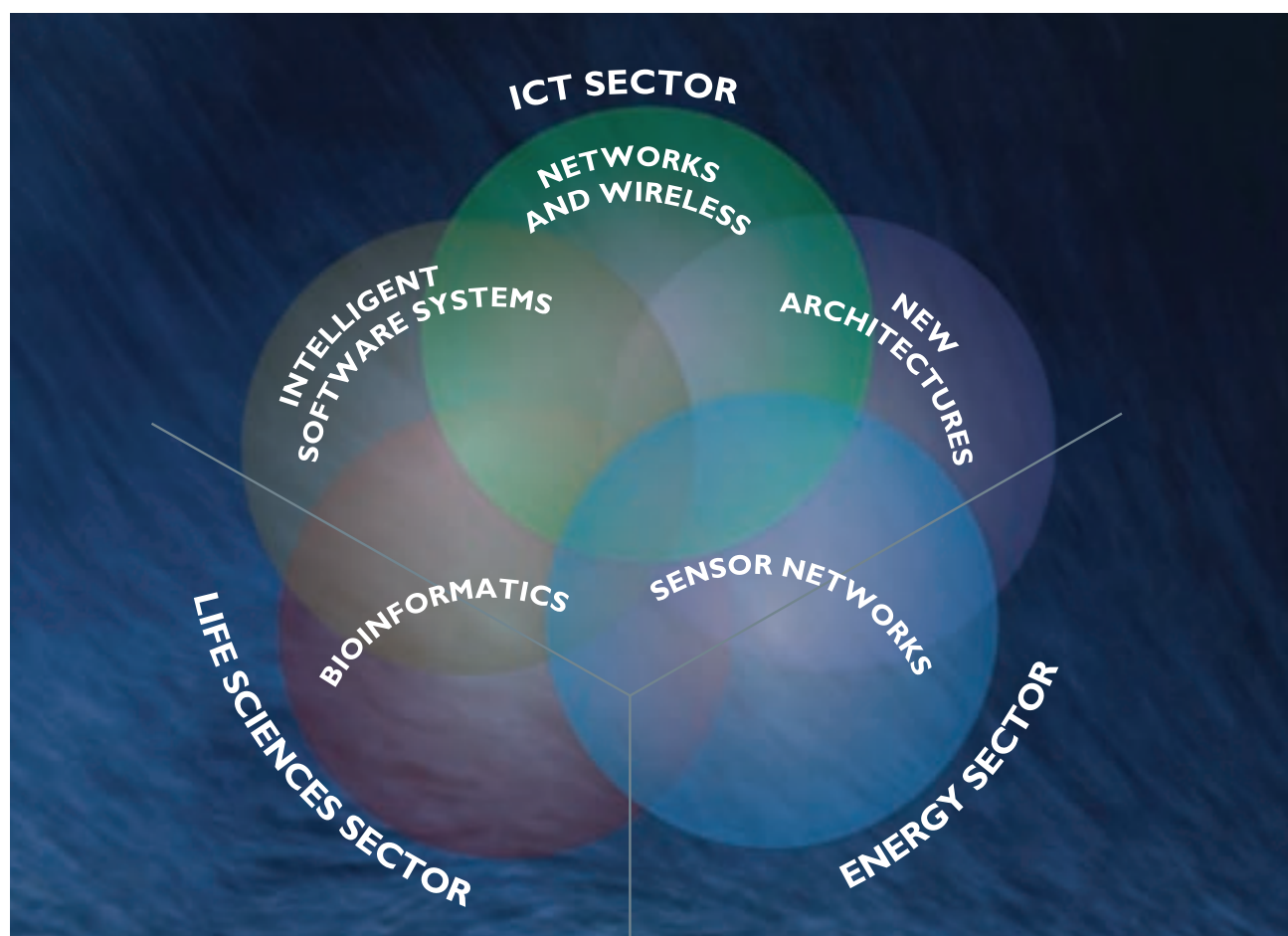
Bioinformatics

iCORE Bioinformatics researchers are investigating biocomplexity and using biosystems informatics and applied bioinformatics to optimize Alberta's quality health care and improve the efficiency and effectiveness of health care service delivery.

Dr Stuart Kauffman's work laid the groundwork for the investigation of the living state from the perspective of Systems Biology, using the tools offered by physics, chemistry, biology, computer

science, mathematics, and informatics. This theoretical launching point meshed with the work of Dr Christoph Sensen, who joined the iCORE Academy in the same year.

Dr Christoph Sensen's virtual CAVE is showing doctors inside the human body in a way that will revolutionize the practice of medicine. More complicated than any machine, this Chair's technology promises to help doctors visualize the complex interactions within the human body, in



real-time.

Dr Ross Mitchell joined the Bioinformatics cluster as an iCORE Industry Chair in 2008. His team is developing software to allow the transmission of medical images to doctors for viewing on mobile devices, cutting down on the time patients wait to receive treatment. Saving time can equal saving lives in a medical emergency, when every second counts.

Latest addition Dr Gane Ka-Shu Wong's work mapping genomics could lead to new medicines and a range of value-added plant products.

The Alberta 1,000 Plants Initiative is this Chair's project to sequence the genomes of 1,000 plants – with only 100 done by other researchers to date, represents a giant leap forward in genomics and partners iCORE with the Beijing Genomics Institute.

[Note: Dr Ross Mitchell is not reporting in this period]



Dr Stuart Kauffman



Dr Christoph Sensen



Dr Gane Ka-Shu Wong



Biocomplexity and Informatics

Through the coordinated efforts of many, including iCORE Chair Dr Stuart Kauffman, the Institute for Biocomplexity Informatics (IBI) in the past year restructured, refocused, reformulated, and in a very important sense, has been reborn. From this perspective, the IBI is climbing a “maturity curve” essential to any leading-edge research enterprise. The original purpose of the institute remains, but it has been enhanced, sharpened, diversified, and grown, and is now being comprehensively activated. In the past year, the IBI has emerged as a fully functioning institute at the University of Calgary.

The mission statement of the IBI has evolved to become: to understand the living state from the perspectives of Systems Biology and non-equilibrium thermodynamics, based on physics, chemistry, biology, computer science, and mathematics. In keeping with this revised vision, the research thrust of the IBI has expanded from the initial focus on Systems Biology, especially the genetic regulatory networks of cancer stem cells, to more broadly address the flow and processing of matter, information, and energy in cells. This expansion now includes these new research areas: “Atoms/Molecules to Cells,” especially multi-scale system structures and functions; “Origins of Life,” molecular machines and prebiotic chemistry; and an over-arching “Physics of Life,” investigating how fundamental principles of biology are manifestations of fundamental laws of physics.

Five faculty members, Drs Kauffman, Huang, Noskov, Chua, and Salahub, are now in place in the IBI. Commensurate numbers of PDFs and graduate, undergraduate, and summer students mean that, including administrative and lab support, more than 25 people work full-time in coordinated IBI research teams under the leadership of these faculty.

The 1500 ft² Kauffman Lab has been completed. High-throughput screening and image analysis of cancer cell lines is now taking place. The experimental work of the team is now beginning to allow better understanding of cell differentiation regulatory networks and mechanisms in both healthy and diseased states. These are the first steps on the highly complex and challenging journey of seeking novel drug targets.

1. To accommodate the growing research teams, phased physical expansion of the IBI continues. To date, appropriate laboratory, office, and meeting space has been acquired. Most importantly, however, with the planned growth of the IBI to 10 faculty with a full complement of PDFs and students, further space will be needed and acquisition is being planned.
2. The IBI Steering Committee is now fully operational, providing necessary guidance and advice regarding IBI governance. The position of Deputy Director has been reformulated into the position of Director of Operations.
3. Plans are continuously being put into place and activated to continue the search for appropriate funding. Grants have been successfully acquired by Drs. Huang (CFI), Noskov (NSERC, AHFMR) and Salahub (NSERC).
4. Formative and established networks of scientific collaboration are in place and continue to be built at the University of Calgary, throughout Alberta, across Canada, and internationally.
5. Faculty and staff of the IBI continue to publish extensively in respected journals in Biological Sciences, Physics, and other fields, present research findings in a wide variety of venues, explore new avenues of thought and scientific advance, and from the lead of two patents having been filed in 2007 as a result of intensive theoretical work, patentable work continues.

Dr Stuart Kauffman

6. New Masters and Doctoral students, summer students, and an increasing number of post-doctoral fellows have joined and will continue to join the IBI adding strength to its teams, its research and publication capabilities, and its interdisciplinary foundation. All of these young people are living examples of one of the most important reasons for the IBI: to educate and train a new generation of highly capable interdisciplinary leading-edge scientists for the future.
7. Science policy networking continues as an outreach thrust of the IBI, with ongoing meetings, consultations and science policy work at local, provincial, national, and international levels. The IBI now runs a highly successful program of weekly seminars, frequent guest speakers, regular weekly and bi-weekly institute meetings, and other aspects of a vibrant communal intellectual life. Also, the Director of the IBI, Stuart Kauffman, has written a new book addressing questions having to do with the intertwined roles of science and religion in relation to the future of humanity.
8. Advance strategic planning for the renewal of the IBI is becoming increasingly important as the halfway point of its first five-year terms has passed. Initial steps in the planning process are now underway.
9. Stuart Kauffman was Program Chair for the iCORE Banff Summit held August 23–25, 2007. This well-received event focused on interdisciplinary potentials of computer science, machine learning, complexity studies, medicine, biochemistry, molecular biology, and cell biology in relation to the development of Systems Biology.

The IBI will continue to build, activate, assess, modify and re-evaluate its strategic plans to carefully guide the shaping and development of the IBI as it evolves. These plans will address ongoing strategic expansion, enhancement of research results, proactive outreach and collaboration, educational and training programs, and industry relations ⑥



Location: University of Calgary

Department: Biological Sciences

Team Members: 23

Website: www.ibi.ucalgary.ca

Biography: Dr Stuart Kauffman has been an iCORE Chair since 2005. He is a professor at the University of Calgary with a shared appointment between biological sciences and physics and astronomy. He is an emeritus professor of biochemistry at the University of Pennsylvania, a MacArthur Fellow, and was an external professor at the Santa Fe Institute, and was recently elected as a Fellow of the Royal Society of Canada.

Originally a medical doctor, Dr Kauffman's primary work has been as a theoretical biologist studying the origin of life and molecular organization. Dr Kauffman was the founding general partner and chief scientific officer of The Bios Group, a company (acquired in 2003 by NuTech Solutions) that applies the science of complexity to business management problems ⑥

COLLABORATIONS

<i>Participants</i>	<i>Nature of Collaboration</i>
Provincial Collaborations	
Randy Goebel, U of Alberta and iCORE	High performance computing and Machine Learning applied to problems in Systems Biology
National Collaborations	
Leon Glass, McGill University	IBI seminar / workshop, November 2007, Cardiac Arrhythmias
Philip Stamp, University of British Columbia	IBI seminar / workshop, October 2007, Condensed Matter Theory
International Collaborations	
Dr. Vladimir Yarov-Yarov, Dept. of Pharmacology, University of Seattle	Joint IBI / HBI [Hotchkiss Brain Inst.] seminar / workshop, October 2007, Rosetta Membrane
Dr. Toby W. Allen, University of California [Davis]	IBI seminar / workshop, October 2007
Dr. Ilya Shmulevich, Institute for Systems Biology, Seattle	IBI seminar / workshop, February 2008, Criticality in Complex Systems
Dr. Louis De Felice, Dept. of Pharmacology, Valderbuilt University	IBI seminar / workshop, March 2008, Ion Channels in Neurotransmitters
Dr. Eric Smith, Professor, Santa Fe Institute, Santa Fe, New Mexico	IBI seminar / workshop, April 2008 [forthcoming]
Dr. Alexi Stuchebrukhov, Department of Chemistry, University of California [Davis]	IBI seminar / workshop, May 2008 [forthcoming]

Industry Collaborations	
Don Aldridge, IBM Canada; Roger Piquette, IBM Canada; Gustavo Stolovitzky, IBM Functional Genomics and Systems Biology Group [Hawthorne, New York]	Collaborative workshops with IBI, other participants; strategic planning for technical, service, student education and science policy advice / support
Kirk Jordan, IBM Deep Computing [Cambridge MA]	Collaborative workshops with IBI, other participants; strategic planning for technical, service, student education and science policy advice / support; planning for MITACS support
Tom McClure, IBM Deep Computing [Houston, TX]; Chris Pratt, IBM Strategic Initiatives [Toronto, ON]	Collaborative workshops with IBI, other participants [Engineering]; strategic planning for technical, service, student education and science policy advice / support

INTELLECTUAL PROPERTY

<i>Patents/Author</i>	<i>Title/Name</i>	<i>Status</i>
Andrecut and Kauffman	“Network Inference Methods”	In process
Andrecut	“Analogue Random Coding”	In process



Applied Bioinformatics



The elements of the immersive working in the CAVE on the 3D image registration, outlining a patient's skull

The goal of the Applied Bioinformatics laboratory, led by Dr Christoph Sensen, is to build the next generation of bioinformatics tools for data exploration, information integration, and advanced 4D visualization. The diverse set of large-scale data currently produced by genome research efforts needs new data integration approaches to reveal its full potential. The laboratory also seeks innovative solutions to several other underlying technical challenges: high degree of usability through fully visual and portable interaction; scalability of

the visualization through the use of level-of-detail management; a number of security provisions; and platform independence.

The Applied Bioinformatics laboratory is working in two broad directions: creating the computational environment for next-generation bioinformatics in collaboration with computer scientists, mathematicians and industrial partners (the main topic of the iCORE/Sun Microsystems activity); and creating models of biological systems in collaboration with clinical and wet-lab research-

ers, who were funded by other means. The users of the newly developed tools include life science researchers, both at the University of Calgary and other institutions, as well as students and trainees whose work involves biological data exploration.

The third year of this iCORE Chair has been filled with a wide variety of research, development, and outreach activities. The Chair's research team now has 990 genomes annotated with the Magpie Automated Genomics Project Investigation Environment system. The comparative genomics functionality of the Bluejay genome browser now includes a number of innovative features. The Seahawk Moby client went public and has been continually updated. The team also developed several new software systems for bioinformatics analysis such as DNA motif finding, microarray data analysis, and conversion of legacy applications to Web Services.

The team has also completed the creation of a 4D atlas of the adult male human anatomy and announced the CAVeman project, utilizing Cave Automatic Virtual Environment technology, to media for wide publicity. The CAVeman system is now highly portable

Dr Christoph Sensen



Dr Sensen with his research team

across different platforms and is capable of mapping gene expression and pharmacokinetic data onto the human atlas. They also developed new software tools for 3D biomedical data visualization, including surface morphing, medical image stack alignment, stack fitting within a 3D model, and histological data representation in anatomical context.

Dr Sensen continues to serve as Director of the Centre for Advanced Technologies, which currently coordinates 15 core facilities in the Faculty of Medicine of the University of Calgary. He is also Vice Chair of Scientific Advisory Committee of the 3rd International Conference on Advanced Digital Technology in Head and Neck Reconstruction as well as Member of Scientific Committee of the Fifth International Symposium on Integrative Bioinformatics ⑦



Location: University of Calgary

Department: Biochemistry and Molecular Biology

Team Members: 28

Website: <http://www.visualgenomics.ca/sensencw/>

Biography: Dr Christoph Sensen has been an iCORE Chair since 2005. He received his PhD in Cologne, Germany. His laboratory has been involved in Genomics and Bioinformatics for more than seven years and features the first Java 3D™-enabled CAVE worldwide, which is used to analyze and visualize complex genomics data.

Dr Sensen is a tenured full professor at the University of Calgary in the Faculty of Medicine and the Department of Biochemistry and Molecular Biology, and an adjunct professor in the Department of Computer Science. He heads the Sun Center of Excellence for Visual Genomics, one of the largest Bioinformatics Laboratories in Canada. He is also the Principal Investigator of Genome Canada's Bioinformatics Platform, which is coordinated by Genome Alberta ⑦

Bioinformatics

COLLABORATIONS

<i>Participants</i>	<i>Nature of Collaboration</i>
Industry Collaborations	
Kasterstener (Red Deer, AB)	Completion of the virtual human body
Sun Microsystems	A virtual reality-based genomic exhibit has been on display at the Executive Briefing Center at Sun Microsystems headquarters for about a year since March 2007. Sun Microsystems donated the first object-oriented data storage system (called “Honeycomb”) in Canada. Sun considers the platform as a test case for this emerging technology and the Chair is actively pursuing the possibility of using this system.

INTELLECTUAL PROPERTY

<i>Patents/Author</i>	<i>Title/Name</i>	<i>Status</i>
Gordon P.M.K., Sensen C.W.	(2004) Osprey: A comprehensive tool employing novel methods for the design of oligonucleotides for DNA sequencing and microarrays. Nucleic Acids Research 29: e133.	TimeLogic Inc. has licensed this code for distribution with their high-throughput database search engines (DeCyPher machines). The Chair is currently working with the company on the industrial version pending siRNA design module.



Biosystems Informatics

The completion of the human genome DNA sequencing project has transformed biology into an information science, and new technologies that dramatically lower the costs of acquiring DNA sequence information are about to transform the field again. The iCORE Chair in Biosystems Informatics was created in 2007 to research new opportunities to understand and apply this information to all fields of biology, from medicine to agriculture to next generation bioproducts.

One of the corollaries of Moore's Law, the observation that computers get faster and cheaper every year, is that new opportunities continually arise as the costs of computing decrease with improvements in technology. Much the same changes are occurring in molecular biology, where the costs of DNA sequencing are decreasing even faster than the costs of computing. Gane Ka-Shu Wong is using these developments to launch Alberta to the forefront of several arenas, leveraging off the technol-

ogy platform that has already been capitalized and is operational at his research lab in China, at the internationally renowned Beijing Genomics Institute (BGI).

A new initiative that was launched in November 2008 combines two visions for biotechnology in Alberta: systems and synthetic biology. It will start by acquiring gene sequence information for 1000 medicinal plants and other species that make valuable bioproducts. As the largest project of



Dr Wong is working on projects such as the sequencing of one thousand plant genomes

Dr Gane Ka-Shu Wong

its kind worldwide, this will attract attention to the growing scientific activities in this province, facilitating the recruitment of additional collaborators who, for example, might focus on a small subset of these plants to reverse-engineer their metabolic pathway and create synthetic organisms that can make the valuable bioproducts.

Dr Wong and his team are also developing novel methods to help identify infectious agents, which is of great practical interest because medical science has made gains towards cures for, prevention of, or treatments for most infectious diseases, but there are many prominent diseases for which there are no cures. There is a growing realization that the methods of studying pathogens in the past ignored more than 99% of microbial species by requiring that they be grown in pure cultures, thereby limiting the number of pathogens that could be studied. Scientists now accept that DNA sequencing of uncultured samples is a very effective way to study these previously uncharacterized microbes, but enormous quantities of data must be collected for these projects; inevitably, computational analyses play a central role.

There will also opportunities to collaborate directly with BGI on large-scale projects that are initiated from within China. Two recent examples include projects to sequence 1000 human genomes and the giant panda genome ⑦



Location: University of Alberta

Department: Biological Sciences, Medicine

Team Members: 8

Website: http://www.biology.ualberta.ca/faculty/gane_wong

Biography: Gane Ka-Shu Wong has been an iCORE Chair since 2007. He received a BASc in engineering physics from the University of British Columbia in 1983, and a PhD in low temperature physics from Cornell University in 1990.

As the Millikan Fellow in Experimental Physics at the California Institute of Technology, he developed an interest in biology, and ultimately joined the Human Genome Project at the University of Washington. From there he went to China to start the Beijing Genomics Institute, where he is now an Associate Director (and a Guest Professor with the Chinese Academy of Sciences).

Now back in Canada at the University of Alberta, he is appointed in the Department of Biological Sciences and the Department of Medicine. Some time in the past, he received a Governor General's medal from the Canadian government ⑧

COLLABORATIONS

<i>Participants</i>	<i>Nature of Collaboration</i>
International Collaborations	
U of A, BGI-Beijing (CAS) BGI-ShenZhen, University of Washington Andrew Mason, et al.	Viral metagenomics
U of A, BGI-Shenzhen, Cardiff University, Chengdu Research Base of Giant Panda Breeding, Institute of Zoology (CAS), Kunming Institute of Zoology (CAS), University of Copenhagen and UC-Berkeley, University of Hong Kong, Wolong Giant Panda Protection Base, World Wildlife Fund, Zoological Society of San Diego	The Panda Genome
USDA-ARS East Lansing, Die Universität Wageningen, Fred Hutchinson Cancer Research Center, L'Institut National de la Recherche Agronomique, Norwegian University of Life Sciences, Purdue University, University of Wisconsin at Madison, Washington University in Saint Louis, Cobb Vantress, Hendrix Genetics	Chicken GMAS Team A newly funded effort to unite the chicken breeders and develop a genome wide marker assisted selection (GMAS) protocol.

Industry Collaborations	
U of A, Musea Ventures Michael Deyholos, Talli Somekh	1000 medicinal plants; significant, even at this early stage, because of the industrial contacts it has attracted investors who have successfully raised funds from top Silicon Valley venture capitalists
Dr Gane Ka-Shu Wong, Michael Deyholos	Sequence the flax genome

Sensor Networks

The larger and more complex the system, the greater the demands for monitoring status and for location.

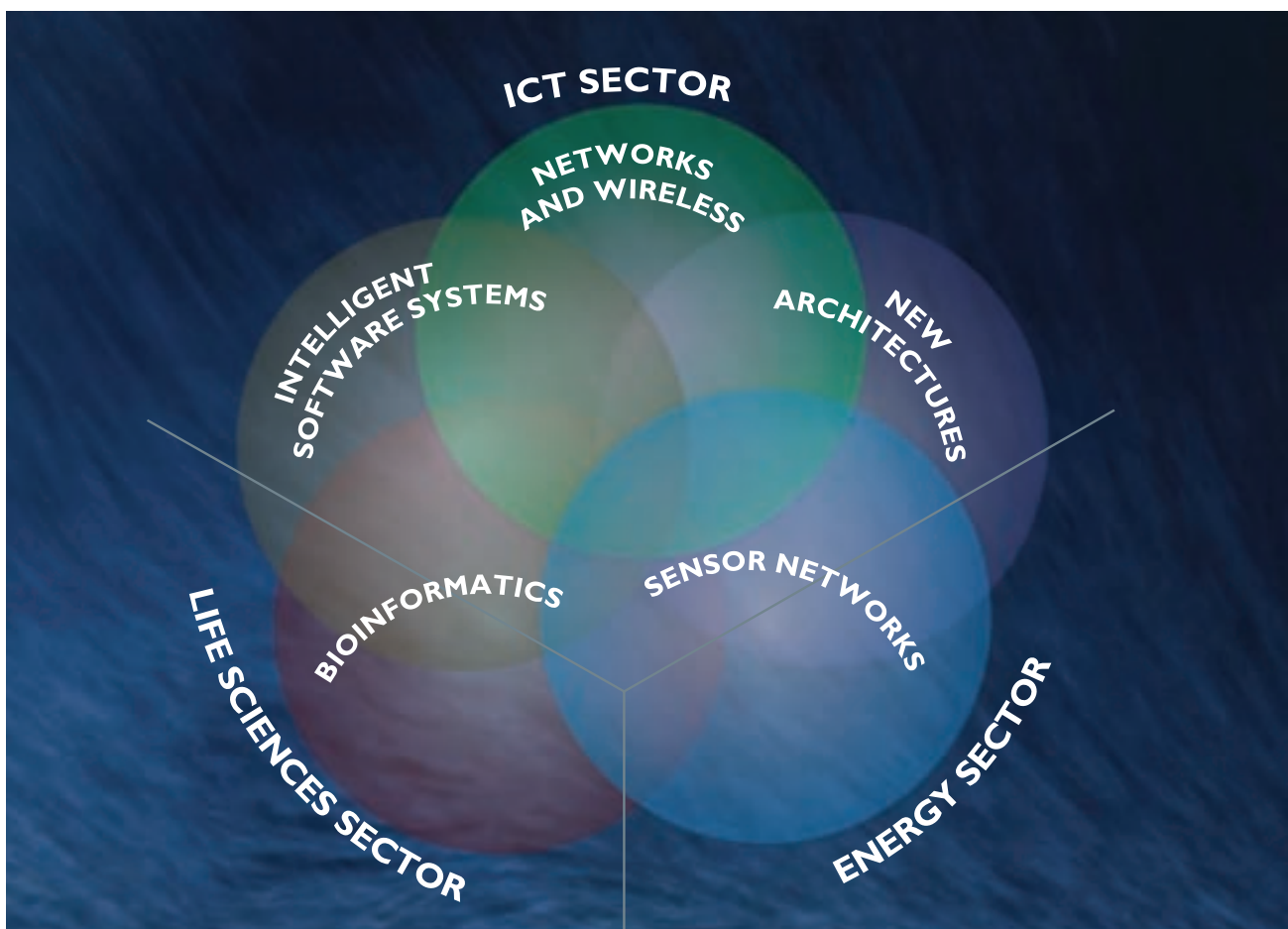
Geomatics researcher and iCORE Chair Dr Gérard Lachapelle is looking more accurate ways to determine position and speed. In 2001, iCORE began funding Dr

Lachapelle's work on developing high-performance navigation and positioning using global navigation satellite systems, outdoor and indoor wireless location, and ground-based radio frequency positioning techniques.

Now, with the addition of Dr Wilsun Xu in 2008 and Dr

Eleni Stroulia in 2009, iCORE Industry Research Chairs are conceptualizing Sensor Networks to solve even more real-world problems.

This is an era in which the demands on the power grid and generation capacity are greater than ever before. Gathering and analyzing information in



fractions of a second is key, not just to diagnose faults, but to anticipate and correct problems before systems fail. Dr Xu is working with the Alberta Power Industry consortium to increase power quality, reliability, and efficiency, which will set the stage for more growth across the province.

Dr Eleni Stroulia is working with IBM to adopt artificial-intelligence and machine-learning methods to partially automate the tasks of software developers and designers, in order to improve their productivity and effectiveness. She is harnessing the strength of Sensor Networks, in which the whole is greater than the sum of its parts.

Note: Dr Stroulia is not reporting in this period



Dr Gérard Lachapelle



Dr Wilsun Xu

Sensor Networks



Wireless Location Research

Dr Gérard Lachapelle's Chair focuses on research related to outdoor and indoor wireless location, high performance navigation and positioning using global navigation satellite systems (GNSS) and ground-based radio frequency (RF) techniques, and the integration with self-contained sensors for navigation and the development of related innovative applications. The iCORE grant supports this research for the period from 2001 to 2010. The various projects

conducted during the reporting period by the Position, Location, And Navigation (PLAN) group, headed by the Chair, consisted of a mix of long-term fundamental research projects and projects arising from the constant interface with industry.

Collaborations with faculty members at the University of Calgary and at other universities in Canada and abroad, with industry and government, have contributed to

the progress achieved on eight major research projects. These ranged from the design of novel GNSS signal acquisition and tracking algorithms to the development of an ultra-light and ultra-precise positioning and timing device to assist Canadian Olympic skiers in their training. These research projects have resulted in high quality personnel training, publications, and technology transfer. Personnel training in the PLAN Group included the degree completion of



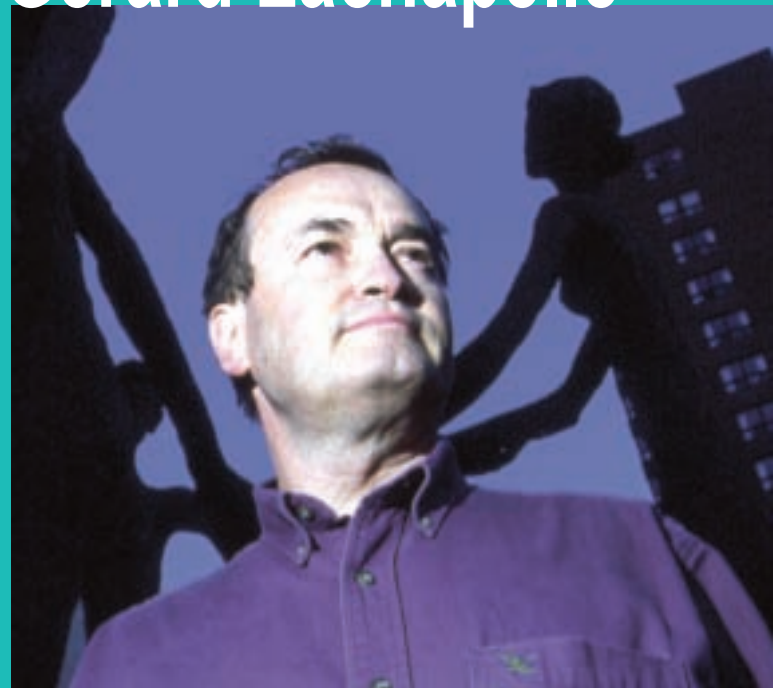
Dr Lachapelle with members of the Wireless Location Research team

Dr Gérard Lachapelle

five Masters, one MEng and five PhD students and the transfer of three research engineers to industry and academia. Three senior research engineers joined the group and five new MSc and PhD candidates started their studies during the reporting period. Fifty research engineers, Masters and PhD candidates, internship and visiting students were associated with the group. Group members published ten papers and several more were accepted and/or submitted for publication in refereed journals; 22 were presented at conferences and published in conference proceedings. The Chair made numerous invited oral presentations in Canada and abroad. Technology transfer consisted of the licensing of software and contracts and grants from third parties in Canada and abroad. In recognition of their efforts, members of the research team and collaborators received 17 awards that have contributed to the sustained international recognition of the PLAN Group and the Alberta GNSS industry.

Thanks to the success of the Chair holder and his collaborators in securing external sponsors for the above research activities, over \$1.8M was raised in external funding during the reporting period, in addition to the iCORE grant of \$0.6M.

The objectives for the forthcoming 12-month period continue to be a mix of planned and opportunity-driven research and development. The latter is considered most important for the overall activities of the Chair's PLAN group to remain relevant, innovative, and to maximize high-quality personnel training and economic development ⑦



Location: University of Calgary

Department: Geomatics Engineering

Team Members: 49

Website: <http://plan.geomatics.ucalgary.ca/professors/lachap>

Biography: Dr Gérard Lachapelle has been an iCORE Chair in the Department of Geomatics Engineering at the University of Calgary (U of C) since 2001. He has 30 years of industrial and academic research experience related to wireless location. His contributions to the development, dissemination and commercialization of GPS technologies have had a major impact, and the GPS software that he has developed with his colleagues has been successfully licensed to thousands of users throughout the world.

Throughout his career, he has proved to be an effective team builder and leader, able to identify research areas of importance, and effectively transfer the outcome of this research to industry. He has been a faculty member at the U of C since 1988 ⑦

Sensor Networks

COLLABORATIONS

<i>Participants</i>	<i>Nature of Collaboration</i>
Provincial Collaborations	
Professors M. E. Cannon, M. Petovello, K. O’Keefe and S. Skone, Dept of Geomatics Eng, U of C	Joint GNSS-related research and grants, joint graduate student co-supervision
Professor J. Nielsen, Dept of Electrical and Computer Engineering, U of C	Development of ground-based wireless location methods and GNSS signal processing methods, graduate student co-supervision
National Collaborations	
UBC Okanagan (Professor Richard Klukas)	GNSS signal enhancements
Carleton University (Professor Jim Wight)	GNSS signal enhancements
Aerospace Engineering Test Establishment, DND	Navigation system performance analysis
Defence Research and Development Canada, DND	Ultra-tight GNSS-INS integration and software receiver development and Ground-based RF navigation system development
General Motors of Canada Ltd	GNSS technologies for automobile industry
International Collaborations	
University College Cork, Ireland	GNSS signal enhancements
Politecnico di Torino, Italy	GNSS signal enhancements
U.S. Navy - NAWC	Aircraft buffeting estimation
University of Copenhagen	GNSS RTK positioning

Technical University at Graz, Austria	GPS signal simulation
Industry Collaborations	
European ICT company	Wireless location
ESYS PLC (UK) and Telespazio (Italy)	Galileo signal evaluation
Asian automobile manufacturer	Integrated vehicular navigation systems
Asian GNSS company	GNSS software receiver

INTELLECTUAL PROPERTY

<i>Patents/Licenses</i>	<i>Title/Name</i>	<i>Status</i>
Patent Application	New Unambiguous BOC (n,n) Signal Tracking Algorithm	Patent Pending (Submitted to U.S. Bureau of Patents (2004)
Patent Application	Differential Signal Processing Schemes for Enhanced GPS Acquisition	Patent Pending (Submitted to U.S. Bureau of Patents (2005)
Patent Application	A new method of Doppler Removal and Correlation for software GNSS receivers	Patent Pending (Submitted to U.S. Bureau of Patents (2006)
Patent Application	Vehicular navigation and positioning systems	Submitted to U.S. Bureau of Patents (2006)
Software	GSRNx™	Licensed to one third party (2007)

Sensor Networks



Power Quality

The NSERC/iCORE Alberta Power Companies Industry Research Chair in Power Quality was established in October 2007. Led by Dr Wilsun Xu, its objective is to research energy system oriented information and computing innovations and develop a new generation of monitoring and control technologies for Alberta's electric energy infrastructure. In the area of applied informatics, the program will conduct fundamental and applied research in the three

directions:

- Information extraction from power disturbances,
- Active disturbance generation for information extraction
- Intelligent devices for power disturbance mitigation

Each of these directions will cover two to three cohesive but distinct research projects.

Since the launch of the chair program, the team has conducted four project initiation meetings with the sponsoring companies. The projects are being conducted in the Power Disturbance and Signaling Research Lab recently formed for the Chair program. Field measurements have been taken for some of the projects. The Chair also offered a one-day continuing education course to the sponsors. The course attracted about 80 attendees and received excellent ratings from the



Dr Xu with his research team

Dr Wilsun Xu



The launch for Dr Wilsun Xu at the University of Alberta

participants. In the area of team building, the hosting department of the program successfully recruited an excellent junior faculty member for the program. This faculty member will join the team in July 2008. The team is currently actively recruiting additional researchers and building collaboration with other faculties. We expect to grow substantially next year in terms of both team-building and research output ⑦



Location: University of Alberta

Department: Electrical and Computer Engineering

Team Members: 17

Website: <http://www.ee.ualberta.ca/~wxu>

Biography: Dr Wilsun Xu has been an iCORE Chair since 2008. He completed his PhD at the University of British Columbia, Canada; his MASc at the University of Saskatchewan, Canada; and his BSc at the Xian Jiaotong University, China. He has been recently elected a Fellow of the Institute of Electrical and Electronics Engineers (IEEE).

Before joining the U of A in 1996, Dr Xu was a senior engineer in the Grid Operation Division of BC Hydro. Dr Xu has more than ten years of industry and research experience in the area of power engineering, and has worked on many engineering and research projects related to power quality, voltage stability, distribution automation, and electromagnetic transients ⑦

Sensor Networks

COLLABORATIONS

<i>Participants</i>	<i>Nature of Collaboration</i>
Provincial Collaborations	
University of Alberta Prof Venkata Dinavahi	Collaborating on distributed generation through student co-supervision
Prof Tongwen Chen	University of Alberta Collaborating on voltage stability monitoring through student co-supervision
Prof Yunwei Li	University of Alberta Collaborating on flexible AC signaling through student co-supervision
National Collaborations	
University of Concordia Prof Luiz Lopez	Collaboration on distributed generation
International Collaborations	
Universidad Politécnica of Madrid, Spain Prof Julio Garcia Majordomo	Collaborating on power system harmonic analysis, sponsored by Electricity de France
University of Campinas, Brazil Prof Walimir Freitas	Collaborating on power system dynamics, sponsored by Brazilian government
University of Campinas, Brazil Prof Luiz da Saliva	Collaborating on power system stability, Sponsored by Brazilian government
Industry Collaborations	
Epcor T&D Inc. Mr John Byron, Mr Gus Antonio, Ms Marta Buryn, Dr Ashish DeSarkar, Mr Gus Antonio	Member of industry advisory board, project collaborators

ATCO Electric Mr Barrie Gorrie, Mr Case Muskens, Mr Tom Greenwood-Madsen	Member of industry advisory board, project collaborators
FortisAlberta Inc. Mr John Holmes, Mr Gord McKinlay, Mr Richard Bahry	Member of industry advisory board, project collaborators
AltaLink Mr Daniel Wong	Principal Engineer Member of industry advisory board
AESO Mr Fred Ritter Ms Pamela Mclean, Mr Derek Mercer, Mr Ming Hu, Mr Rob Davidson, Mr Kun Xiong	Alberta Electric System Operation (AESO) Member of industry advisory board, Direction of Engineering project collaborators

INTELLECTUAL PROPERTY

<i>Patents</i>	<i>Title/Name</i>	<i>Status</i>
US 7,304,403 B2	Power signaling based technique for detecting islanding conditions in electric power distribution systems	Granted Dec 4, 2007



ALGORITHMIC NUMBER THEORY

QUANTUM INFORMATION SCIENCE

WORLD-CLASS RESEARCHERS

HIGH CAPACITY DIGITAL COMMUNICATIONS

APPLICATIONS AND PERFORMANCE

REINFORCEMENT LEARNING ARTIFICIAL INTELLIGENCE

COMPUTER PROCESS CONTROL

WIRELESS TRAFFIC MODELLING

APPLIED RESEARCH

NANOENGINEERED ICT DEVICES

SERVICES SYSTEMS MANAGEMENT

WIRELESS COMMUNICATIONS
INTELLIGENT RF RADIO TECHNOLOGY
ADVANCED TECHNOLOGY INFORMATION PROCESSING SYSTEMS
HIGH CAPACITY DIGITAL COMMUNICATIONS
BROADBAND WIRELESS NETWORKS, PROTOCOLS, APPLICATIONS AND PERFORMANCE
WIRELESS TRAFFIC MODELLING
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