DATE: Monday 11 January 2016
TIME: 10:30 a.m. – 12:00 noon
PLACE: Needles Hall, Room 3318

UNIVERSITY OF WATERLOO
SENATE GRADUATE & RESEARCH COUNCIL
NOTICE OF MEETING

AGENDA

<table>
<thead>
<tr>
<th>Item</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Renewal of Senate-approved Centres and Institutes</td>
<td>Decision (SGRC)</td>
</tr>
<tr>
<td>a. Centre for Computational Mathematics in Industry and Commerce* (Kevin Hare)</td>
<td></td>
</tr>
<tr>
<td>2. Declarations of Conflict of Interest</td>
<td>Information</td>
</tr>
<tr>
<td>a. Excerpt from Bylaw 1, section 8*</td>
<td></td>
</tr>
<tr>
<td>3. Minutes of 7 December 2015* and Business Arising</td>
<td>Decision (SGRC)</td>
</tr>
<tr>
<td>4. Co-chairs’ Remarks</td>
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</tr>
<tr>
<td>5. White Paper on Bibliometrics* (Oszu, Jana Carson)</td>
<td>Information</td>
</tr>
<tr>
<td>6. GSO Activities Supporting Graduate Student Recruitment (Marta Bailey)</td>
<td>Information</td>
</tr>
<tr>
<td>7. Curricular Submissions</td>
<td></td>
</tr>
</tbody>
</table>
| a. Engineering* | 1 Decision (SGRC)
2 SEN-regular |
| 8. Academic Program Review Reports | Information/Member Reference |
| - Handling Of Final Assessment Reports Related To Academic Program Reviews And Follow-Up Two-Year Progress Reports* | SEN-consent |
| a. Augmented Final Assessment Report – Fine Arts* | |
| b. Augmented Final Assessment Report - Geography and Environmental Management* | SEN-consent |
| c. Augmented Two-Year Report – Management Sciences* | SEN-consent |
| 9. Graduate Awards* (Hildebrandt) | |
| a. MSW Award of Excellence – operating | Decision (SGRC) |
| b. Stieber Family Graduate Scholarship in German Studies – trust | Decision (SGRC) |
| c. Risk Management, Economic Sustainability and Actuarial Science Development in Indonesia (READI) Training Award – research account | Decision (SGRC) |
| d. Paul Bridger Graduate Award in Advanced Applied Science – endowment | Decision (SGRC) |
| e. Dr. Brian Rudrick Memorial Graduate Award in Applied Philosophy – trust | Decision (SGRC) |
| f. Hertha Brictha Award for German Studies – endowment | Information |
| 10. Graduate Studies Academic Calendar (Hildebrandt, Trevor Clews) | Information |
| 11. Other Business | |
| 12. Next Meeting: Monday 8 February 2016 from 10:30 a.m. to 12 noon in NH 3318 | |

* material attached
** to be distributed separately
“SGRC” to be approved on behalf of Senate
“SEN” to be recommended to Senate for approval

6 January 2016
Mike Grivicic
Assistant University Secretary
The 2015 CCMIC 5 Year Report

January 5, 2016

To:
Senate Research Council

From:
Kevin G. Hare, Director CCMIC
# Table of Content

1. Introduction and Background................................................................. Page 3

2. Administrative Organization ............................................................... Page 3

3. Mission.................................................................................................. Page 3

4. Development, Promotion, and Management of Undergraduate Programs. Page 4

5. Development, Promotion, and Management of Graduate Programs ....... Page 4

6. Promotion and Facilitating Collaborative Research ............................... Page 5

7. Facilitating Research Relationships with the Public and Private Sectors .. Page 5

8. Future 5-year Plans............................................................................. Page 5

9. Appendix A: Centre Membership ......................................................... Page 7-11

10. Appendix B: Undergraduate Program Description.............................. Page 12-14

11. Appendix C: Undergraduate Program Description............................. Page 15-18


   - Dr. Alan George ................................................................................ Page 25
   - Dr. Mark Giesbrecht ......................................................................... Page 26-27
   - Dr. Stephen Watt ........................................................................... Page 28
   - Dr. Thomas Coleman ...................................................................... Page 29-30
Introduction and Background

The Mathematics Faculty’s vision for Computational Mathematics always included the establishment of a formal centre so as to manage, develop, and promote undergraduate and graduate plans in Computational Mathematics, provide education opportunities for Faculty of Mathematics students and to serve as a catalyst for collaborative research activity within the Faculty and the University in all areas of Computational Mathematics. In 2005, the UW Senate approved the creation of the Centre for Computational Mathematics in Industry and Commerce (CCMIC or simply the Centre) for this purpose.

At the inception of the Centre, the Faculty of Mathematics had hired 11 Faculty complement for Computational Mathematics to support the new initiative and to have more faculty computationally oriented research and interests across the academic units. Since this time, three of the compliment have left the University, leaving the centre with a complement of eight. (Appendix A). In addition to the CM complement, membership of the Centre is open to any Faculty members on campus who have interests and expertise in Computational Mathematics. Currently 60 regular faculty members (Appendix A) from all academic across the Faculty and from Engineering and Science are affiliated with the Centre and participate in Centre activities. This is an increase from 37 from the 2011 CCMIC 5 year Report.

Administrative Organization

The Administrative structure has been simplified since the last Centre review. The main elements of governance is made up of the Director, the Graduate Officer and three committees. The Director oversees day-to-day operations of the Centre, and the Graduate Officer oversees the Graduate Program. The colloquium committee oversees the colloquium series and is composed of the Director and two additional Faculty members. The Graduate committee, which oversees the Graduate Program, is composed of the Director, Graduate Officer and one additional Faculty member. Lastly the Steering committee oversees the running of the Centre. The membership of the Steering committee is the union of that of the other two committees. The Math undergraduate Office does the administration of the day-to-day operations of the Undergraduate Program.

Mission

At the establishment of the CCMIC, the statement of mission identified the following activities as goals of the Centre:

1. The development, promotion, and management of Honours Undergraduate Programs in Computational Mathematics,
2. The development, promotion, and management of Graduate Programs in Computational Mathematics,
3. Promoting and facilitating collaborative research activity in Computational Mathematics, across departmental boundaries within the Faculty, and across the University, and
4. Facilitating the development of research relationships with Government and the private sector.
Each of these will be described in more detail below.

Development, Promotion, and Management of Undergraduate Programs

The CCMIC oversees the Undergraduate program in Computational Mathematics. The day-to-day operation of the Undergraduate program is administered by the Math Undergraduate Office. The program has approximately 48 declared students, which have been reasonably stable for the last 5 years. This number is an underestimate of the program size, as many students do not officially declare their major until 3rd or 4th year.

The program is now well developed and stable. The Centre does not plan to do major new course or program development to support this program, as it is felt that only routine maintenance is now needed. A complete program description is given in Appendix B.

Development, Promotion, and Management of Graduate Programs

In 2005, the Centre undertook the design of a new twelve-month Master's degree in Computational Mathematics. This new program is targeted to students with a bachelor's degree in mathematics, statistics, computer science, or equivalent. It provides students a fast track to PhD studies or to an exciting job in technology, finance, biomedical applications, research labs, etc.

The Master's degree program is offered through the CCMIC, in collaboration with the Faculty's five academic units. To support the new program, new graduate courses (CM 740, CM 770) were developed by CM faculty members.

The program received University approval in 2006 and approval of the Ontario Council on Graduate Studies (OCGS) in Winter 2007. The first cohort of graduate students began in Fall 2008, finished in August 2009, and convocated in Fall 2009. The eight cohort just began in Fall 2015.

A complete program description is given in Appendix C. Students take six graduate courses in the first eight months and spend four months on a research project with their supervisor. The research results are written in a research paper, and are presented in a Symposium in August.

Since the last report, new funding has been found to better support the graduate students financially. The support is now similar to that found in other graduate programs in the Math Faculty.

In its eight years of operation, there have been an average of 50 applicants per year, about 12-13 offers and an average of 11 students enrolled each year. A small number of applicants are admitted to part-time study. Currently, there are 9 full-time students enrolled in the program. In recent years our applications numbers have increase significantly.

After graduation, some students chose to go on to further graduate study in UW or other institutions such as Stanford University. Those who sought employment have been successful in acquiring excellent positions in well established firms such as American Gaming
Systems, Barclays Capital, eBay Inc., SAP Labs Canada, Kubra Data Transfer Ltd., Open Text Corporation. Historically a majority of the students go into industry after graduation.

In June 2012 the Centre entered into an agreement with a major donor to create the Fong Computational Mathematics Graduate Award to be given to a top entering graduate student. In addition, the graduate student lab was renamed to the E.F. Computational Mathematics Graduate Laboratory in recognition of his many donations to the Faculty of Mathematics.

**Promotion and Facilitating Collaborative Research**

This is an area where Computational Mathematics has added considerable value to the Faculty and to the University. Through the Centre activities, faculty from a variety of mathematical research cultures and home academic units have had regular interaction with one another and have come to appreciate the value of other areas of mathematical and computational research. In some instances, this has led to collaborative research papers.

Collaborative research builds on these informal relationships, the understanding of the value of one another's expertise, and on common purpose. This has been facilitated through the Centre activities such as outreach to industry, some granting opportunities, common program and course design (undergraduate and graduate) and in particular, the CM Colloquium/Seminar series. The series brought prominent researchers from local, national, and international institutions as well as from the industry such as Hydro Quebec and Google Research. The seminars are well attended by graduate students and faculty members. Appendix C lists some of the speakers and topics in the CM Colloquium/Seminar series.

**Facilitating Research Relationships with the Public and Private Sectors**

The Centre is currently trying to strengthen its relations to Industry. We are currently in discussion with MITACS and CECA to involve our graduate students in industry, either through internships or co-operative education. Based on recommendations from Thomas Coleman and Stephen Watt, we plan to organize a meeting involving company representatives, the current class of students (both graduates and senior undergraduates) and interested faculty. We hope to make this an annual event. In addition, informal talks are on-going with both Google and CSE.

Other CM faculty have been involved in collaborative research projects within industry generated by their own initiatives, which are not listed here.

**Future 5-year Plans**

Since the last review, major changes have been made to the Undergraduate program, and the Administration of the program. The Admission to this program is now done at second year, instead of being an entry-level program. The rarely utilized options have been eliminated, and the plan vastly simplified. The day-to-day operation is now done by the Math
Undergraduate Office. The Centre has no current plans to make major changes to the Undergraduate program within the next five years.

The CM Graduate program is now within its eighth year of operation, and is relatively stable. Based upon feedback from past and present graduate students, the Centre is currently investigating the possibility of adding a course work Masters as an alternative to the research paper Masters. We are currently talking to MITACS about the option for industrial internships for our graduate students, as well as with CECA about the availability for co-op for our students. Given that a majority of our students go into industry upon graduation, we feel that these changes have the opportunity to grow and improve the program.

The Centre will continue to promote and facilitate collaborative research in Computational Mathematics. The CM Colloquium/Seminar series have been successful in bringing prominent researchers from academia and industry. The Centre will continue to support the series and in addition, organize joint seminars with other academic units to broaden the audience as well as to bring more computational researchers from different fields. The Centre will continue to develop research relationships with the public and private sectors through the various outreach activities of the Mathematics Faculty.

The academic units within the Faculty of Mathematics have all been supportive and very cooperative with the Computational Mathematics Centre and its programs. We plan to continue to promote and strengthen these collaborative efforts through CM research seminars, CM student supervision, CM participation in other Centres such as IC$^3$, WATRISQ, and others, and, as before, through the continued involvement of all CM complement and affiliates in ongoing undergraduate and graduate program development.

Yours sincerely,

Kevin G. Hare
Director, Centre for Computational Mathematics, Industry and Commerce
Associate Professor
Pure Mathematics
University of Waterloo
Appendix A: Centre Membership

**CCMIC Complement:**

<table>
<thead>
<tr>
<th>Name</th>
<th>Dept</th>
<th>Research Interests</th>
<th>Degrees</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ali Ghodsi</td>
<td>Stats &amp; ActSci</td>
<td>Machine learning, Big data</td>
<td>BSc(Shiraz), MSc(Concordia), PhD (UW)</td>
</tr>
<tr>
<td>Arne Storjohann</td>
<td>CS</td>
<td>Symbolic and Exact Linear Algebra, Algorithmic Number Theory</td>
<td>BMath (UW), MMath (UW), PhD (Swiss Federal Institute of Tech.)</td>
</tr>
<tr>
<td>Jeff Orchard</td>
<td>CS</td>
<td>computational neuroscience</td>
<td>BMath (UW), MSc (UBC), PhD (SFU)</td>
</tr>
<tr>
<td>Jochen Koenemann</td>
<td>C&amp;O</td>
<td>Approximation Algorithms, Algorithmic Game Theory, Combinatorial Optimization</td>
<td>MSc (Saarbrucken), PhD (Carnegie Mellon)</td>
</tr>
<tr>
<td>Kevin Hare</td>
<td>PM</td>
<td>Number Theory, Fractal Geometry</td>
<td>BMath (UW), MSc (SFU), PhD (SFU)</td>
</tr>
<tr>
<td>Marek Stastna</td>
<td>AM</td>
<td>Stratified fluid dynamics, climate dynamics, Wave dynamics in porous media</td>
<td>BMath, MMath, PhD (UW)</td>
</tr>
<tr>
<td>Stephen Vavasis</td>
<td>C&amp;O</td>
<td>continuous optimization and numerical analysis</td>
<td>A.B. (Princeton), Cert. of Adv. Study (Cambridge), PhD (Stanford)</td>
</tr>
<tr>
<td>Yuying Li</td>
<td>CS</td>
<td>continuous optimization, scientific computing</td>
<td>BS (Sichuan-China), MMath (UW), PhD (UW)</td>
</tr>
</tbody>
</table>

**Affiliated Members**

<table>
<thead>
<tr>
<th>Name</th>
<th>Dept</th>
<th>Research Interests</th>
<th>Degrees</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adam Kolkiewicz</td>
<td>Stats &amp; ActSci</td>
<td>statistics and financial mathematics</td>
<td>PhD (UW), M.Math (Technical University of Wroclaw)</td>
</tr>
<tr>
<td>Bin Li</td>
<td>Stats &amp; ActSci</td>
<td>actuarial science, applied probability, mathematical finance, and partial differential equations</td>
<td>BS, MS (Xi'an Jiaotong University), PhD (Iowa)</td>
</tr>
<tr>
<td>Brian Ingalls</td>
<td>AM</td>
<td>Control Theory, Math Biology</td>
<td>BSc (University of Kings College), MSc (Dalhousie), PhD (Rutgers)</td>
</tr>
<tr>
<td>Chaitanya Swamy</td>
<td>C&amp;O</td>
<td>combinatorial optimization, approximation algorithms, algorithmic game theory, stochastic optimization, network design, scheduling.</td>
<td>BTech (IIT), MS, PhD (Cornell)</td>
</tr>
<tr>
<td>Name</td>
<td>Department</td>
<td>Research Areas</td>
<td>Degree Details</td>
</tr>
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</tr>
<tr>
<td>Chong Zhang</td>
<td>Stats &amp; ActSci</td>
<td>machine learning, mainly in margin-based classification and other non-parametric statistics, with application in public health and cancer research.</td>
<td>PhD (North Carolina)</td>
</tr>
<tr>
<td>Chris Bauch</td>
<td>AM</td>
<td>Mathematical Biology, Ecology and Epidemiology, Dynamical Systems, Behavioural Models</td>
<td>BS (Texas), PhD (Warwick)</td>
</tr>
<tr>
<td>Chris Fletcher</td>
<td>Geo &amp; EnvM</td>
<td>Atmospheric circulation in determining regional patterns of temperature and precipitation</td>
<td>BSc (Manchester), MSc (Reading), PhD (University College London)</td>
</tr>
<tr>
<td>Chris Godsil</td>
<td>C&amp;O</td>
<td>Homomorphisms and Colorings, EKR Theorems, Complex Lines, Graph Spectra</td>
<td>BSc, MSc, PhD (Melbourne)</td>
</tr>
<tr>
<td>Christiane Lemieux</td>
<td>Stats &amp; ActSci</td>
<td>Quasi-Monte Carlo methods and their applications</td>
<td>BSc (Laval), MSc, PhD (Montreal)</td>
</tr>
<tr>
<td>Christopher Batty</td>
<td>CS</td>
<td>Physics-Based Animation</td>
<td>BMath, MMath (Manitoba), PhD (UBC)</td>
</tr>
<tr>
<td>Dan Brown</td>
<td>CS</td>
<td>Understanding of sequential data, evolutionary theory, probabilistic modeling.</td>
<td>SB (MIT), MS, PhD (Cornell)</td>
</tr>
<tr>
<td>Dong Eui Chang</td>
<td>AM</td>
<td>Control, mechanics, applied differential geometry, machine learning.</td>
<td>BS, MS (Seoul), PhD (California Inst. Of Tech.)</td>
</tr>
<tr>
<td>Eric Schost</td>
<td>CS</td>
<td>computer algebra.</td>
<td>BSc (École Normale Supérieure), MSc, PhD (École Polytechnique)</td>
</tr>
<tr>
<td>Francis Poulin</td>
<td>AM</td>
<td>Geophysical fluid dynamics, Stochastic differential equations, Biological fluid dynamics.</td>
<td>BSc, MSc (Alberta), PhD (MIT)</td>
</tr>
<tr>
<td>George Labahn</td>
<td>CS</td>
<td>Computer Algebra, Computational Finance</td>
<td>MSc, PhD (Alberta)</td>
</tr>
<tr>
<td>Gladimir Baranoski</td>
<td>CS</td>
<td>Light transport models, auroral phenomena</td>
<td>BSc, MSc (Federal Univ. of Rio Grande Do), PhD (Calgary)</td>
</tr>
<tr>
<td>Henry Wolkowicz</td>
<td>C&amp;O</td>
<td>Optimization, linear, nonlinear and semidefinite programming; matrix eigenvalue problems; and numerical analysis of algorithms.</td>
<td>BSc, MSc, PhD (McGill)</td>
</tr>
<tr>
<td>Ilias Kotsireas</td>
<td>WLU</td>
<td>Symbolic Computation, Computer Algebra, Combinatorial Matrix Theory, Combinatorial Optimization, Commutative Algebra &amp; Algebraic Geometry, Combinatorial Designs,</td>
<td>BSc (Athens &amp; Paris 6), MSc (Paris 6), PhD (Paris 6)</td>
</tr>
<tr>
<td>Name</td>
<td>Department</td>
<td>Research Interests</td>
<td>Education</td>
</tr>
<tr>
<td>--------------------</td>
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</tr>
<tr>
<td>Jesse Hoey</td>
<td>CS</td>
<td>artificial intelligence, affective computing, and health informatics</td>
<td>BSc (McGill), MSc, PhD (UBC)</td>
</tr>
<tr>
<td>Jun Liu</td>
<td>AM</td>
<td>Hybrid systems and control</td>
<td>BS (Shanghai Jiao-Tong), MS (Peking), PhD (UW)</td>
</tr>
<tr>
<td>Justin Wan</td>
<td>CS</td>
<td>numerical solutions of partial differential equations, iterative methods, and multigrid preconditioning cell image segmentation, tracking of cell images, computational finance.</td>
<td>BSc (Hong Kong), MA, PhD (UCLA)</td>
</tr>
<tr>
<td>Ken Seng Tan</td>
<td>Stats &amp; ActSci</td>
<td>Actuarial science, finance.</td>
<td>BMath, MMath, PhD (UW)</td>
</tr>
<tr>
<td>Kevin Lamb</td>
<td>AM</td>
<td>Computational fluid dynamics</td>
<td>BMath (UW), PhD (Princeton)</td>
</tr>
<tr>
<td>Kirsten Morris</td>
<td>AM</td>
<td>Infinite-dimensional control systems.</td>
<td>BSc (Queens), MMath, PhD (UW)</td>
</tr>
<tr>
<td>Levent Tunçel</td>
<td>C&amp;O</td>
<td>mathematical optimization.</td>
<td>BSc (Dokuz Eylül), MS, PhD (Cornell)</td>
</tr>
<tr>
<td>Lilia Krivodonova</td>
<td>AM</td>
<td>Discontinuous Galerkin methods, Error estimation and adaptive methods, Finite element methods, Numerical solution of PDEs in complex geometries, Hyperbolic conservation laws</td>
<td>BS, MS (Peterburg State University), PhD (Rensselaer Polytechnic Inst.)</td>
</tr>
<tr>
<td>Marius Hofert</td>
<td>Stats &amp; ActSci</td>
<td>development of mathematical, statistical and computational tools in copula modeling</td>
<td>MSc (Syracuse), PhD (Ulm)</td>
</tr>
<tr>
<td>Mark Giesbrecht</td>
<td>CS</td>
<td>computer algebra, algebraic algorithms and computational complexity</td>
<td>BSc (UBC), MSc, PhD (Toronto)</td>
</tr>
<tr>
<td>Martin Lysy</td>
<td>Stats &amp; ActSci</td>
<td>Continuous stochastic processes, Graphical and hierarchical modeling, Mediation analysis</td>
<td>BSc (McGill), MSc, PhD (Harvard)</td>
</tr>
<tr>
<td>Matthias Schonlau</td>
<td>Stats &amp; ActSci</td>
<td>applied survey sampling and survey methodology, machine learning.</td>
<td>PhD (UW)</td>
</tr>
<tr>
<td>Michael Rubinstein</td>
<td>PM</td>
<td>Number Theory</td>
<td>BA, MA, PhD (Princeton)</td>
</tr>
<tr>
<td>Michael Waite</td>
<td>AM</td>
<td>Turbulence in rotating stratified fluids, Vortices in stratified fluids, Mesoscale atmospheric dynamics, Tropical convection</td>
<td>BMath (UW), PhD (McGill)</td>
</tr>
<tr>
<td>Mu Zhu</td>
<td>Stats &amp; ActSci</td>
<td>statistical machine learning and multivariate analysis, with their health informatics, bioinformatics, and data mining</td>
<td>BSc, MSc (Harvard) PhD (Stanford)</td>
</tr>
<tr>
<td>Name</td>
<td>Department</td>
<td>Field</td>
<td>Education Details</td>
</tr>
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</tr>
<tr>
<td>Pascal Poupart</td>
<td>CS</td>
<td>artificial intelligence machine learning, health informatics, natural language processing</td>
<td>BSc (McGill), MSc (UBC), PhD (Toronto)</td>
</tr>
<tr>
<td>Paul Marriott</td>
<td>Stats &amp; ActSci</td>
<td>Statistics</td>
<td>MA (Oxon), MSc, PhD (Warwick)</td>
</tr>
<tr>
<td>Peisong Han</td>
<td>Stats &amp; ActSci</td>
<td>Statistics</td>
<td>BS (University of Sci. and Tech. of China) MS (Michigan State) PhD (Michigan)</td>
</tr>
<tr>
<td>Peter Forsyth</td>
<td>CS</td>
<td>Financial derivative securities</td>
<td>BSc (Western), MSc (Australian National) PhD (Western)</td>
</tr>
<tr>
<td>Ricardo Fukasawa</td>
<td>C&amp;O</td>
<td>Mixed Integer Programming, Operations Research, Polyhedral Combinatorics, Combinatorial Optimization</td>
<td>BSc, MSc (PUC-Rio), PhD (Georgia Tech)</td>
</tr>
<tr>
<td>Robert Gracie</td>
<td>Civil and Environmental Engineering</td>
<td>Geomechanics and Risks of Hydraulic Fracturing for Shale Gas Development</td>
<td>BSc (Ottawa), PhD (Northwestern)</td>
</tr>
<tr>
<td>Ruodu Wang</td>
<td>Stats &amp; ActSci</td>
<td>actuarial science, quantitative risk management, mathematical finance, operations research, applied probability, and statistics.</td>
<td>BS, MS (Peking), PhD (Georgia Inst. Of Tech.)</td>
</tr>
<tr>
<td>Sander Rhebergen</td>
<td>AM</td>
<td>Finite element methods, Preconditioners, Fluid dynamics, aerodynamics, magma/mantle dynamics, two-phase flows</td>
<td>PhD (Twente)</td>
</tr>
<tr>
<td>Serge D'Alessio</td>
<td>AM</td>
<td>Fluid Dynamics</td>
<td>B. Eng, MEng (McMaster), PhD (Western)</td>
</tr>
<tr>
<td>Shai Ben-David</td>
<td>CS</td>
<td>Statistical and computational machine learning</td>
<td>BSc, MSc, PhD (Hebrew)</td>
</tr>
<tr>
<td>Soroosh Yazdani</td>
<td>Google</td>
<td>Computational Number Theory/Arithmetic Geometry</td>
<td>PhD (Berkeley)</td>
</tr>
<tr>
<td>Stefan Steiner</td>
<td>Stats &amp; ActSci</td>
<td>business and industrial statistics focusing on process improvement</td>
<td>BMath (UW), MSc (UBC), PhD (McMaster)</td>
</tr>
<tr>
<td>Stephen Watt</td>
<td>CS</td>
<td>computer algebra, pen-based computing, mathematical knowledge management, programming languages and compilers.</td>
<td>BSc (New Brunswick), MMath, PhD (UW)</td>
</tr>
<tr>
<td>Tom Coleman</td>
<td>C&amp;O</td>
<td>Continuous Optimization</td>
<td>BSc, MSc, PhD (UW)</td>
</tr>
<tr>
<td>Tony Wirjanto</td>
<td>Stats &amp; ActSci</td>
<td>Quantitative Finance including Computational Finance and data analytics.</td>
<td>M.Eng (TU Munich), BA &amp; MA (Queens), MS (Alberta), PhD (Stanford), PhD (Queens)</td>
</tr>
<tr>
<td>Name</td>
<td>Department</td>
<td>Research Interests</td>
<td>Education</td>
</tr>
<tr>
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<tr>
<td>Wayne Oldford</td>
<td>Stats &amp; ActSci</td>
<td>Statistical reasoning, exploratory data analysis, data visualization.</td>
<td>BMath (UW), MSc, PhD (Toronto)</td>
</tr>
<tr>
<td>William J. Cook</td>
<td>C&amp;O</td>
<td>Integer programming and combinatorial optimization</td>
<td>BA (Rutgers), MS (Stanford)</td>
</tr>
<tr>
<td>Yeying Zhu</td>
<td>Stats &amp; ActSci</td>
<td>causal inference, machine learning and the interface between the two</td>
<td>BS (East China Normal U), MS (Singapore) PhD (Penn State)</td>
</tr>
<tr>
<td>Yingli Qin</td>
<td>Stats &amp; ActSci</td>
<td>hypothesis testing for high-dimensional data with applications to gene sets testing and estimating and testing for large dimensional covariance matrices using the random matrix theory</td>
<td>BSc (Northeast Normal U), MA, PhD (Iowa)</td>
</tr>
</tbody>
</table>
Appendix B: Undergraduate Program Description

Mathematical models arise in a wide variety of fields: business, economics, engineering, finance, medicine, science, and many others. The application of computer methods to simulate such models was traditionally called “scientific computation,” though the practice has spread far beyond its roots in science to encompass problems arising in all areas of society. The results of such simulations are numerical answers, formulae, data sets, plots, charts, and images that help us to understand the nature of the world around us, and allow us to predict and influence the future. Developing and analyzing such models involves a blend of mathematics and computer science. It includes issues such as the implications of finite precision arithmetic, the efficiency, accuracy, and stability of numerical computations, the development and maintenance of mathematical software, and the effects of modern developments in computer architectures and networks. Graduates of Computational Mathematics will be able to deploy effectively a wide range of mathematical and computational techniques in areas of application.

Computational Mathematics Major

Students in this plan must fulfill all the requirements in Table I and Table II. This must include at least 26 math courses, and the following specific requirements:

One of
- MATH 237 Calculus 3 for Honours Mathematics
- MATH 247 Calculus 3 (Advanced Level)

One of
- MATH 239 Introduction to Combinatorics
- MATH 249 Introduction to Combinatorics (Advanced Level)

All of
- AMATH 242/CS 371 Introduction to Computational Mathematics

One of
- CS 230 Introduction to Computers and Computer Systems
- CS 241 Foundations of Sequential Programs

One of
- CS 234 Data Types and Structures
- CS 240 Data Structures and Data Management

Notes:
CS 240 requires CS 245 and 246 as prerequisites, CS 241 requires CS 246 as a prerequisite. CS 240 and 241 have restricted access for non-CS majors.
Four of the following "core" courses

- AMATH 342 Computational Methods for Differential Equations
- CO 250 Introduction to Optimization
- CS 245 Logic and Computation
- CS 246 Object-Oriented Software Development
- CS 475 Computational Linear Algebra
- STAT 340 Computer Simulation of Complex Systems or STAT 341 Computational Statistics and Data Analysis

**Note:** *CS 245 and 246 require CS 136 as a prerequisite.*

Four additional courses

- AMATH/BIOL 382 Computational Modeling of Cellular Systems
- AMATH 442 Computational Methods for Partial Differential Equations
- CO 353 Computational Discrete Optimization
- CO 367 Nonlinear Optimization
- CO 370 Deterministic OR Models
- CO 372 Portfolio Optimization Models
- CO 450 Combinatorial Optimization
- CO 452 Integer Programming
- CO 454 Scheduling
- CO 456 Introduction to Game Theory
- CO 485 The Mathematics of Public-Key Cryptography
- CO 487 Applied Cryptography
- CS 341 Algorithms
- CS 466 Algorithm Design and Analysis
- CS 473 Medical Image Processing
- CS 476 Numerical Computation for Financial Modeling
- CS 482 Computational Techniques in Biological Sequence Analysis
- CS 487 Introduction to Symbolic Computation
- PMATH 370 Chaos and Fractals
- STAT 440 Computational Inference
- STAT 441 Statistical Learning - Classification
- STAT 442 Data Visualization
- STAT 444 Statistical Learning - Function Estimation

Three (1.5 units) non-math courses from one of the following departments: Economics, any one Science department, any one Engineering department

**Note:** *Engineering courses may not be open to Mathematics students or may not easily fit schedules.*

At least one of these three courses must be at the 200-, 300-, or 400-level. Other course concentrations may be eligible subject to approval by a Computational Mathematics advisor.
Computational Mathematics Minor

This minor is only available to students within the Faculty of Mathematics. One of

- AMATH 242/CS 371 Introduction to Computational Mathematics
- CS 370 Numerical Computation

Three of

- AMATH 342 Computational Methods for Differential Equations
- CO 250 Introduction to Optimization
- CS 245 Logic and Computation
- CS 246 Object-Oriented Software Development
- CS 475 Computational Linear Algebra
- STAT 340 Computer Simulation of Complex Systems or STAT 341 Computational Statistics and Data Analysis

Three additional courses

- AMATH/BIOL 382 Computational Modeling of Cellular Systems
- AMATH 442 Computational Methods for Partial Differential Equations
- CO 353 Computational Discrete Optimization
- CO 367 Nonlinear Optimization
- CO 370 Deterministic OR Models
- CO 372 Portfolio Optimization Models
- CO 450 Combinatorial Optimization
- CO 452 Integer Programming
- CO 454 Scheduling
- CO 456 Introduction to Game Theory
- CO 485 The Mathematics of Public-Key Cryptography
- CO 487 Applied Cryptography
- CS 341 Algorithms
- CS 466 Algorithm Design and Analysis
- CS 473 Medical Image Processing
- CS 476 Numerical Computation for Financial Modeling
- CS 482 Computational Techniques in Biological Sequence Analysis
- CS 487 Introduction to Symbolic Computation
- PMATH 370 Chaos and Fractals
- STAT 440 Computational Inference
- STAT 441 Statistical Learning - Classification
- STAT 442 Data Visualization
- STAT 444 Statistical Learning - Function Estimation

At most three of these seven courses may also be used to satisfy an explicit choice list course requirement of the student’s major. For CS majors, at most three of the seven can have (or be cross-listed with course having) a CS label.
Appendix C: Graduate Program Description

**Master of Mathematics (MMath) program in Computational Mathematics (CM)**

The Master of Mathematics in Computational Mathematics is a one year project based master's program leading to the degree of Master of Mathematics (Computational Mathematics). Mathematical models and their computational forms underlie the use of computers in economics, engineering, finance, medicine, science, and other disciplines. “Computational mathematics” is a relatively new term for the study of these models and forms, as well as related computing technologies. There is a significant demand for people with graduate training in the field of computational mathematics: that is, those who are able to deploy effectively a wide range of mathematical and computational techniques both in fundamental research as well as in product and applications development.

**Objectives**

The objective of the Master of Mathematics program in Computational Mathematics is to provide academic training to individuals interested in the computational and mathematical modeling of problems of substantive scientific and technological interest. In particular, graduates of this program with appropriate Bachelor’s degrees will meet the minimum requirements to apply to the PhD programs of the departments of the Mathematics Faculty at the University of Waterloo. This objective is achieved through required courses covering the foundations of computational mathematics and elective courses in diverse areas of specialization within the theory and practice of computational mathematics. Students spend one term working on a research project and write a substantial report.

The Faculty of Mathematics supports a broad based graduate program in computational mathematics, one which can accommodate graduates from Waterloo’s undergraduate program as well as graduates from other suitably quantitative, computational and/or mathematically oriented programs.

See the Programs section for specific admission and degree requirements.

The Faculty of Mathematics offers a strong research program in computational mathematics. Professors in the Faculty of Mathematics have diverse research interests in various fields of computational mathematics, including Scientific Computing, Symbolic Computing, Computational Finance, Computational Fluid Dynamics, PDEs, Optimization, Data Mining, and Computational Number Theory.

The Centre for Computational Mathematics in Industry and Commerce was inaugurated in January 2005 and serves as a focal point of collaborative research in computational mathematics and its applications, offering many seminars and colloquia throughout the year. The Centre manages the existing undergraduate program and has recently introduced exciting new options at this level such as a Biomedical option, a Data Mining option, and Earth and Space option, and an Economics option. The Centre administers the MMath in Computational Mathematics.
The Master of Mathematics (MMath) program in Computational Mathematics (CM) is administered through the Centre of Computational Mathematics in Industry and Commerce (CCMIC). It is expected that students will normally take twelve months to complete the program.

**Admission Requirements**

Applications will be made to the CCMIC, according to the usual procedures for the Faculty of Mathematics. The Graduate Program Committee of the CCMIC will review applications and make appropriate recommendations. The CM graduate committee will determine the suitability of each applicant’s background for success in this program.

The program is targeted to students with a bachelor’s degree in mathematics, statistics, or computer science, or in another program with a strong mathematical component including economics, engineering and any of the physical sciences.

Students with strong backgrounds in some core areas may be granted exemption from the corresponding core courses required by the program; in each such case another course will be substituted for the exempted course so that the total courses required remains the same.

The minimum requirements for admission to the MMath program (Computational Mathematics) normally include:

- 4-year honours bachelor's degree or its equivalent with specialization in some area of the mathematical, statistical and computer sciences. Note: graduates of other quantitative and mathematically oriented programs are also encouraged to apply; this includes, but is not restricted to, graduates of commerce, economics, engineering, finance, and any of the physical sciences. The CM graduate committee will determine the suitability of each applicant’s background for success in this program.
- An overall B+ (78%) average or its equivalent for undergraduate work.
- Three letters of reference, normally from academic sources.
- Provide proof of proficiency in English (if applicable); accepted examinations and required minimum scores for graduate studies are listed on the English Language Proficiency page.

**Degree Requirements**

The degree requirements for the Master of Mathematics in Computational Mathematics include six one-term (0.50 unit weight) graduate level courses and completion of a master’s research paper (1.0 unit weight).

**Course Requirements**

Students are required to take six courses from lists A and B below. At least four must be taken from list A. Students are also required to attend a Symposium, which normally takes place the 3rd week in August, to present their research papers.
List A Core Courses:

- CM 730 (CS 687) Introduction to Symbolic Computation
- one of CM 740 (CO 602) Fundamentals of Optimization; CM 741 (CO 666) Continuous Optimization
- CM 750 (AMATH 741/CS 778) Numerical Solution of Partial Differential Equations
- one of CM 761 (STAT 840) Computational Inference; CM 762 (STAT 842) Data Visualization; CM 763 (STAT 841) Statistical Learning - Classification; CM 764 (STAT 844) Statistical Learning - Function Estimation
- CM 770 (AMATH 740/CS 770) Numerical Analysis

List B Courses (typically held with undergraduate courses):

- CO 650 Combinatorial Optimization
- CO 652 Integer Programming
- CO 663 Convex Optimization and Analysis
- CO 671 Semi-definite Optimization
- CO 681 (CS 667) Quantum Information Processing
- CO 685 The Mathematics of Public-Key Cryptography
- CO 687 Applied Cryptography
- CO 778 (ACTSC 973) Portfolio Optimization
- CO 781 Topics in Quantum Information
- CS 666 Algorithm Design and Analysis
- CS 673 Medical Image Processing
- CS 676 Numeric Computation for Financial Modelling
- CS 682 Computational Techniques in Biological Sequence Analysis
- CS 683 Computational Techniques in Structural Bioinformatics
- CS 686 Introduction to Artificial Intelligence
- CS 688 Introduction to Computer Graphics
- CS 763 Computational Geometry
- CS 774 Advanced Computational Finance
- CS 775 Parallel Algorithms in Scientific Computing
- CS 780 Advanced Symbolic Computation
- CS 786 Probabilistic Inference and Machine Learning
- CS 787 Computational Vision
- CS 867 Advanced Topics in Quantum Information and Computation
- STAT 846 Mathematical Models in Finance
- STAT 901 Theory of Probability
- ACTSC 970 Finance 1
- AMATH 655 Control Theory
- AMATH 663 Fluid Mechanics
- AMATH 731 Applied Functional Analysis
- AMATH 753 Advanced PDEs
- AMATH 881 Introduction to Mathematical Oncology
• AMATH 882 Mathematical Cell Biology
• any other course at this level approved by the graduate committee.

The courses listed above are regularly offered within the Faculty. Other advanced courses are offered within the Faculty of Mathematics on topics of computational mathematics on a more irregular basis. These courses may be taken with approval of the graduate committee. Similarly, courses offered outside the Faculty, in Computational Mathematics or in some area of its application may be approved by the graduate committee. At most two of the six courses taken may be courses in which undergraduate students predominate.

Part-time students
The Master's in Computational Mathematics can also be taken on a part-time basis. Part-time students will be expected to complete the program in a time period of two to three years. The minimum duration of study for part-time students is two years.

Master's Research Paper Requirement
Students must undertake an independent research project culminating in a research paper. It is intended that the research project will be approximately the equivalent of two full courses and will be conducted under the direction of the student’s research supervisor.

To be successfully completed, the research paper must be unanimously approved by the student's advisory committee, consisting of the student's research supervisor and one additional reader.

Students must maintain an average of 70% in order to remain in good standing. Formal progress reports will be required in the event that a student wishes or needs to remain in the program longer than one year.
## Appendix D: CM Colloquium/Seminar Speakers (Spring 2010 - Spring 2015)

### 2010/2011 Colloquiums

<table>
<thead>
<tr>
<th>Date</th>
<th>Name</th>
<th>Affiliation</th>
<th>Title of Talk</th>
</tr>
</thead>
<tbody>
<tr>
<td>5/13/10</td>
<td>Andrea Lodi</td>
<td>University of Bologna</td>
<td>Quadratic {-1,0,1} Optimization</td>
</tr>
<tr>
<td>5/17/10</td>
<td>Andreas Buja</td>
<td>University of Pennsylvania</td>
<td>Seeing is Believing: Statistical Visualization for Teaching Data Analysis</td>
</tr>
<tr>
<td>7/26/10</td>
<td>Jon Wilkening</td>
<td>University of California, Berkeley</td>
<td>Computation of time-periodic solutions of fluid interface problems</td>
</tr>
<tr>
<td>8/5/10</td>
<td>Marianne Francois</td>
<td>Los Alamos National Laboratory</td>
<td>A Balanced-Force Volume Tracking Algorithm for Modeling Interfacial Flows with Mass Transfer</td>
</tr>
<tr>
<td>9/20/10</td>
<td>Mark Braverman</td>
<td>University of Toronto</td>
<td>Computability and Complexity of Julia Sets</td>
</tr>
<tr>
<td>10/5/10</td>
<td>Dustin Lang</td>
<td>Princeton University</td>
<td>Automatic recognition and modeling of astronomical images</td>
</tr>
<tr>
<td>10/7/10</td>
<td>Peter Forsyth</td>
<td>University of Waterloo</td>
<td>Bankers, Bonuses and Busts</td>
</tr>
<tr>
<td>9/26/11</td>
<td>Annie Chu</td>
<td>University of California</td>
<td>Comparison of ETAS parameter estimates across different global tetonic zones</td>
</tr>
</tbody>
</table>

### 2011/2012 Colloquiums

<table>
<thead>
<tr>
<th>Date</th>
<th>Name</th>
<th>Affiliation</th>
<th>Title of Talk</th>
</tr>
</thead>
<tbody>
<tr>
<td>7/28/11</td>
<td>Inderjit Dhillon</td>
<td>University of Texas</td>
<td>Fast and memory-efficient low rank approximation of massive graphs</td>
</tr>
<tr>
<td>9/26/11</td>
<td>Annie Chu</td>
<td>University of California</td>
<td>Comparison of ETAS parameter estimates across different global tetonic zones</td>
</tr>
<tr>
<td>Date</td>
<td>Name</td>
<td>Affiliation</td>
<td>Title of Talk</td>
</tr>
<tr>
<td>------------</td>
<td>---------------------</td>
<td>--------------------------------------------------</td>
<td>-------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>10/24/11</td>
<td>Uri Ascher</td>
<td>University of British Columbia</td>
<td>Adaptive and Stochastic Algorithms for piecewise constant EIT and DC resistivity problems with many measurements</td>
</tr>
<tr>
<td>11/1/11</td>
<td>Kevin Leyton-Brown</td>
<td>University of British Colombia</td>
<td>Computational Mechanism Analysis: Towards a &quot;CPLEX&quot; for Mechanisms</td>
</tr>
<tr>
<td>11/22/11</td>
<td>Michael Braun</td>
<td>MIT Sloan School of Management</td>
<td>Generalized Direct Sampling for Hierarchical Bayesian Models</td>
</tr>
<tr>
<td>12/16/11</td>
<td>David Parkes</td>
<td>Harvard School of Engineering and Applied Science</td>
<td>Mechanism Design through Monotone Branch-and-Bound Search</td>
</tr>
<tr>
<td>1/30/12</td>
<td>Christopher Batty</td>
<td>Columbia University</td>
<td>Animating Liquids for Visual Effects: Splashing Sheets, Viscous Coiling and Rigid Body Interaction</td>
</tr>
<tr>
<td>3/6/12</td>
<td>G. Bard Ermentrout</td>
<td>University of Pittsburgh</td>
<td>Flicker Hallucinations: Faraday waves in the brain</td>
</tr>
</tbody>
</table>

### 2012/2013 Colloquiums

<table>
<thead>
<tr>
<th>Date</th>
<th>Name</th>
<th>Affiliation</th>
<th>Title of Talk</th>
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</thead>
<tbody>
<tr>
<td>6/22/12</td>
<td>Bernhard von Stengel</td>
<td>The London School of Economics and Political Science, UK</td>
<td>Constructing and computing equilibria for two-player games</td>
</tr>
<tr>
<td>9/17/12</td>
<td>Vincent Conitzer</td>
<td>Duke University, NC</td>
<td>Computing Game - Theoretic Solutions for Security</td>
</tr>
<tr>
<td>10/19/12</td>
<td>Fei Sha</td>
<td>University of Southern California</td>
<td>Domain Adaptation for Learning in a Changing Environment</td>
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<tr>
<td>10/29/12</td>
<td>Tim Roughgarden</td>
<td>Stanford University</td>
<td>Porting the Computer Science Toolbox to Game Theory and Economics</td>
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<tr>
<td>12/12/12</td>
<td>Fabrice Deluzet</td>
<td>Institut Mathematiques de Toulouse</td>
<td>Asymptotic preserving methods for anisotropic elliptic problems and applications to simulation of plasma under large magnetic fields</td>
</tr>
</tbody>
</table>

### 2013/2014 Colloquiums

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<tr>
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</thead>
<tbody>
<tr>
<td>5/31/13</td>
<td>Joachim von zur Gathen</td>
<td>University of Bonn</td>
<td>Generating safe primes and safe moduli</td>
</tr>
<tr>
<td>Name</td>
<td>Date</td>
<td>Affiliation</td>
<td>Title of Talk</td>
</tr>
<tr>
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<td>---------------------------------------------------</td>
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<tr>
<td>Shaoshi Chen</td>
<td>5/31/13</td>
<td>North Carolina State University</td>
<td>On the Integrability and Summability of Bivariate Rational Functions</td>
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<td>Sung Ha Kang</td>
<td>7/19/13</td>
<td>Georgia Tech University</td>
<td>Variational and RKHS approach for image Colorization and Segmentation</td>
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<td>Ruslan Salakhutdinov</td>
<td>9/20/13</td>
<td>University of Toronto</td>
<td>Annealing Between Distributions by Averaging Moments</td>
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<td>Bernardo Cockburn</td>
<td>10/2/13</td>
<td>University of Minnesota</td>
<td>The HDG methods for partial differential equations</td>
</tr>
<tr>
<td>Kees Vuik</td>
<td>11/4/13</td>
<td>Delft University of Technology</td>
<td>Fast and Robust iterative solvers for the Helmholtz equation</td>
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<tr>
<td>Eric Schost</td>
<td>12/16/13</td>
<td>Canada Research Chair in Algebra (Western University)</td>
<td>Building Fields</td>
</tr>
<tr>
<td>Ian M. Mitchell</td>
<td>4/3/14</td>
<td>Department of Computer Science at the University of British Columbia</td>
<td>The Monotone Acceptance Ordered Upwind Method (A Causal Algorithm for Minimum Time / Cost Optimal Control) and some Lessons in (Ir) Reproducible Research in Computational Math</td>
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<tr>
<td>Manuel Kauers</td>
<td>4/9/14</td>
<td>Research Institute for Symbolic Computation (RISC)</td>
<td>Learning with Marginalized Corruption</td>
</tr>
</tbody>
</table>

### 2014/2015 Colloquiums

<table>
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<th>Date</th>
<th>Name</th>
<th>Affiliation</th>
<th>Title of Talk</th>
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<tbody>
<tr>
<td>9/22/14</td>
<td>Éva Tardos</td>
<td>Winner of the Fulkerson Prize, and professor of Computer Science at Cornell University</td>
<td>Games, Learning, and the Price of Anarchy</td>
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<tr>
<td>10/10/14</td>
<td>Erich Kaltofen</td>
<td>North Carolina State University</td>
<td>Cleaning-up Data With Errors: When Symbolic-Numeric Sparse Interpolation Meets Error-Correcting Codes</td>
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<td>11/17/14</td>
<td>Petros Drineas</td>
<td>Rensselaer Polytechnic Institute</td>
<td>Randomized Algorithms in Numerical Linear Algebra (RandNLA)</td>
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<td>1/12/15</td>
<td>Marius Hofert</td>
<td>University of Waterloo</td>
<td>Parallel and other simulations in R made easy: An end-to-end study.</td>
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<tr>
<td>3/18/15</td>
<td>Csaba Szepesvari</td>
<td>University of Alberta</td>
<td>Exploiting Symmetries to Construct Efficient MCMC Algorithms with an Application to SLAM.</td>
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<tr>
<td>Name</td>
<td>Date</td>
<td>Institution</td>
<td>Presentation Title</td>
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<td>Anthony Peirce</td>
<td>3/26/15</td>
<td>University of British Columbia</td>
<td>Modeling Multi-Scale Processes in Hydraulic Fracture Propagation Using the Implicit Level set Algorithm (ILSA)</td>
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## 2014/2015 (Budget $92,250.00)

<table>
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<td>Computer Equipment &amp; Software</td>
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<td>Entertainment &amp; Travel (Colloquiums, Events)</td>
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<td>Scholarships/Bursaries-Undergrad</td>
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<td>Staff-Part Time and Casual</td>
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<td>Supplies</td>
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<td><strong>Total for 2014/2015</strong></td>
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## 2013/2014 (Budget $91,545.00)

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## 2012/2013 (Budget $84,875.00)

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## 2011/2012 (Budget $80,075.00)

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The 2015 CCMIC 5 Year Report
Appendix E: CCMIC Financial History 2010 - 2015
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<td>Scholarships/Bursaries-Undergrad</td>
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2010/2011 (Budget $76,215.00)

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2009/2010 (Budget $75,936.00)

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<td><strong>Total for 2009/2010</strong></td>
<td><strong>$77,770.93</strong></td>
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Dear Kevin,

I am writing in very strong support of the renewal of the Centre for Computational Mathematics in Industry and Commerce (CCMIC).

Scientific computing is increasingly pervasive in every branch of mathematics, science and engineering. In the Mathematics Faculty, it plays a fundamental role in numerous research activities in every department/school. The CCMIC provides an ideal platform for researchers from all units within the Faculty (and externally) to come together to study problems of mutual interest.

Since computational mathematics is everywhere and does not “belong” in any unit, having it as a freestanding Centre within the Faculty seems entirely natural. It has been immensely successful over its lifetime, and I strongly endorse its renewal.

Sincerely,

Alan George
Distinguished Professor Emeritus
David R. Cheriton School of Computer Science
Dear Professor Hare,

This letter is to express my support for the Centre for Computational Mathematics in Industry and Commerce (CCMIC) at the University of Waterloo. The CCMIC was established as an initiative in the Dean of Mathematics office in 2005. Started as an administrative structure to coordinate the undergraduate Computational Mathematics program between the academic units in the Faculty, it was also mandated to promote Computational Mathematics at the graduate and research levels. In 2008, a new master’s degree program in Computational Mathematics was created. The graduate program has been highly successful, bringing in students with broad computational background in all disciplines of computer science and mathematics.

Computer Science faculty members have been actively involved in the Centre since its beginning. Three of the eleven Computational Mathematics faculty complement are in the School of Computer Science and eleven additional CS faculty members are affiliated members of the Centre. These people have been involved with the administration of the Centre. CS Professor Justin Wan served as the Director of the Centre from 2010–2015. CS Professor Arne Storjohann has been the CM Graduate Officer since 2010. CS Professor George Labahn was on the Steering Committee, and CS Professor Jeff Orchard is the CM Colloquium Committee Chair.

CS faculty, students, and visitors regularly participated and gave presentations at the CM Colloquium series, which has hosted nearly 50 colloquia since 2010. The CM graduate program has successfully graduated more than 60 Masters students since 2009, many of them supervised by CS faculty members. A number of the CM graduates have continued their graduate studies to a PhD here in Computer Science at UW. Faculty members from CS have also been engaged in the development of CM-oriented courses.

The Centre has been highly successful in bringing together computational researchers from across campus – faculty members, postdoctoral fellows, research staff and graduate students – and attracting world-class researchers at events such as the CM organized colloquia and symposia of graduate student presentations. These activities greatly benefit CS faculty and students to discuss current topics in mathematical computing, and in some cases, these events have served as the initial interactions that further developed into new research collaborations.
For all these reasons, I enthusiastically support the renewal of the CCMIC. As a focus for computation and mathematics it has been very effective at promoting research and education in this crucial area, and leads to many opportunities for new collaborations, educational opportunities, and funding initiatives.

Yours truly,

Mark Giesbrecht
Professor and Director
Cheriton School of Computer Science
December 8, 2015

Professor Kevin Hare
Director, CCMIC
University of Waterloo

Dear Kevin:

I am writing in strong support for the renewal of the Centre for Computational Mathematics in Industry and Commerce (CCMIC).

The CCMIC has been successful in bringing together world renowned researchers with multi-disciplinary expertise through activities such as the Computational Mathematics Colloquium series. The twelve-month graduate program has been highly successful for attracting strong students locally and internationally with broad interests in mathematics and computation. It has clearly been of tremendous value to the Faculty of Mathematics.

Beyond these fundamental contributions, the CCMIC serves as a model of a well-functioning Centre with with programs operating outside of a departmental structure.

I enthusiastically support its renewal.

Sincerely,

[Signature]

Stephen M. Watt
Dean, Faculty of Mathematics
Professor Kevin Hare,
Director, CCMIC

I am happy to write a letter of support for the Centre for Computational Mathematics in Industry and Commerce (CCMIC). I will restrict my comments to the Masters program since I have had no interaction with the CCMIC undergraduate program. However, I have been very engaged with the CCMIC Masters program – I have supervised more than seven Masters students and have worked with an equal number as research assistants upon graduation on industry applications.

First let me express my view that there is strong demand and need in industry for students trained in computational mathematics. For example, the leading technology companies such as Amazon, Google, Facebook, Microsoft etc. increasingly need highly trained personnel with expertise in a fusion of computer science, numerical methods, computational statistics, computational optimization, and big data/predictive analytics. Frankly, their futures depend on such people. Moreover, even traditional companies – such as the major banks, energy and big pharma are increasingly looking for such personnel as exploiting big data and using predictive analytics becomes part of their core business strategies. The CCMIC Masters program produces such graduates.

Personally I have worked with logistics companies, manufacturing companies, and financial institutions and I involve ‘just graduated’ masters students whenever I can – my first choice is always to look to the CCMIC Masters graduates (a variety of applied/computational mathematical skills are always need – not just statistics, not just computer science, not just optimization, etc.) Summarizing, there is a growing need for students trained in applied and computational mathematics at the Masters level – our CCMIC program produces exactly such students. As director of WatRISQ I meet with many financial institutions – they all say the same thing: they are looking for highly trained personnel with a blend of computational mathematical skills. This blend is achieved naturally in the CCMIC Masters program but is much harder to achieve in departmental programs (that are more geared toward specialization).
The CCMIC Masters program has my strong support. However, it can be improved:

1. Many of our graduates have no working experience. Companies are hesitant to hire new masters graduates, even with the right technical background, w/o some proven working experience. I strongly recommend that this program have a 1-term internship option (to replace the required essay). This would be of significant interest to our students and increase their employability. Our current MQF program has an internship and it is quite successful.

2. I suggest also allowing for a complete course –based option with no research essay. An additional course or two could be asked for (instead of the internship). The fact is that there is not enough time to do real research in this program – the students have extensive course and TA duties and often can only start research in the last summer term. This is just not enough time and the research essays are of questionable value to anyone.

3. The CCMIC should look for ways to increase its interaction with industry. In fact there is essentially zero structured industry interaction – this means companies do not know the program, and good industry research ties are not being built. This, in my view, is a serious deficiency in a program that has ‘industry’ in its title. (An example interaction with industry: an annual get together with invited company reps and the current class augmented with interested faculty. This could include some selected presentations (certainly an overview presentation from the Director), and opportunity to hear from the companies on technical/research directions, as well as plenty of socializing time).

4. Students need the opportunity to emphasize certain areas in their studies – computational finance, and big data/predictive analytics are two such areas. There should be some special designation for this sort of emphasis (on the degree) and these areas of emphasis should be promoted in advance to help attract highly motivated students. (E.g., a graduating undergraduate student who wants to become trained in big data/predictive analytics would have a seriously hard time realizing the CCMIC program is a good fit. Potential employers would have the same difficulty.)

In conclusion, The CCMIC Masters program produces graduates with an industry-attractive set of skills in the mathematical sciences. Graduates at the Masters level with this blend of applied/computational math skills are much in demand and this demand will seriously grow in the next decade. However, our CCMIC program can do much better and can play more prominent role in this movement -- four potential ways to improve are listed above.

Thomas F. Coleman
Professor, Combinatorics and Optimization
Director, Waterloo Research Institute in Insurance, Securities, and Quantitative Finance (WatRISQ)
### 8. Declarations of conflict of interest

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<thead>
<tr>
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<td>8.02</td>
<td>A member shall be considered to have an actual, perceived or potential conflict of interest, when the opportunity exists for the member to use confidential information gained as a member of Senate, or any of Senate’s committees or councils, for the personal profit or advantage of any person, or use the authority, knowledge or influence of the Senate, or a committee or council thereof, to further her/his personal, familial or corporate interests or the interests of an employee of the university with whom the member has a marital, familial or sexual relationship.</td>
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<td>Members who declare conflicts of interest shall not enter into debate nor vote upon the specified item upon which they have declared a conflict of interest. The chair will determine whether it is appropriate for said member to remove themselves from the meeting for the duration of debate on the specified item(s).</td>
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Present: Pascal Calarco, Jack Callaghan, Maya D’Alessio, George Dixon, Bernard Duncker, Lowell Ewert, Jim Frank, Anwar Hasan, Bruce Hellinga, Robert Hill, Richard Kelly*, Tim Kenyon, Srinivasan Keshav, Raymond Legge, Sepehr Mohaddes, Maureen Nummelin, Tamer Özsu, Paul Parker, Mike Szarka, Aaron Thompson, John Thompson, Lana Vanderlee, Linda Warley

Secretariat: Mike Grivicic

Resources: Jennifer Kieffer, Kerry Tolson

Guests: Marta Bailey (4), Jana Carson (3), Vic DiCiccio (1a), Dan McCarthy (1b), Amanda McKenzie (2), Frances Westley (1b)

Absent: Rhona Hanning*, Michael Hartz, Sarah Hildebrandt*, Bruce Muirhead, Samantha Shortall, Suzanne Tyas

*regrets

Organization of Meeting: Jim Frank, co-chair of the council, took the chair, and Mike Grivicic, acted as secretary. The secretary advised that due notice of the meeting had been given, a quorum was present, and the meeting was properly constituted.

1. RENEWAL OF SENATE-APPROVED CENTRES AND INSTITUTES
   a. Institute for Computer Research. Vic DiCiccio spoke to the report: purpose of the institute; connections to industry; leveraging of funding opportunities; intellectual property arrangements; involvement of multiple faculties; good financial health of institute. Members discussed: benefits of membership; revitalization of linkages with industry in the future; facilitation of members’ research vs. being a centre for research. Council heard a motion to renew the institute for an additional five-year term ending December 2020. Frank and Özsu. Carried.
   b. Waterloo Institute for Social Innovation and Resilience. Dan McCarthy and Frances Westley spoke to the activity of institute which includes seminars, courses, training of highly-qualified personnel, and funded projects. Members discussed: potential new linkages into Arts; funding has historically come from private foundations; impact is significant in areas of focus; relationship of the institute to the academic program which it no longer delivers; legacy of intellectual property; question of diminished value-added for the institute compared to recent years; importance of scholarship in emerging areas, and institute’s leadership within Canada. Council heard a motion to renew the centre for an additional five-year term ending December 2020. Parker and Hill. Carried, with two abstentions. A distillation of the discussion will be forwarded to the representatives.

2. HANDLING OF ACADEMIC PROGRAM REVIEW REPORTS
   Amanda McKenzie provided an overview of the document, and by consensus members agreed that this process will be utilized going forward.

3. WHITE PAPER ON BIBLIOMETRICS
   This item was deferred to the next meeting.

4. GSO ACTIVITIES SUPPORTING GRADUATE STUDENT RECRUITMENT
   This item was deferred to the next meeting.

5. DECLARATIONS OF CONFLICT OF INTEREST
   None declared.
   a. Excerpt from Bylaw 1, section 8. This item was received for information.

6. CO-CHAIRS’ REMARKS
   The co-chairs offered no remarks.

7. MINUTES OF 9 NOVEMBER 2015 AND BUSINESS ARISING
   A motion was heard to approve the minutes as distributed. Callaghan and Hasan. Carried.
8. CURRICULAR SUBMISSIONS

a. Applied Health Sciences. Council took items 1-3 together and heard a motion to approve the items as presented. Callaghan and Legge. Carried. Council considered item 4 and members ascertained that past and present students were surveyed and are in favour of the milestone change. Council heard a motion to recommend that Senate approve item 4 as presented. Callaghan and Vanderlee. Carried.

b. Arts. Council took items A and B together and heard a motion to approve the items as presented. Warley and Hellinga. Carried. Item C was deferred. Council considered item D and noted that this is a double degree rather than a joint degree with Warwick. Council heard a motion to recommend that Senate approve item D as presented. Warley and Ewert. Carried. Council discussed item E and noted that the new plan addresses SSHRC concerns to prepare graduates for a variety of career outcomes. Council heard a motion to recommend that Senate approve item E as presented. Warley and Hill. Carried.

c. Engineering. Item 1 was deferred. Council heard a motion to approve item 2 as presented. Hellinga and Legge. Carried.

d. Environment. Council took all items together, and Parker noted that the text “…or permission of instructor” is deleted due to the presence of prerequisites. Council heard a motion to approve the submission as presented. Parker and Kelly. Carried.

e. Mathematics. Council took the course revision items together and heard a motion to approve the changes as presented. Keshav and Warley. Carried.

f. Renison University College. Council heard a motion to approve the item as presented. Ewert and Legge. Carried.

9. FINAL ASSESSMENT REPORT – GEOGRAPHY AND ENVIRONMENTAL MANAGEMENT
This item was deferred to the next meeting.

10. AUGMENTED TWO-YEAR REPORT – MANAGEMENT SCIENCES
This item was deferred to the next meeting.

11. OTHER BUSINESS
There was no other business.

12. NEXT MEETING
The next meeting will be on Monday 11 January 2016 from 10:30 a.m. to 12 noon in NH 3318.

6 January 2016
Mike Grivicic
Assistant University Secretary
### 8. Declarations of conflict of interest

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White Paper
Measuring Research Productivity and Impact through Bibliometrics

Prepared by the Working Group on Bibliometrics, University of Waterloo

Fall 2015

Suggested Citation


Prepared by

Lauren Byl, Jana Carson, Annamaria Feltracco, Susie Gooch, Shannon Gordon, Tim Kenyon, Bruce Muirhead, Tamer Özsu, Daniela Seskar-Hencic, Kathy MacDonald, Peter Stirling, of the University of Waterloo Working Group on Bibliometrics

For further information regarding this report, please contact:

Working Group on Bibliometrics
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200 University Avenue West
Waterloo ON Canada
N2L 3G1
Email: iap-bibl@uwaterloo.ca
White Paper | Measuring Research Productivity and Impact through Bibliometrics

DRAFT FOR CONSULTATION

TABLE OF CONTENTS

Executive Summary and Recommended Practices ............................................................... 4
Forward ............................................................................................................................... 7

1. Measuring Research Productivity and Impact Through Bibliometrics........................................... 8
   1.1. Purpose .................................................................................................................. 8

2. Overview ..................................................................................................................... 9
   2.1. Rationale for measuring research productivity and impact ........................................... 10

3. Common Measures in Research Productivity and Impact ....................................................... 11
   3.1. Measures .............................................................................................................. 12
       3.1.1. Publication Counts ......................................................................................... 13
       3.1.2. Citation Counts .............................................................................................. 13
       3.1.3. H-index ........................................................................................................... 14
       3.1.4. Collaboration Networks .................................................................................. 14
       3.1.5. Journal Impact Ranking ............................................................................... 15
       3.1.6. Top Percentiles ............................................................................................... 15
       3.1.7. Other measures of research productivity and impact ..................................... 15
   3.2. Summary ............................................................................................................... 15

4. Limitations of Bibliometrics ............................................................................................ 16
   4.1. Discipline-specific variations .................................................................................. 16
   4.2. Temporal factors ................................................................................................... 20
   4.3. Impact on behaviour and practice ......................................................................... 20
   4.4. Scope of citation-tracking tools ............................................................................. 21
   4.5. Specific measures .................................................................................................. 22
   4.6. Bibliometric tools .................................................................................................. 23
   4.7. Addressing limitations ........................................................................................... 24

5. Appropriate Uses for Bibliometrics .................................................................................. 24
   5.1. Optimizing thoughtful use of bibliometrics ........................................................... 25
       5.1.1. Create a strong research question ................................................................. 25
       5.1.2. Clearly understand the context for comparison ............................................. 25
       5.1.3. Understand discipline-specific effects ......................................................... 27
       5.1.4. Understand implications of the sample size ............................................... 27
       5.1.5. Select the appropriate type of productivity and impact measure .................. 27
   5.2. Uses for research productivity and impact and common bibliometric measures ......... 28
   5.3. Standards of good practice for researchers ........................................................... 32

6. Recommended Practices for Bibliometric Analysis at the University of Waterloo ................. 33

Appendix A ....................................................................................................................... 35
Appendix B ....................................................................................................................... 36

References ......................................................................................................................... 37
Executive Summary and Recommended Practices

The University of Waterloo is interested in promoting a better institutional understanding of research productivity and impact, using a range of measures. Research productivity and impact may be measured by assessing a wide variety of research outputs. These include research published and cited in refereed journals, conference proceedings, books, policy reports, works of fine art, software and hardware, artifacts, scholarly blogs, the type and amount of intellectual property produced (e.g., patents, licenses, spin-offs), the type and amount of research awards, the nature and number of highly qualified personnel developed by the researcher or group, and publication acceptance rates (the proportion of papers or conference presentations accepted compared to the number submitted). Bibliometrics is one family of approaches to measuring research productivity and impact, primarily through counting publications and citations.

Important stakeholders, including funders and ranking organizations, increasingly use bibliometrics to understand research productivity and impact as part of efforts to encourage university accountability for funding, and to determine how to distribute funding or with whom to partner. In 2011, the University of Waterloo, along with other Canadian universities, began to build institutional understanding and awareness of bibliometrics and its use as a tool to measure research impact and productivity. This process will support efforts to identify how, and under what circumstances, bibliometrics may be used effectively.

Key University stakeholders including the Library, Office of Research, Institutional Analysis and Planning (IAP), interested researchers and Faculty representatives formed a Bibliometrics Working Group (BWG) in 2012. The purpose of the BWG was to assist the University in meeting new realities of how bibliometrics are used. One of the working group’s initial steps was to identify the need for resources, including a white paper, to foster a common institutional understanding of bibliometrics, and its role in capturing research performance. The group established a sub-committee, with representatives from the Library, IAP, Office of Research, and a faculty member tasked this group with creating the white paper. This sub-committee conducted a comprehensive literature review of peer reviewed literature published within the past four years, and an extensive grey literature to identify relevant position papers. The group identified, reviewed and summarized key articles and drafted the white paper with support of a principal writer. The resulting document is a resource for institutional and Faculty leadership and researchers, students, and other members of the campus community who are interested in understanding more about how research productivity and impact are measured through bibliometrics.

This white paper provides a high-level review of issues relevant to understanding bibliometrics, and provides practical recommendations for how to appropriately use these measures. This is not a policy paper; instead it defines and summarizes evidence that addresses appropriate use of bibliometric analysis at the University. Understanding the types of bibliometric measures and their limitations makes it possible to identify both appropriate uses and crucial limitations of bibliometrics analysis. Recommendations offered at the end of this paper provide a range of opportunities for how researchers and administrators at Waterloo and beyond can integrate bibliometric analysis into research productivity and impact assessment practices. Further efforts will build on this white paper, including sharing practice-based learnings with members of the University community, and a subject guide to facilitate access to background research literature in bibliometrics.

Bibliometrics offer an opportunity to quantify selected types of research outputs; however, there are important limitations to the use of bibliometric measures. These include the following:

- Academic disciplines have differing traditions for producing and distributing research outcomes, and not all of these are consistent with what is indexed by citation-tracking databases (such as Web
of Science, Scopus, and Google Scholar). This includes research that is not published in English, interdisciplinary research, or research outcomes or elements susceptible to context, for example, the extent and type of some research collaborations.

- Citation-tracking databases each have their own methodological approach, and how they index research publications from various fields of study can produce important limitations.
- Each research analytic tool (such as InCites and SciVal) uses different citation tracking tools and none index every type of publication, thus comprehensive coverage of research publications has not been possible.
- The issue of how the passage of time impacts on bibliometrics is also complex. Citations, a key research bibliometric measure, accrue with time after publication. The time required for understanding the impact of a paper using citations differs by disciplines. Moreover, research analytic tools themselves change their scope and coverage and thus assessments of productivity and impact taken at different times cannot always be meaningfully compared.
- The use of bibliometric measures may lead to changes in publication practices in order to enhance opportunities for bibliometric coverage and may provide potential opportunities to manipulate metrics.

In aggregate, these factors strongly suggest that bibliometric comparisons across disciplines or sub-disciplines, or longitudinal comparisons within a group, may generate unclear or misleading results. Using bibliometrics appropriately shares many elements that are consistent with conducting good research:

- Be explicit about other non-bibliometric data sources that should also be considered
- Use a research question with the appropriate scope and clarity to the discipline and the bibliometric information available
- Understand the research and comparison context, including discipline-specific effects and the implications of sample size, and
- Select appropriate tools and measures to investigate the research question.

Bibliometrics can offer important contributions to understanding research productivity and impact when used thoughtfully, and in conjunction with other measures. Bibliometrics are most useful when used in combination with peer and other expert review to assess the impact and volume of scholarly work. They can be used to provide an indication of research activity and impact within the scientific community. They should be used in conjunction with other measures and framed carefully in terms of their disciplinary context. They can be quite useful for evaluating scientific output and impact at the institutional level.

The consensus in the peer-reviewed literature on bibliometrics is that they are not suited for comparing research productivity and impact across disciplines, nor as a single indicator of individual research productivity and impact assessment. The scientific content and quality of publications and research outcomes is more important than simple publication metrics and the different discipline cultures are too strong an effect for most cross-discipline comparisons to be effective. For these reasons, relying on bibliometric measures for hiring, tenure and promotion decision making is strongly discouraged.

Despite known limitations, bibliometric analysis is a common approach for understanding research productivity and, if used carefully, can provide a data point, in conjunction with others, for evaluating research outcomes. The following recommendations are geared toward Waterloo researchers, administrators and others interested in using bibliometrics, or assessing the relevance of bibliometric...
results. Implementing the following practices can ensure that bibliometric analysis is used appropriately, as one part of a broader framework of analysis, to provide a more robust and accurate understanding of research productivity and impact.

- Consider bibliometric measures as one data point among a set of others for understanding research output and impact. Best practice is to work from a basket of measures. It is impossible for any bibliometric analysis to present a complete picture. Bibliometrics is an imprecise science at best and bibliometric assessments should not be treated as an absolute outcome. Bibliometrics is optimally used to complement, not replace, other research assessment measures such as peer review, keeping in mind that “both need to be used with wisdom, discretion and the rigorous application of human judgement” (Phillips & Maes, 2012, p. 3).

- Understand and account for variations in how disciplines produce and use research publication. The nature of research (and more generally, scholarly) output (e.g., journal articles, books and book chapters, conference proceedings, performances, social outcomes, research artifacts) differs across disciplines, and thus the relevance and applicability of bibliometrics also differs across disciplines. It is important to use bibliometric measures relevant for each discipline.

- Involve those evaluated in the analysis process. Bibliometrics are appropriately used within specific fields or disciplines to understand quantitative aspects of research productivity and impact, considering the limitations outlined above. Given the significant role and impact of context in the use of bibliometrics, researchers in the field or discipline under investigation may be best equipped to understand the variability of how bibliometric measures capture and reflect research outcomes in their field. This will help to ensure that using bibliometric measures incorporates a full understanding of their limitations, particularly at the discipline level.

- Understand the distinctions among bibliometric measures. Be aware of the methodology, purpose, and limitations of bibliometric databases (such as Web of Science, Scopus, and Google Scholar) and of individual bibliometric measures (such as the Journal Impact Factor and h-index). As an example, it is important to recognize the value of normalized measures compared to whole/raw counts while also recognizing that normalized measures can be vulnerable to outliers (e.g., a single highly cited paper can increase the average somewhat artificially). Regular review and updating of research methods and definitions will ensure a strong and current understanding of methodologies used.

- Exercise caution when using journal impact rankings. Journal impact rankings such as JIF or Scimago Journal Rank (SJR) should not be broadly used as a surrogate measure of the quality of individual research articles, or an individual’s performance when opportunities exist for an in-depth evaluation of individual publications.
Forward

The University of Waterloo is committed to better understanding how to measure and reflect research productivity and impact using a range of measures. The increasing use of bibliometrics by important stakeholders including funders, ranking organizations and various accountability processes necessitates a better understanding of bibliometrics.

In 2012, the University of Waterloo formed the Bibliometrics Working Group (BWG) comprised of key stakeholders across the University including the Library, Office of Research, Institutional Analysis and Planning (IAP), interested researchers and Faculty representatives. The BWG established a sub-committee tasked with creating resources to better support institutional understanding of bibliometrics and how to use them effectively to measure research impact and productivity. A key deliverable was to create a white paper to explore and understand the use of bibliometrics to monitor research performance at all levels.

With representatives from the Library, IAP and Office of Research, the Sub-Committee conducted an environmental scan of current bibliometric practices through a comprehensive literature review. This process involved identifying articles from peer reviewed journals published within the last four years, as well as position papers via grey literature. These findings were managed by RefWorks, a bibliographic management system. Team members then reviewed findings of the literature search, a process that involved identifying key publications by reading and summarizing article content. Through a collaborative process, the group developed an outline for the White Paper which was shared with the BWG for feedback. Following approval of the outline, the Sub-Committee developed the white paper with support of a principal writer. This White Paper is an important resource for institutional and Faculty leadership, researchers and stakeholders who seek to understand research productivity and impact, either at the individual or broader level. It includes recommendations for how bibliometrics can be used more effectively where appropriate, and how to interpret and understand bibliometric analysis.

This White Paper is an important contribution to Waterloo’s evolving understanding of how to use bibliometrics to measure research productivity and impact. It provides a high-level review of issues relevant to understanding this topic, and provides practical recommendations for how to improve our bibliometrics practices. Further efforts will build on this White Paper, including a communication plan to share practice-based learnings with specific members of the University community, and a website to facilitate access to background research literature.

For more information, please contact:

Working Group on Bibliometrics
iap-bibl@uwaterloo.ca
1. Measuring Research Productivity and Impact Through Bibliometrics

Bibliometrics serves as one tool, among many, used by universities, funders, ranking organizations and others to measure research productivity and impact.

Post-secondary institutions face increasing pressures from funding bodies, the public and other institutions to measure and understand the amount, and impact of, research conducted by their institution. Bibliometrics serves as one tool, among many, used by universities, funders, ranking organizations and others to measure research productivity and impact. Bibliometric measures are used to inform this analysis. As in every approach used to assess research productivity and impact, bibliometrics present both opportunities and challenges for accurate assessment. This is particularly true when considering the use of bibliometrics in specific disciplines and over time, and when recognizing the value and limitations of available measures. A careful understanding of bibliometrics will result in stronger use and understanding of bibliometric analysis and its meaning.

1.1. Purpose

The purpose of this White Paper is to define and summarize evidence that addresses appropriate use of bibliometric analysis at the University of Waterloo. By understanding the various types of bibliometric measures and their limitations, it is possible to identify how, and under what circumstances, bibliometrics can be used effectively. Recommendations offered at the end of this paper provide a range of opportunities for how researchers and administrators at Waterloo and beyond can integrate bibliometric analysis into research productivity and impact assessment practices.

The European Commission on Research and Innovation has defined bibliometrics as “a statistical or mathematical method for counting the number of academic publications, citations and authorship” and notes that it is frequently used as a measure of academic output (Directorate-General for Research, Assessing Europe’s University-Based Research, 2010). This White Paper outlines the rationale for measuring research productivity and impact through bibliometric analysis, describes commonly used bibliometric measures and provides an overview of the limitations of bibliometric analysis as both a method and within various disciplines. It addresses a thoughtful approach for how individual researchers and institutions can use bibliometrics to understand research productivity and impact. This is essential to understand the limitations of bibliometrics and to learn how to use them effectively. An exploration of limitations for use in the context of research productivity and impact is presented in section 4.
2. Overview

In academia, the culture of ‘publish or perish’ has long been linked to determining the success of individual researchers. However, in recent years, there has been a shift from the understanding that publishing is an important result of research productivity, to a market competitions approach driven by the need to produce a variety of quantitative measures of research impact (Van Dalen & Henkens, 2012).

Bibliometric analysis is one important tool among a basket of potential processes and related tools used by a wide range of stakeholders to understand aspects of research productivity and impact. Common assessment activities that incorporate bibliometric measures can include: individual peer review of funding applications and institutional funding, rankings, individual assessment for promotion and tenure, and granting of awards.

A few definitions provide context for this discussion:

- **Bibliometric measures** are used to express an amount or degree of research or academic output. Measures typically includes the number of academic publications, citations of a single researcher, a group of researchers or an institution.

- **Research impact** is considered to be “…the social, economic, environmental and/or cultural benefit of research to end users in the wider community regionally, nationally, and/or internationally” (Bornmann & Marx, 2014, p. 212). Also, “the impact of a piece of research is the degree to which it has been useful to other researchers” (Bornmann, Mutz, Neuhaus, & Daniel, 2008, p. 93).

- **Research metrics** are the quantitative measures that are used to quantify research productivity and impact. These measures may include, but are not limited to, bibliometrics. Additional research metrics include research funding awards, publication acceptance rates and the development of highly qualified personnel (HQP).

- **Research productivity** is the measure of the research activity, or the output. It is considered a key element of a university’s and academic’s achievement and is typically defined by the number and quality of research output a researcher, department, or institution has produced within a specific timeframe. Typical research outputs can include research published in refereed journals, and conference proceedings, books, patents, policy reports, and other artifacts (e.g., exhibitions, developed systems, software and hardware artifacts). Sometimes scholarly blogs and radio or television broadcasts are included as part of research productivity.

- **Citation-tracking databases** have the ability to track citations by counting how many times a particular work has been cited by others indexed in the same database. This provides opportunities for citation analysis, whether forward or backward. As each of these databases index different content and only consider citations within their collections (i.e., they are closed systems), citation counts will naturally differ in each resource. Common citation-tracking databases include the databases Web of Science, Scopus and Google Scholar. Data collected and indexed by citation-tracking databases are often used as the basis of bibliometric measures.
2.1. Rationale for measuring research productivity and impact

Key stakeholders – governments, industry partners, and other funders – use bibliometric measures to assess the University of Waterloo’s research productivity and impact. However, there are substantive limitations and restrictions to using bibliometrics. These are explored fully in section 4.1.¹

As an example of how stakeholders use measures of research productivity and impact, the Ministry of Training, Colleges and Universities (MTCU) in Ontario has developed Strategic Mandate Agreements (SMA) with each of the province’s colleges and universities. The Agreements outline key areas of differentiation for the institutions and how each institution is meeting those goals, along with the metrics that will be used to assess their progress. The province has identified the number of publications (five year total and per full-time faculty member), number of citations (five year total and per full-time faculty member), and citation impact (normalized average citation per paper) as measures it will use to understand institutional research impact across Ontario. Understanding the bibliometric measures used by the MTCU, and others, will give Waterloo a better understanding of how the University itself, and centres, institutes, departments, and schools within the University, may be assessed by external stakeholders. It will also enable us to engage the external stakeholders about reasonable uses of bibliometric measures.

University ranking programs also frequently use bibliometrics as one way to compare research productivity and impact of post-secondary institutions. Ranking programs produce a rank-ordered list of post-secondary institutions based, in part, on their research impact and productivity. There is no universally accepted set of measures that fully and appropriately assess research productivity and impact. Nonetheless, bibliometrics as a component of research productivity and impact have been used for this purpose (Van Vught & Ziegele, 2011).

In addition to external assessment, bibliometric analysis has been used to understand and interpret internal productivity and impact. For example, some bibliometric measures may be used as a proxy for research quality or scholarship excellence. University researchers within a department or institute commonly use bibliometrics to assess their own research performance at a single point, or over time, as well as to compare their productivity against peers or those whom they seek to mentor. Hiring committees sometimes use an individual’s research productivity and impact, quantified through bibliometrics, to assess the relative quality of prospective faculty members.

From an institutional perspective, bibliometrics have been used to inform a discussion about areas of strength and weakness relative to wider institutional and disciplinary performance. This information has been used to inform strategic planning, and to support grant applications (Morphew & Swanson, 2011).

Funders (governments, industry and organizations) are also using bibliometric analysis to provide and assess evidence of the impact of their investments, and to assess social, economic, industrial and cultural impacts of research (Bornmann & Marx, 2014). For example, in 2007 the Canadian Federal Government developed the Mobilizing Science and Technology to Canada’s Advantage plan which outlined Federal

¹ Other measures, in addition to bibliometric measures, exist for assessing research productivity and impact and key stakeholders also use other approaches for this purpose. Other measures are outlined in section 3.1.7 of this paper.
Government support for ‘world-class research excellence’ in priority areas. Demonstrating research excellence, using bibliometric measures and other means, is an important approach to support funding opportunities in priority areas.

It is clear that the uses of measuring research productivity and impact extends broadly, and in both external and internal environments. Systemic issues with the use of bibliometrics for measuring research productivity and impact, however, do exist. These limitations must be carefully identified and considered before making any determinations or judgements about bibliometrics analysis for research productivity and impact. To further enhance understanding, individuals and organizations using bibliometrics should likewise take precautions when developing analysis frameworks. Limitations are explored in section 4. In section 5, appropriate uses and recommended approaches for using bibliometric measures and analysis provide guidance to support more effective use by a variety of stakeholders.

### 3. Common Measures in Research Productivity and Impact

This section outlines common bibliometric measures to understand research productivity and impact. Understanding the type of metric, what it quantifies, how the data is collected and when, and using that information to best select meaningful measures appropriate to the subject area and the context, is a crucial task. It is important to understand that bibliometric measures are just one type of metric within a basket of different measures that are used to assess research productivity and impact. Some of these other measures include peer review, which may include elements of bibliometrics, research funding awards, publication acceptance rates and the development of highly qualified personnel (HQP). Another measure – Altmetrics\(^2\) – is an emerging metric that ‘counts’ online events that have been stimulated by an institution’s output. Many different commercial databases, or data sources, exist that index research outputs. Most of these databases are proprietary – they index selected journals and other content in their collection. Notable citation-tracking databases which are multidisciplinary in scope

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\(^2\) Online events could include:
- **Scholarly activity** - the number of times an institution’s output has been posted in commonly used academic online tools. For example: Mendeley, CiteULike or SlideShare.
- **Scholarly commentary** - the number of times an institution’s output has been commented on in online tools that are typically used by academic scholars. See above examples.
- **Social activity** - the number of times an institution’s output has stimulated social media posts. For example: Facebook, Twitter, and blogs (public or science based).
- **Mass media** - the number of times an institution’s output has been referred to by news websites and online media.

Online sources that have been indexed also continue to evolve and the tools identified are not a definitive list but instead provide examples of the type of activity that should be counted in each category (Colledge, 2014)
No citation-tracking database is comprehensive. At best, they present a large dataset of research outputs based on specific collection parameters.

include the Web of Science and Scopus. Like all databases, each of these is limited in the content they index. Google Scholar is slightly different as it uses the Google search engine to crawl and index content on the Web that is considered to be scholarly.

None of these databases is comprehensive. At best, they present a large dataset of research outputs based on specific collection parameters. In addition to commercial databases, some institutions may create their own organizational repositories of research productivity and impact. One example of this is the University of Waterloo’s Institute for Quantum Computing’s (IQC) Publications Database which is a resource developed and maintained internally to collect publications by IQC researchers.

Additional research analytics tools have also emerged to support institutions interested in exploring their research productivity. One of these products is InCites, a web-based Thomson Reuters product. The University of Waterloo subscribes to InCites.

Research analytics tools, like InCites, allows institutions to analyze their research productivity and impact, and to benchmark against institutions on a global scale. However, each of these tools are based on an underlying proprietary tracking database as the data source. In the case of InCites, the Web of Science database serves as this data source and means that any InCites data is naturally limited to Web of Science content. Therefore, InCites provides a snapshot of research productivity and research impact within the Web of Science data universe. SciVal, a similar Elsevier product, uses the Scopus database as a data source which makes SciVal data naturally limited to Scopus content.

Products like InCites and SciVal offer institutions unique ways to explore research productivity and impact which are not possible in a citation-tracking database’s native interface, such as Web of Science and Scopus. These analytic tools provide opportunities to observe research productivity and impact across a period of time, and to make institutional comparisons which can inform strategic decision making.

3.1. Measures

Several common bibliometric measures are relevant to Waterloo’s institutional context. In addition to the definitions outlined here, Table 2 provides a brief look at each measure, its intended function and how it can be used appropriately.

3.1.1. Publication Counts

Absolute number of publications. As an absolute count (i.e., a cumulative total number of publications), publication counts are key to the formula used to calculate other measures such as citation counts, h-index, normalized citation impact, international and industrial collaborations, etc. It is important to recognize that the terminology used to describe bibliometric measures sometimes differs across resources. InCites, for example, uses the term 'Web of Science Documents' to capture total publications.
indexed by Web of Science. In contrast, Snowball Metrics, including SciVal, uses the term ‘Scholarly Output’ for the same purpose within the context of its data source (Colledge, 2014). Regardless, the term publication count represents the total number of publications indexed by a particular database, within a specified area.

While absolute number of publications is important, normalized publication counts offer potential for meaningful comparisons. This is important to avoid situations as that described in the University World News, where a single paper with “massive citations for its 100-plus contributors” skewed university ranking results because citation scores were not normalized (Holmes, 2013). Normalizing a measure such as a publication count accounts for outliers in the dataset by providing a more appropriate metric for comparing research productivity across similar research areas, document type, and time period. For example: Institution X has a total of 2,000 published journal articles indexed in Web of Science. Normalized publication counts weight an institution’s publication rate against the expected performance in the specific field or discipline (field normalized publications). While normalized measures are powerful, it is important to recognize that normalized measures with small sample sizes may be susceptible to outliers. As a result, percentiles may be a more suitable approach depending on the context.

3.1.2. Citation Counts

Absolute number of times that a given article is cited. For example: Article X has been cited 11 times, by documents indexed by Scopus. Citation counts have also been normalized or refined to reflect expected performance within a specific field or discipline. For example, mean normalized citation score normalizes citation counts by subject category and publication year (Waltman & Eck, 2013). The mean normalized citation score is used in the Leiden Ranking as one measure of impact.

Measures based on citations are among the most frequently used bibliometric indicators, and they are used in a myriad of ways (Mercier & Remy-Kostenbauer, 2013). As an example, a partial list of citation count based research productivity metrics used by InCites includes:

- Total Citations - the absolute number of citations to a specific work or group of publications.
- Proportion of Documents Cited - the proportion of publications cited one or more times.
- Citation Impact - average (mean) number of citations per paper.
- Normalized citation impact - citation impact (citations per paper) normalized for subject, year and document type.
- Highly cited Papers - papers that rank in the top 1% by citations for field and year (Thomson Reuters, 2015).

Citation counts, however, are not always directly correlated to positive research impact and quality. For example, a discredited paper may receive many citations before it is retracted, and may continue to receive citations post-retraction. Highly cited papers may have achieved that designation but later revealed to be a result of a high level of error, or the inclusion of self-citations. In some situations, universities may pursue an even more direct approach to elevate their citation counts. There is at least one reported example of a university that has actively recruited highly cited researchers to become “distinguished adjunct professors” at its institution. In exchange for a fee, airfare and hotel stays to visit the institution, the researchers are required to update their Thomson Reuters’ highly cited researcher listing to include their affiliation to the university and occasionally attach the university’s name to papers that they publish. The result of this “citation for sale” approach is that the university’s rankings in certain areas were raised to levels that are generally considered unjustified (Messerly, 2014).

Another consideration is the issue of self citations. A self citation is a citation from a citing article to a source article, where the same author name is on both the source and citing articles (Thomson Reuters,
Self-citations can be perceived as inflating an individual researcher’s citation count. However, there are contexts where self-citations are warranted. For example, an individual researcher may have published seminal work earlier in their career, and not citing that work would be ill-advised. Additional reading on self citations are available (Carley, Porter & Youtie, 2013).

The inclusion of self-citations in a citation analysis, as well as the type of counting used, are important issues of which to be aware as they typically offer differing snapshots of research impact. For example, applying whole counting to self-citations would typically result in higher citation totals, whereas applying fractional counting to self-citations would most often present a slightly different snapshot of a researcher’s impact.

Total publication and citation counts can also be combined to create new measures that seek to measure elements of both research productivity and impact. The Snowball Metrics initiative uses citations per output (average citations received by each output in a particular dataset) as a measure. H-index is another example of a measure which combines publication and citation counts.

3.1.3. H-index

A researcher’s h-index is k if the researcher has k papers each of which has received at least k citations. The h-index captures output using both total number of publications and number of citations. This index is a productivity measure that can be useful for a focussed snapshot of an individual’s research performance, but is not useful as a means to compare between researchers. A further discussion of the h-index can be found at http://nfgwin.uni-duesseldorf.de/sites/default/files/Ireland.pdf. Other measures have been developed which are generalizations of h-index such as the g-index (“h-index for an averaged citations count”), i10-index (number of publications with at least ten citations), the m-index (“the m-index is a correction of H-index for time”) and the Py-index (“the mean number of published items per year”) (Halbach, 2011).

3.1.4. Collaboration Networks

The type and extent of research collaborations in publications. How collaboration is measured depends on the discipline being examined. Measuring publishing collaborations may refer to collaborations with researchers from different geographic regions, in different sectors (industry, government) or among defined groups of individuals (service providers, participants). Considering collaborations in the industry sector, monitoring collaboration of this nature can be particularly valuable for identifying opportunities for funding and partnerships. Spinoffs of industry collaborations can result in real world experiences in the form of co-op placements as well as job prospects for recent graduates. International or industry collaborations are sometimes given significance based on the citation impact of the paper produced; however, collaborations are by their nature context-dependent (Moed, 2005).

InCites uses both international collaborations (number of papers having one or more international co-author, and the proportion of publications having international co-authors) and industry collaborations (proportion of publications having co-authors from industry). The Leiden Ranking (http://www.leidenranking.com/ranking/2015) shows collaboration measures based on Web of Science data. A range of both impact and collaboration measures are presented for institutions, including collaboration with international co-authors and collaboration with industry partners.

3.1.5. Journal Impact Ranking
The relative importance of the journal, not individual articles in the journal. This measure uses aggregate data of citations from articles published in the journal to determine the journal’s impact ranking (Falagas & Alexiou, 2008; Krauskopf, 2013). Thomson Reuters’ Journal Impact Factor (JIF) is a widely known example of this measure. The common rationale is that an individual researcher who publishes their research in journals with a high impact ranking produces work of higher quality. However, the quality of an individual publication should be judged on its own merit. Individual article-based citation counts, rather than journal-based citation counts are the preferred metric.

3.1.6. Top Percentiles

The top percentile (for example 1% or 10%) is typically a measure of the most cited documents or citations in a subject area, document type, and year. For example, the top 10% most cited works in a specific discipline or among an institution’s publication output. The Snowball Metrics Recipe Book includes several metrics that use impact factors as part of bibliometric measures for research productivity and impact. The Publications in Top Journal Percentiles measure establishes citation limits for the top 1%, 5%, 10% and 25% of journals being used in each publication year and measures the absolute count, and the proportion of total counts, of outputs that fall within each of the identified limits.

3.1.7. Other measures of research productivity and impact

Other measures to understand research productivity and impact exist. The most commonly known measure is peer review. The scholarly review of a researcher’s body of work by a group of peers or experts in the same field has long been considered the gold standard for understanding research productivity and impact. Other measures of research productivity and impact include the type and amount of intellectual property produced (e.g., patents, licenses, spin-offs), the type and amount of research awards, the nature and number of highly qualified personnel developed by the researcher or group, and publication acceptance rates (the proportion of papers or conference presentations accepted compared to the number submitted). Acceptance rates can be a useful proxy for scholarly quality. Using a “basket of measures” approach – where bibliometric measures are used along with other measures -- can lead to a stronger understanding of research productivity and impact.

3.2 Summary

Common measures for bibliometric analysis are typically quantitative in nature. Absolute measures (total publications, total citations) are used extensively, either as they are or as components of more complex measures to quantify research productivity including field normalized citations, acceptance rates, journal impact rankings, h-index, and peer review. Further, these measures are not without limitations. Understanding the conditions under which bibliometric measures are optimally used is vital to using them effectively.

4. Limitations of Bibliometrics

Bibliometric analysis and measures make important contributions to understanding research productivity and impact. However both the bibliometric analysis process and the measures have limitations that impact the reliability of the information generated and how it should be used. These limitations are specific to the measures used, and in the broader context, how they are used.
The process of understanding bibliometric analysis and measures can be significant given the time and expense it takes to collect, analyse and report on this analysis. In organizations where resources are limited, staff and researcher time and funds spent on research metrics has both real and opportunity costs (Van Raan, 2007). A thorough understanding of these limitations can optimize the reliability and validity of information related to research productivity and impact, and ensure that resources used to collect and analyse bibliometric measures are well spent.

This White Paper highlights six known limitations of bibliometrics when they are used to assess research productivity and impact. Where possible and appropriate, approaches for mitigating identified limitations are explored. The six areas include:

- Discipline-specific variations
- Temporal factors
- Impact on behaviour and practice
- Scope of citation-tracking tools
- Specific measures
- Bibliometric tools

4.1. Discipline-specific variations

The outcomes of research productivity and impact differ across disciplines. Academic disciplines – and sub-disciplines – each have their own traditions and practices for publishing and disseminating research outcomes. These differences are exhibited in the type of publications and their coverage by the tracking databases, citation cultures in different disciplines, and in collaboration patterns.

In some disciplines, aspects of productivity and impact are well-captured by journal publications and citations. However in other disciplines, the number of journal article publications and times cited can be less of an indicator of impact than is the number of patents, papers in conference proceedings, produced systems developed and widely used, or hardware and software artifacts. In the Social Sciences and Humanities, policy papers, white papers and reports produced for non-governmental organizations, and books can provide more accurate understanding of research productivity and impact. In Arts, works produced and exhibitions may be more important. Citation-tracking databases, which provide the data for bibliometric analysis, do not consistently capture the various types of research productivity produced by different disciplines. As a result, there is frequently a disconnect between the amount and calibre of research produced by various disciplines and the research productivity and outcome data indexed by bibliometric services.

As publishing cultures vary across disciplines, the presence or lack of conference proceedings in a citation-tracking database could be a very important consideration. The presence of conference proceedings in Web of Science, and Scopus differs. For example, the Scopus citation-tracking database indexes 6.8 million conference papers (Elsevier, 2015). In contrast, the Web of Science’s conference
proceedings citation indexes only capture 160,000+ conference proceedings from 1990 to the present (Thomson Reuters, 2015). This naturally means that pre-1990 citation impact data is currently unavailable for conference proceedings indexed in Web of Science. Consequently, a researcher in a discipline (such as Computer Science or Engineering) that predominantly publishes via conference proceedings, and whose research productivity is assessed via Web of Science data, will not receive an accurate reflection of their research productivity and impact as a result of how conference proceedings are indexed by the data source compared to Scopus. In turn, these methods impact how representative the bibliometric data is for different disciplines and makes it integral to understand the strengths and weaknesses of a data source in order for the data to be meaningful.

In some fields of the Arts and Humanities, books and book chapters – not journals - constitute the major scholarly publication venues (Federation for the Humanities and Social Sciences, 2014). These are notoriously absent in tracking databases. By contrast, in the medical sciences almost all research publications are made through serial publications (Archambault & Lariviere, 2010; Chang, 2013) that are very well covered in the same databases. Chang adds that researchers in Arts and Humanities also tend to cite older literature (Chang, 2013). All of this means that the use of bibliometrics to assess research productivity and impact would not be effective for disciplines such as language and linguistics, law, political science, sociology and educational sciences (Van Raan, 2007). The Federation for the Humanities and Social Science Research also recommends that bibliometrics should not be the only tool used to assess research productivity and outcomes in the Humanities and the Social Sciences (2014).

In 2005, Moed summarized the extent to which various disciplines were ‘covered’ within the Web of Science database. Moed’s summary of how extensively the Web of Science database documented research publications by disciplines is summarized in Table 1 (Moed, 2005). Further, Wainer and Jacques noted in 2011 that even within a discipline, bibliometric database coverage can vary significantly. As an example, discipline subsets of computer science may have very different coverage in Web of Science (Wainer, Goldenstein, & Billa, 2011). While the specific level of coverage may have changed in the ensuing years, it provides an important demonstration of the variability with which research productivity and impact is captured within various disciplines.
Another consideration is that some disciplines publish primarily in English, while others do not. Since bibliometric processes favour English publications, this language bias means that the social sciences and humanities are less well represented than other disciplines where publishing in English is the norm (Archambault, Vignola-Gagne, Cote, Lariviere, & Gingras, 2006). A 2005 analysis by Archambault et al illustrates that more research in the social sciences and humanities is published in languages other than English, than in the natural sciences and engineering.

Moreover, citation-tracking databases such as Web of Science favour English-speaking countries and institutions (Paul-Hus, & Mongeon, 2014; Van Raan, Leeuw, & Visser, 2011). In practice, being aware of language bias would influence how an individual uses a tool to make international comparisons. For example, a researcher publishing in another language should not be compared with those publishing in English. Van Raan, Leeuwen, and Visser (2011) note that the language bias in bibliometrics is carried over into university ranking programs that use bibliometrics as a measure of institutional success.

Interdisciplinary researchers are also at a disadvantage. As an example, major databases do not provide adequate coverage of regional or some interdisciplinary journals. Using these databases to assess research productivity and impact for individuals or institutions who publish regionally or in interdisciplinary journals will under-represent actual output, and comparing them against researchers who publish in different regional, national, international or discipline-specific journals is not appropriate (Moed, 2005; Van Raan, 2005).

Some measures, such as the extent of collaborations or international involvement, are particularly

<table>
<thead>
<tr>
<th>Discipline</th>
<th>Web of Science Coverage</th>
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<tbody>
<tr>
<td>Physics</td>
<td>Excellent</td>
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<tr>
<td>Chemistry</td>
<td>Excellent</td>
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<tr>
<td>Molecular Biology</td>
<td>Excellent</td>
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<tr>
<td>Biochemistry</td>
<td>Excellent</td>
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<tr>
<td>Biological sciences (humans and clinical medicine)</td>
<td>Excellent</td>
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<tr>
<td>Applied engineering and engineering sciences</td>
<td>Good</td>
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<tr>
<td>Biological sciences (animals and plants)</td>
<td>Good</td>
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<tr>
<td>Geosciences</td>
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<td>Mathematics</td>
<td>Good</td>
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<tr>
<td>Psychology</td>
<td>Good</td>
</tr>
<tr>
<td>Social sciences (related to medicine and health)</td>
<td>Good</td>
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<tr>
<td>Sociology</td>
<td>Moderate</td>
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<tr>
<td>Political science</td>
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<tr>
<td>Anthropology</td>
<td>Moderate</td>
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<tr>
<td>Educational sciences and humanities</td>
<td>Moderate</td>
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<td>Computer science</td>
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Table 1. Web of Science coverage by discipline (Moed, 2005)
susceptible to context. For example, research collaborations with industry may be more common within certain disciplines, and international collaborations may be more common within specific nations or geographic regions. As well, a high proportion of collaborations with industry or international peers could reflect collaborations with several researchers, or a high proportion of collaborations could represent many collaborations with a single researcher. It is also true that collaboration practices change over time, and to a certain extent, are influenced by an institution’s local culture and traditions. The internet age has directly influenced a researcher’s ability to more easily explore collaborative opportunities. This could possibly complicate a retrospective analysis of collaborative measures data if the context for collaborative practices at different points of time, within the context of a specific discipline, is unknown.

Ultimately, measures of collaboration only have meaning if they are considered within the discipline and relevant time period in which the data was collected. The power of these measures however, is that in the right context, having access to the proportion of international collaborations and/or the proportion of industry collaborations provides evidence-based intelligence to inform strategic decision making. As the proportion of international collaborations captures an institution’s international research collaborations, and the proportion of industry collaborations captures an institution’s research collaborations with industry, this

A deeper understanding of how publication behaviours vary within disciplines, and how that translates into coverage by citation-tracking databases is necessary. Moreover, the relevance of bibliometric measures in effectively representing discipline-level research publication and impact, is also required.

Figure 1. Publication behaviours across disciplines
information can provide useful data to influence strategic directions.

In summary, Figure 1 developed by Colledge and Verlinde in 2014 illustrates, at a high level publication behaviours across disciplines. A deeper understanding of how publication behaviours vary within disciplines, and how that translates into coverage by citation tracking databases is necessary. Moreover, the relevance of bibliometric measures in effectively representing discipline-level research publication and impact, is also required.

4.2. Temporal factors

Time is an important element in understanding research productivity and impact. A lack of understanding for how the passage of time impacts bibliometrics generally and within specific disciplines can lead to challenges interpreting bibliometrics effectively.

Some authors suggest citations within one to two years of publication cannot be counted accurately, even with field normalization efforts (Wang, 2013). However, each discipline is unique in how new research is disseminated and integrated into a field. The time required for research impact to be understood in the field varies by discipline. A three-to-five year window from publication time is recommended as the ideal choice for citations within the Natural Sciences and Engineering (Council of Canadian Academies, 2012). Others have suggested a three-year citation window is necessary for effective citation analysis (Bornmann, 2013; Wang, 2013). However, in Anatomy it can take fifty years or longer for a publication's findings to be analyzed. Taxonomy papers, the branch of science that classifies organisms, are regularly cited decades, even 100 years, after publication (Cameron, 2005). Using citations to understand research impact must reflect the citation culture of the discipline(s) being assessed.

In addition to understanding publication culture across disciplines, the process used to collect bibliometric data also impacts the ability to compare data over time. If one were to compare research productivity over a ten year timeframe using a particular set of bibliometrics, the methodology used to gather that data may have changed, and certainly the data sets themselves (authors, publications) are constantly evolving. This makes it problematic to compare the data over time. As is the case for all databases, Web of Science and Scopus are continuously indexing more items which increases their coverage. This means that increased citations over time may be partly due to the fact that the underlying database simply includes more material.

Another challenge is that a researcher’s impact is understood to change over time. More established researchers will naturally have higher citation counts than researchers early in their career, regardless of the quality of their research or findings. This calls for temporal normalization of data.

In other cases, the scientific findings of a publication may be challenged over time. In these cases there will still be citations attributed to that publication, even though the science behind the article was disputed. In a well-publicized case, a study on genetics predicting longevity was retracted before publication in Science due to technical errors in the scientific data (Ledford, 2011). However, before it could be retracted it was published in PLoS One, resulting in 57 citations to the 2010 pre-print, and 73 citations to the 2012 published version. In this case, an article of questionable research quality still received numerous citations before it was retracted.

4.3. Impact on behaviour and practice

The very process of measuring research can change the nature of how researchers produce research publications. Whenever research is measured, the opportunity to manipulate metrics (even to commit academic misconduct) exists (Furner, 2014; Gagolewski, 2013; Hazelkorn, 2013; Hicks Wouters, Waltman,
The very process of measuring research can change the nature of how researchers produce research publications. Whenever research is measured, the opportunity to manipulate metrics (even to commit academic misconduct) exists.

Post-doctoral fellows and new faculty are under particular pressure to publish in order to build up their academic profiles and be considered for grants (Lawrence, 2008). Consequences of these pressures to publish range from researchers reading fewer papers, to reduced interest in producing research in layman’s terms for policy papers and for the public, and lowered incentives to publish work in domestic journals (Van Dalen & Henkens, 2012). Additionally, Van Dalen notes that researchers are more likely to engage in behaviours that will produce impressive metrics for themselves, rather than behaviours that will benefit a larger group of people. Lawrence (2008) and Retzer & Juransinski (2009) suggest that measures of research productivity and impact will lose meaning over time, as individuals adjust their behaviour.

4.4. Scope of citation-tracking tools

Bibliometric measures that use citations are fundamentally limited by the scope or coverage of the citation tracking tools on which it relies. No single database indexes every type of publication, and no single citation tracking database has the same coverage. Bibliometrics does not provide a comprehensive indication of a given researcher’s, or institution’s, research productivity and impact.

As an example, Waterloo used the InCites bibliometric database to analyze research productivity within a sample of researchers affiliated with the Institute for Quantum Computing (IQC). This exercise compared IQC’s Publications Database to the results of a search for publications produced by IQC researchers within InCites. While the results revealed a comparable trend between the two sources, there were important differences. InCites contained 94% of the publications that were part of the IQC Publications Database. IQC used multiple data sources to gather citation data for these publications (Web of Science, Scopus and Google Scholar); using InCites (which relies on Web of Science data alone) resulted in a 23% lower citation count for the publications in the IQC Publications Database.

This exercise indicates that it is impossible to reproduce bibliometric data generated from one citation-tracking database with that created by another.

No single database indexes every type of publication, and no single citation-tracking database has the same coverage. Bibliometrics does not provide a comprehensive indication of a given researcher’s, or institution’s, research productivity and impact.

1. Citation-tracking databases calculate their bibliometric...
data based on the items they index. For example, Web of Science does not index the journal 21st Century Music. Therefore, if a researcher publishes an article in 21st Century Music, neither that article, nor any citations it garners, will be captured by bibliometrics that use data from the Web of Science.

2. Bibliometric indicators offered by one source may not be offered by another source. For example, InCites, which uses Web of Science data, offers the metric ‘Impact Relative to Subject Area’. In contrast, SciVal is based on Scopus data and does not offer a metric by this name.

3. Validation of data is difficult within sources. To report the number of citations a paper receives, Web of Science and Scopus match the references from the end of each paper to other papers that they index. When the reference matches the paper information exactly, a citation is added. The problem exists when authors incorrectly cite a paper; even a simple error in the page numbers of a reference can mean that a citation is not counted. Completely accurate citation counts are a myth.3

Understanding that bibliometrics is not a comprehensive data set is vital to using bibliometrics effectively. Consequently, anyone using bibliometrics is advised to consider bibliometrics as reflecting a certain degree of arbitrariness. Provided we do not expect too much precision from the exercise, we may treat the range of such analyses as a large sample of data indicating trends over time within a specific context (Allen, 2010).

4.5. Specific measures

The specific measures used to assess research productivity and impact are vital to a robust bibliometrics methodology. The definition of the measures, as well as the context in which the measures are being provided, are critical components to the understanding of the question being assessed. Moreover, the use and analysis of citations and journal impact factor are two measures that are specifically identified as having limitations.

Fundamental questions exist about how citation counts contribute to the understanding of research productivity and impact. Citation counts are based on the assumption that the greater the number of citations a publication receives, the more influential it is. Publications, however, are cited for a number of reasons: to support arguments, as an example of a flawed methodology or weak analysis, or to indicate the amount of research conducted on an issue. The fact that an article has been cited does not necessarily indicate the influence or impact of a particular researcher (Johnson, Cohen, & Grudzinskas, 2012).

One of the most critical concerns for using citations as a method for understanding research productivity and impact is that they require time to accumulate and are time-dependent. In context, this means that most recent publications (those published within the last three years) should not be analyzed for impact as they have not yet had time to fully demonstrate citation impact. Nonetheless, bibliometric measures like h-index, m-index and Py-index are capable of suggesting trends and providing a snapshot of performance over the career of the researcher (Bornmann, 2013). In citation analysis, comparisons can be problematic because of inflated citation records, bias in citation rates, and using differing methods.

3 The University of Waterloo offers a number of resources to support researchers and academics build strong tracking practices. One of these resources is the Library’s Academic Footprint Guide [http://subjectguides.uwaterloo.ca/calculate-academic-footprint?hs=a]. This resource was developed to give authors a process that makes tracking citation counts and the h-index relatively self-sustaining over time.
of handling multi-authored papers. Solutions are being proposed in response to these issues to address some of the complexity of citation analysis and achieve greater objectivity (Retzer & Jurasinski, 2009). Researchers have also questioned the reliability of the Journal Impact Factor (JIF), a widely known Thomson Reuter's measure, as a measure of research impact. The JIF uses citation analysis to identify journals that have a higher rate of papers being cited, and this citation rate is used as an indication of journal quality. The suggestion is that papers published in a journal with a high JIF are also of higher quality. While it is true that more high quality papers appear in journals with high JIF than in those with low JIF, depending too heavily on JIF can be problematic. Harnad (2008) observes, “comparing authors in terms of their JIFs [journal impact factors] is like comparing university student applicants in terms of the average marks of the secondary schools from which they graduated, instead of comparing them in terms of their own individual marks” (p. 104). The key to understanding this metric is that the JIF is a journal level metric, not an publication level measure.

The JIF is also problematic when considering the differences in citation culture between disciplines. Dorta-Gonzalez compared science and social science using the JIF (2013). Dorta-Gonzalez (2013) noted that while there are, on average, 30% more references in social science publications than in science publications, 40% of the sources in social science are not indexed by the Thomson Reuters' Journal Citation Reports (JCR) and therefore do not have a journal impact factor, compared to only 20% of science references that are not indexed in the same. As a result, the aggregate impact factor in science is 58% higher than in social science (p. 667-8).

This evidence does not mean that citation analysis and journal impact factor measures do not have a place in bibliometrics. What it does mean is that bibliometric measures need to be validated to ensure that metrics are being used for their intended purpose, and capable of measuring what they were intended to measure. The fundamental point should be to encourage researchers to publish in venues where their publications are likely to have the highest impact on the field.

4.6. Bibliometric tools

Each citation tracking database, such as Web of Science or Scopus, applies their unique methodological approach to determine which journals and other works to index, as well as preferred document types. These differences, combined with differences in areas or disciplines covered by a database, directly impact how research productivity and impact can be captured. Discipline-specific limitations related to this issue are addressed in section 4.1.

Understanding how databases index various fields of study can identify important limitations. A study of highly cited papers in the environmental sciences done by Khan and Ho (2012) noted that due to the interdisciplinary nature of this field, it was difficult to track publications in this subject area. The study used Web of Science categories to find environmental science articles, but found that many of the discipline's landmark articles were not published in the journals found in this subject area.

Google Scholar, a commonly used citation-tracking database, has its own caveats. Google Scholar finds citations by searching the web which means that citations to papers are not always from scholarly or peer-reviewed sources. For example, an undergraduate thesis or an acknowledgement from a paper might be counted as a citation. Google Scholar search offers limited abilities with precision for author names and lacks the capability for searching affiliations/institutions. This can result in very messy results for common author names, as refinement is difficult. Further, Google Scholar only provides...
bibliometric measures (h-indexes, among others) for researchers that have a Google Scholar Citations Profile, a service which requires researchers to set up a profile and validate the publications that Google Scholar has suggested are their own.

How citation tracking databases attribute authorship of publications also poses a challenge. Authorship is assigned differently across disciplines, and sometimes even within a discipline (Abramo, D’Angelo, & Rosati, 2013; Retzer & Jurasinski, 2009). For example, in one discipline author names might be placed in alphabetical order, while in another, author names might be placed in order of contribution level.

Another aspect of authorship is full counting, which attributes equal credit to all authors of a paper. When bibliometrics are used in some rankings programs, this means that if an author from Institution A collaborates with an author from Institution B, both institutions get credit for this paper. Fractional counting⁴, however, gives less weight to collaborative publications.

4.7. Addressing limitations

The uses and abuses of bibliometrics are well-documented, and some solutions to address these limitations have been proposed (Johnson, Cohen, & Grudzinskas 2012). The known limitations of bibliometrics do not mean that they cannot be used appropriately. Mindful use of bibliometrics will be addressed in section 5.

5. Appropriate Uses for Bibliometrics

Bibliometrics are used for a wide variety of purposes. While this white paper focusses on the use of bibliometrics to assess research productivity and impact, institutions and organizations use bibliometrics to develop university rankings (Marope, Wells, Hazelkorn, & UNESCO, 2013). Bibliometrics can offer important contributions to understanding research productivity and impact when used in conjunction with other measures (Pendlebury, 2009; Rodríguez-Navarro, 2011). As an example, the League of European Research Universities and the Australian Group of Eight Coalition of research universities, each identify the use of bibliometrics as one tool, among a suite of tools, to assess research productivity and impact (Phillips, & Maes, 2012; Rymer, 2011).

Understanding how to use bibliometrics appropriately can help to provide a stronger, and more

⁴The Leiden Ranking methodology provides the following example, “For instance, if the address list of a publication contains five addresses and two of these addresses belong to a particular university, then the publication has a weight of 2/5 = 0.4 in the calculation of the indicators for this university” (Centre for Science and Technology Studies, Leiden University, 2015). InCites uses whole counting for authorship and credits all authors of a paper equally (http://researchanalytics.thomsonreuters.com/m/pdfs/indicators-handbook.pdf] and Leiden provides users the option to use full or fractional counting for authorship. It is unclear whether QS uses whole or fractional counting for faculty and citation attributions. Similarly, Webometrics uses an excellence rating provided by ScImago (10% of papers by citations) but it is unclear if it is fractional. In contrast, ARWU distinguishes the order of authorship using weightings to credit the institutions to which the author is affiliated. This means that a 100% weight is assigned for corresponding author affiliation with 50% for first author affiliation (or second author affiliation if the first author is the same as the corresponding author affiliation), 25% for the next author’s affiliation, and 10% for subsequent authors (Shanghai Ranking Consultancy, 2014).
5.1. Optimizing thoughtful use of bibliometrics

Bibliometric analysis can be a useful contributor for understanding research productivity and impact if used appropriately and with proper understanding of its shortcomings. Bibliometric measures are just one type of measure for understanding research productivity and impact among a host of others. Understanding the limitations of bibliometric analysis and measures, and using them appropriately within that context, can help to mitigate these impediments. Using bibliometrics within a context of other measures will provide a more comprehensive understanding of research productivity and impact.

5.1.1. Create a strong research question

Developing a sound bibliometric analysis is not unlike conducting good research. A carefully crafted research question increases the likelihood that the results reflect the question asked, rather than the question reflecting the results found.

Strong research questions should be as specific as possible. In particular, discipline parameters, research outputs of interest, as well as the scope of the desired comparison should each be identified. An example of a strong research question is: what is the publication and citation output for the University of Waterloo in journals classified as Materials Science? Further, how does this compare to peer institutions?

There are numerous on-campus supports for using bibliometrics effectively. To learn more about resources that are available to support the use of bibliometrics, contact the Bibliometrics Working Group.

5.1.2. Clearly understand the context for comparison

Many bibliometric processes involve comparing two, or more, sets of researchers or institutions to understand relative research strengths. All comparisons, rankings or aggregating of data must be conducted within a very clear and defined context, and this context must be a critical element of the comparison process. Figure 2 outlines possibilities for bibliometric analysis at various levels, while acknowledging known limitations.

Comparing bibliometric measures within a defined set or group of researchers and within similar disciplines/fields can help mitigate the challenges outlined in the limitations section. For example, research productivity of researchers, or those within a particular institute or centre, can be compared with a higher degree of reliability when stage of career (early researcher, established researchers) is considered, although caution is still advised. Even when comparing individual researchers, subtle differences in research sub-disciplines can result in negative impacts on the comparability of research productivity and outcomes (Institute of Electrical and Electronics Engineers, 2013). As research assessment tools, such as InCites, typically draw on a limited dataset they should not be used for...
comparisons at the individual level as they are designed to answer questions about research productivity and impact at the institutional level.

Bibliometrics can also play a role in making meaningful comparisons between similar institutions. Selecting similar institutions for the comparison should include such factors as enrolment, number of faculty, research strengths, faculties, programs and schools. As an example, the University of Waterloo does not have a medical or business school. Given the publication and citation culture in clinical research, the lack of a medical school seriously impacts institutional research productivity and impact outcomes that use number of publications and citations as measures. Similarly, other institutions which have teaching as their main mission may not compare favorably when assessed according to bibliometric measures.

Understanding research productivity and impact within larger contexts – across institutions within a country or internationally, is more problematic. There are so many different elements comprising the institutional and national or international research context that understanding the relative strength of research would be limited to a very high level comparison without a great amount of detail. Figure 2 provides a summative illustration of the recommended uses of bibliometrics by level of analysis.

5.1.3. Understand discipline-specific effects

Figure 2. Recommended uses of bibliometrics by analysis level
In section 4, a number of limitations were outlined related to using bibliometrics across disciplines. Importantly, research indicates that subtleties in disciplines are not easily understood by anyone outside the specific field. Even within disciplines, there can be important variations in publication cultures that are likely only understood by individuals within that field (Dorta-Gonzalez & Dorta-Gonzalez, 2013; Stidham, Sauder, & Higgins, 2012).

Individuals or groups interested in understanding bibliometrics within a specific discipline must acknowledge the discipline-specific effects of using that bibliometric tool has on research productivity and impacts (Mryglod, Kenna, Holovatch, & Berche, 2013). Working closely with individuals within specific discipline areas, and using the level of bibliometric analysis appropriate to the comparison context, will help to mitigate and address issues.

5.1.4. Understand implications of the sample size

The size of the comparison group can also impact the bibliometric results. Using a sample size that is large enough to render relevant information, and appropriate statistical methods, is important to provide high quality and relevant results. For example, a small sample size can lead to challenges with outliers – one, or a couple, of researchers with heavily cited papers. It is difficult to normalize for these outlier effects, this is particularly true where research units are small and in low-citation culture disciplines (Vieira & Gomes, 2010; Abramo, D'Angelo, & Viel, 2013; Hicks, et al., 2015).

5.1.5. Select the appropriate type of productivity and impact measure

There are numerous different types of measures for understanding research productivity and impact. Using bibliometrics as one of these measures, or in combination with other types of research productivity and impact measures, can provide a stronger analysis and understanding.

As an example, peer reviewed assessment of research output has long been considered the gold standard of how to determine the quality of research across disciplines (Abramo, D'Angelo, & Di Costa, 2011a; Abramo, D'Angelo, & Di Costa, 2011b; Haeffner-Cavaillon & Graillot-Gak, 2009; Lovegrove & Johnson, 2008; Lowry et al., 2013; Mryglod et al., 2013; Neufeld & von Ins, 2011; Rodríguez-Navarro, 2011; Taylor, 2011; Wainer & Vieira, 2013) Peer review provides much needed qualitative context to research. There are cases where some papers considered in the field as ‘the best’ by experts in the field are not always the most highly cited (Coupe, 2013).

It is widely acknowledged that the peer review process is susceptible to bias (Butler & McAllister, 2009; Van Raan, 1996). Van Raan recommends that a blending of bibliometrics and peer review could possibly mitigate prominent concerns of both methods.

5.2. Uses for research productivity and impact and common bibliometric measures

Table 2 provides a summative view of appropriate uses for bibliometric measures commonly used to assess research productivity and impact. Each of these is defined and considered by how they should be appropriately used (or not used), and includes level of use. This table is useful as a summary for...
researchers, administrators and others making decisions about how to assess research productivity and impact, as well as how to interpret the relevance and accuracy of how bibliometric measures have been used.

Using bibliometrics as one of these measures, or in combination with other types of research productivity and impact measures, can provide a stronger analysis and understanding.
## Table 2. Common bibliometric measures, definitions, suggested uses and levels of use

Bibliometric measures should not be considered in isolation. They should be considered in conjunction with the following factors: time, context, discipline, fractional or whole counting of authors, self citations and stage of researchers’ career.

<table>
<thead>
<tr>
<th>Bibliometric Measure</th>
<th>Definition</th>
<th>Useful For</th>
<th>Not Useful For</th>
<th>Possible level of use and examples</th>
</tr>
</thead>
</table>
| Publication count    | The total count of items identified as scholarly output. For example: journal articles, books, conference proceedings, etc. | • Assessing outputs of an individual, discipline, or institution. | • Assessing quality of a work. | • Individual  
• Subject / Discipline  
• Institutional  
• Eg., Peer review, research funding applications, researcher CVs, collaborations, research impact. |
| Citation count       | The total number of citations received to date by the publications of a researcher, department or institution. | • Measuring an element of impact of a work or set of works. | • Understanding context of the impact (positive vs negative impact). | • Individual  
• Subject / Discipline  
• Institutional  
• Eg., Peer review, research funding applications, researcher CVs, collaborations, research impact. |
| Normalized Citation Impact | Actual citation impact (cites per paper) in comparison to expected citation impact (cites per paper) of subject area globally. This measure is normalized for subject area, document type, and year. A value of 1.00 indicates that the work performs at the expected global average. A value >1.00 indicates that the publication exceeds the world average. | • Comparing between different subjects and sample | • Small sets of publications, as a single highly cited paper can easily skew the calculation through inflation. | • Individual  
• Subject / Discipline  
• Institutional  
• Eg., Peer review, research funding applications, researcher CVs, collaborations, research impact. |
<table>
<thead>
<tr>
<th>Bibliometric Measure</th>
<th>Definition</th>
<th>Useful For</th>
<th>Not Useful For</th>
<th>Possible level of use and examples</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>H-Index</strong>&lt;sup&gt;5&lt;/sup&gt;</td>
<td>As a productivity measure, an author’s h-index can be calculated by locating citation counts for all published papers and ranking them numerically by the number of times cited. A researcher’s h-index will be the point where the number of citations most closely match the rank of the publication (or the point where all the papers ranked lower have an equal or less number of citations).</td>
<td>• Comparing researchers of similar career length. • Comparing researchers in similar field / subject / department and who publish in the same journal categories. • Obtaining a focused snapshot of a researcher’s performance.</td>
<td>• Comparing researchers from different fields/disciplines/subjects. • Assessing fields / departments / subjects where research output is typically books or conference proceedings as they are not well represented by databases providing h-indices.</td>
<td>• A focussed snapshot of an individual’s performance. Caution should be used when comparing between researchers. • Eg., Peer review, research funding applications, researcher CVs.</td>
</tr>
<tr>
<td><strong>Proportion of International Collaborations</strong></td>
<td>Proportion of publications having at least two different countries among the co-author affiliations.</td>
<td>• Capturing a researcher’s or institution’s proportion of work that is co-authored with international colleagues.</td>
<td>• Subject / Discipline • Eg., Research funding application, strategic planning, institutional accountability process.</td>
<td></td>
</tr>
<tr>
<td><strong>Proportion of Industry Collaborations</strong></td>
<td>Proportion of publications having the organization type ‘corporate’ for one or more co-author affiliation</td>
<td>• Capturing an author’s or institution’s proportion of work that is co-authored with industry</td>
<td>• Department • Institutional • Eg., Research funding application, strategic planning, institutional accountability process.</td>
<td></td>
</tr>
<tr>
<td><strong>Journal Impact Ranking</strong></td>
<td>Measures of this type use aggregate citation data of articles published in a journal to capture the journal’s relative importance.</td>
<td>• Identifying relative importance of a journal.</td>
<td>• Identifying relative importance of individual journal articles. • Determining quality of individual journal articles.</td>
<td>• Individual • Discipline • Institutional</td>
</tr>
</tbody>
</table>

<sup>5</sup> Most famous of the single value indices.
<table>
<thead>
<tr>
<th>Bibliometric Measure</th>
<th>Definition</th>
<th>Useful For</th>
<th>Not Useful For</th>
<th>Possible level of use and examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentiles</td>
<td>Top percentile (for example, 1% or 10%) is typically a measure of the most cited documents in a subject area, document type, and year. For example, the top 10% reflects the top 10% most cited works in the above context.</td>
<td>&quot;Only appropriate for large to medium size data sets as a way to measure impact by the number of works located in the top 10%&quot; (Thomson Reuters, 2014, p. 15).</td>
<td>Significant caution should be used when assessing small datasets.</td>
<td>Subject / Discipline, Institutional, E.g., Research funding application, peer review.</td>
</tr>
</tbody>
</table>

| Highly Cited Researchers<sup>6</sup> | A controversial list of highly cited Sciences and Social Sciences researchers created by Thomson Reuters. Highlights researchers whose work represents the top 1% of researchers in a field for citations. | Understanding an individual researcher's impact as it relates other papers in the subject matter in which they have published. | Comparing researchers from different fields / subjects / departments. | Sciences and Social Sciences, Useful for peer review, research application funding, CVs, research collaborations. |

| Altmetrics | Methods of evaluating and discovering scholarly work that focuses on the use of open data and social media sources. Altmetrics diverge from the traditional, where traditional is defined by publication and citation counts and their derivatives (ex. Journal impact factor and h-index). | Currently unknown. As altmetrics are still in their infancy, researchers are just beginning to understand how altmetrics measure impact. Generally, altmetrics providers suggest usefulness to include helping author's see the kind of attention their work is receiving and from whom. | Analysis of a researcher/ department/ institutions work before ~2011. This is due to the reliance of altmetric providers on social media sources, many of which were only recently created. Additionally these providers rely heavily on DOIs which have only been around since 2000. | Individual, Useful for peer review, research funding applications, CVs, strategic planning, institutional accountability planning, research collaborations. |

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<sup>6</sup> For more information on Highly Cited Researchers consult the methodology detailed at [http://highlycited.com/info.htm](http://highlycited.com/info.htm).
When used appropriately, bibliometrics can provide important data for assessing and understanding research productivity and impact. However, no bibliometric measure, nor data collection methodology is without limitations nor can one suit all needs. It is important that those who wish to conduct, and understand, research productivity and impact assessments, have a clear understanding of how to use these.

5.3. Standards of good practice for researchers

Researchers can take important steps to improve the likelihood that their research productivity and impact is captured through bibliometrics more effectively. These steps include:

Define your identity "convention" as an author, and use that identity convention systematically. Researchers can decrease the likelihood that their works are not captured by bibliometric methods by proactively determining how their name will appear in published form throughout their career. Researchers need to be aware that many databases do not disambiguate names with the same last name and first initial. For example: M. Smith represents Mary Smith, Michael Smith, Michelle Smith, etc. This means that the only way to ensure that your publications are listed as your own is to create a researcher ID for that database, or to create a profile like ORCID\(^7\). [http://orcid.org/about/what-is-orcid] ORCID is becoming more pervasive, and may be required by funding institutions in the future; it would be advisable especially for young researchers to establish an ORCID profile early in their career.

Ensure appropriate affiliation / acknowledgement to the University of Waterloo. At the manuscript submission stage, researchers should ensure that the University of Waterloo is properly acknowledged as the author’s institutional affiliation and/or in the manuscript submission’s address line. This institutional attribution should be done consistently and accurately when submitting all research outputs for publication. Papers which do not list the institution in the address line of the submission are not ‘credited’ to the institution. Van Raan (2007) notes, “Put bluntly, this attribution is one of the most crucial elements in the whole evaluation process, and is thus an ethical matter of professional conduct for evaluators” (p. 116).

It is clear that everyone involved in the research process and assessment of research has important responsibilities in building awareness of the appropriate use of bibliometric measures as a way of assessing research productivity and impact. A concerted effort to do so will ensure that bibliometrics used to capture researchers’ productivity and impact will reflect more meaningful and accurate data. However, even with stronger bibliometric understanding and practices, they remain but one approach for understanding research productivity and impact. A comprehensive approach that relies on numerous data points is still needed.

\(^7\) As an international author identification system, ORCID is an interdisciplinary non-profit effort to attribute research output and objects to their true creator. A sixteen digit numeric ORCID code represents a single researcher and their associated works, and offers a solution to author identification challenges such as name ambiguity (ORCID, 2014).
6. Recommended Practices for Bibliometric Analysis at the University of Waterloo

Bibliometrics offer an opportunity to quantify selected types of research outputs; however, there are important limitations to the use of bibliometric measures. These include the following:

- Academic disciplines have differing traditions for producing and distributing research outcomes, and not all of these are consistent with what is indexed by citation-tracking databases (such as Web of Science, Scopus, and Google Scholar). This includes research that is not published in English, interdisciplinary research, or research outcomes or elements susceptible to context, for example, the extent and type of some research collaborations.
- Citation-tracking databases each have their own methodological approach, and how they index research publications from various fields of study can produce important limitations.
- Each research analytic tool (such as InCites and SciVal) uses different citation tracking tools and none index every type of publication, thus comprehensive coverage of research publications has not possible.
- The issue of how the passage of time impacts on bibliometrics is also complex. Citations, a key research bibliometric measure, accrue with time after publication. The time required for understanding the impact of a paper using citations differs by disciplines. Moreover, research analytic tools themselves change their scope and coverage and thus assessments of productivity and impact taken at different times cannot always be meaningfully compared.
- The use of bibliometric measures may lead to changes in publication practices in order to enhance opportunities for bibliometric coverage and may provide potential opportunities to manipulate metrics.

In aggregate, these factors strongly suggest that bibliometric comparisons across disciplines or sub-disciplines, or longitudinal comparisons within a group, may generate unclear or misleading results. Using bibliometrics appropriately shares many elements that are consistent with conducting good research:

- Be explicit about other non-bibliometric data sources that should also be considered
- Use a research question with the appropriate scope and clarity for the discipline and the bibliometric information available
- Understand the research and comparison context, including discipline-specific effects and the implications of sample size, and
- Select appropriate tools and measures to investigate the research question.

Bibliometrics can offer important contributions to understanding research productivity and impact when used thoughtfully, and in conjunction with other measures. Bibliometrics are most useful when used in combination with peer and other expert review to assess the impact and volume of scholarly work. They can be used to provide an indication of research activity and impact within the scientific community. They should be used in conjunction with other measures and framed carefully in terms of their disciplinary context. They can be quite useful for evaluating scientific output and impact at the institutional level.

The consensus in the peer-reviewed literature on bibliometrics is that they are not suited for comparing research productivity and impact across disciplines, nor as a single indicator of individual research productivity and impact assessment. The scientific content and quality of publications and research outcomes is more important than simple publication metrics and the different discipline cultures are
too strong an effect for most cross-discipline comparisons to be effective. For these reasons, relying on bibliometric measures for hiring, tenure and promotion decision making is strongly discouraged.

Recommended Practices for Bibliometric Analysis at the University of Waterloo

Despite known limitations, bibliometric analysis is a common approach for understanding research productivity and, if used carefully, can provide a data point, in conjunction with others, for evaluating research outcomes. The following recommendations are geared toward Waterloo researchers, administrators and others interested in using bibliometrics, or assessing the relevance of bibliometric results. Implementing the following practices can ensure that bibliometric analysis is used appropriately, as one part of a broader framework of analysis, to provide a more robust and accurate understanding of research productivity and impact.

• Consider bibliometric measures as one data point among a set of others for understanding research output and impact. Best practice is to work from a basket of measures. It is impossible for any bibliometric analysis to present a complete picture. Bibliometrics is an imprecise science at best and bibliometric assessments should not be treated as an absolute outcome. Bibliometrics is optimally used to complement, not replace, other research assessment measures such as peer review, keeping in mind that “both need to be used with wisdom, discretion and the rigorous application of human judgement” (Phillips & Maes, 2012, p. 3).

• Understand and account for variations in how disciplines produce and use research publication. The nature of research (and more generally, scholarly) output (e.g., journal articles, books and book chapters, conference proceedings, performances, social outcomes, research artifacts) differs across disciplines, and thus the relevance and applicability of bibliometrics also differs across disciplines. It is important to use bibliometric measures relevant for each discipline.

• Involve those evaluated in the analysis process. Bibliometrics are appropriately used within specific fields or disciplines to understand quantitative aspects of research productivity and impact, considering the limitations outlined above. Given the significant role and impact of context in the use of bibliometrics, researchers in the field or discipline under investigation may be best equipped to understand the variability of how bibliometric measures capture and reflect research outcomes in their field. This will help to ensure that using bibliometric measures incorporates a full understanding of their limitations, particularly at the discipline level.

• Understand the distinctions among bibliometric measures. Be aware of the methodology, purpose, and limitations of bibliometric databases (such as Web of Science, Scopus, and Google Scholar) and of individual bibliometric measures (such as the Journal Impact Factor and h-index). As an example, it is important to recognize the value of normalized measures compared to whole/raw counts while also recognizing that normalized measures can be vulnerable to outliers (e.g., a single highly cited paper can increase the average somewhat artificially). Regular review and updating of research methods and definitions will ensure a strong and current understanding of methodologies used.

• Exercise caution when using journal impact rankings. Journal impact rankings such as JIF or SCImago Journal Rank (SJR) should not be broadly used as a surrogate measure of the quality of individual research articles, or an individual’s performance when opportunities exist for an in-depth evaluation of individual publications. depth evaluation of individual publications.
Appendix A
Working Group on Bibliometrics Members

Advisory Group Members:
Director, Institutional Analysis & Planning: Allan Starr
University Librarian: Mark Haslett
Vice President, University Research: George Dixon

Working Group Members:
Chair: Bruce Muirhead (to August, 2015), Tamer Özsö (beginning September 2015)
Office of Research: John Thompson, Brenda MacDonald
Institutional Analysis & Planning: Daniela Seskar-Hencic, Jana Carson, Kerry Tolson
Library: Kathy MacDonald, Shannon Gordon, Pascal Calarco, Peter Stirling, Susie Gooch, and Lauren Byl
AHS: Brian Laird
Arts: Angela Roorda, Jennifer Simpson
Science: Alain Francq, Bernie Duncker
Math: Tamer Özsö, Kim Tremblay
Engineering: Anwar Hasan, Martha Foulds
Environment: Maren Oelberman

Past Working Group Members:
AHS: John Mielke
Library: Lauren Byl (Graduate Student), Susie Gooch (Graduate Student)
Science: Marc Gibson
Appendix B
Evidence-gathering process used to conduct a comprehensive literature review on current bibliometric practices

1 Searching was conducted during January through August 2014. Note that as additional, relevant literature was discovered throughout the project, further items were added to RefWorks and reviewed as required.

2 Searching was led by a Master of Library and Information Science student, working in a co-op position, with the support of a Professional Librarian, as well as the White Paper Working Group. Sample search strings included:
   “citation analysis” AND “best practices”
   “citation analysis” AND standards
   “citation analysis” AND “current uses”
   “bibliometrics” OR “citation analysis”
   (“bibliometrics” OR “citation analysis”) AND humanities
   (“bibliometrics” OR “citation analysis”) AND science
   (“bibliometrics” OR “citation analysis”) AND “peer review”
   (“bibliometrics” OR “citation analysis”) AND manipulation

3 This work was also completed by a Master of Library and Information Science student, employed in a co-op position.
References


MEMO

TO: Mike Grivicic
   Associate University Secretary

FROM: B. Hellinga, Associate Dean, Graduate Studies
   Faculty of Engineering

RE: Senate Graduate and Research Council Meeting

DATE: December 18, 2015

Please place the following motions on the agenda for the next Senate Graduate and Research Council meeting. These motions were approved by Engineering Faculty Council on December 15, 2015.

The Department of Mechanical and Mechatronics Engineering (MME) is asking for two motions to be approved.

1. Graduate Diploma in Fire Safety for Spring 2016
   o Adding ‘specific’ course requirements.

2. Graduate Diploma in Design (GDD) for Spring 2016
   o Introducing a co-op option to the program.

For Information:
1. Course Changes for Winter 2016

   This motion was approved by SGRC November 9, 2015 pending approval from EGSC and EFC. It was approved by EGSC in November, and EFC on December 15, 2015.
   o ME 753 and ME 751: Adding “also offered online” to course description
   o ME 760: Course title was previously incorrectly changed to Special Topics in Thermal Engineering: Air Pollution and Greenhouse Gases when changing a course topic title within the list of Special Topic courses. We would like to revert the course title back to the original Special Topics in Thermal Engineering.

Bruce Hellinga

BH: jec
Major Modification

Program: Graduate Diploma in Fire Safety, Mechanical and Mechatronics Engineering Department

Degree Designation: Graduate Diploma in Fire Safety (in conjunction with the Master’s of Engineering (MEng) program)

Type of Modification: Modification to the number of ‘Specific’ courses required for graduate diploma. As well, removal and addition of courses offered as ‘Specific’ courses.

Approved at (please note date of approval at previous levels):
Approved by MMEGSC on September 22, 2015
Approved by MME Department on October 22, 2015

Effective Date:
January 1, 2016.

Description of Proposed Change:
The department is requesting to have the following changes made to the Fire Safety Graduate Diploma course requirements. First, the number of specific courses required changed from ‘five (5) within the Specific list’ to ‘three (3) within the Specific list’. Second, the department would like to amend the Specific course list by adding and removing some courses.

Rationale for Proposed Change:
These changes have been driven by evolution of the structure, demand from industry and courses offered in the Fire Safety GDip program over time after inception of the program in 2007. The requirement of three core courses remains the same; however, because of limitations in faculty and teaching resources, sustainability of enrolment numbers in certain courses of the original list of technical courses, and overall interest in certain topics by our largely industrial based student population, the number and list of specific technical electives has had to be pared down by three courses over time. There are now five distinct specific courses that are regularly offered, with alternative course identified for one of those as shown on the revised list of specific courses. With five courses on that list, it is also necessary to realign the requirement of taking ‘five’ specific courses downward to the requested ‘three’ specific courses.
Calendar Description with track changes showing amendments needed:

Graduate Diploma requirements for Fire Safety:

<table>
<thead>
<tr>
<th>Mandatory courses:</th>
</tr>
</thead>
<tbody>
<tr>
<td>ME 671</td>
</tr>
<tr>
<td>ME 672</td>
</tr>
<tr>
<td>ME 673</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Specific courses:</th>
<th>from the following list</th>
</tr>
</thead>
<tbody>
<tr>
<td>CIVE 601</td>
<td>Special Topics in Numerical Methods, Fluid Flow and Heat Transfer: Fire Risk Analysis</td>
</tr>
<tr>
<td>OR</td>
<td>OR</td>
</tr>
<tr>
<td>CIVE 601</td>
<td>CIVE 601: Engineering Risk and Reliability</td>
</tr>
<tr>
<td>ME 720</td>
<td>Special Topics in Solid Mechanics: Fire Resistance</td>
</tr>
<tr>
<td>ME 760</td>
<td>Special Topics in Thermal Engineering: Industrial Fire and Explosion Safety</td>
</tr>
<tr>
<td>ME 765</td>
<td>Special Topics in Fluid Mechanics: Advanced Concepts in Design for Fire Safety</td>
</tr>
<tr>
<td>ME 765</td>
<td>Special Topics in Fluid Mechanics: Smoke Movement</td>
</tr>
<tr>
<td>ME 765</td>
<td>Special Topics in Fluid Mechanics: Human Behaviour in Fires</td>
</tr>
<tr>
<td>ME 770</td>
<td>Special Topics in Numerical Methods, Fluid Flow and Heat Transfer: Experimental Design, Measurement and Data Validation</td>
</tr>
<tr>
<td>ME 770</td>
<td>Special Topics in Numerical Methods, Fluid Flow and Heat Transfer: Fire Testing</td>
</tr>
<tr>
<td>ME 765</td>
<td>Special Topics in Fluid Mechanics: Advanced Concepts in Design for Fire Safety</td>
</tr>
</tbody>
</table>
Major Modification

Program: The Graduate Diploma in Design (GDD)

Degree Designation: Graduate Diploma in Design

Type of Modification: addition of co-op option

Approved at (please note date of approval at previous levels):
Approved by MMEGSC on September 22, 2015
Approved by MME Department on October 22, 2015

Effective Date: Spring 2016

Description of Proposed Change: Addition of co-op option to the current GDip in Design. This option allows the qualified students to have one co-op term in their studies.

Rationale for Proposed Change:
The Graduate Diploma in Design (GDD) was developed in 2007. The GDD is available to those Master of Engineering (MEng) students who select four of the eight MEng courses to be the following GDD core and elective requirements:

- ME 680 Advanced Design Engineering (core)
- ME 681 Advanced Design Engineering- Design Project 1 (core)
- ME 682 Advanced Design Engineering- Design Project 2 (core)
- Design Specific Elective (core elective from prescribed list)

Currently, Design Project courses act as quasi-internships, where academic content is associated with industry engagement. While students are not formally employed, their courses require students to engage in highly authentic and complex design-based project work within an industry environment. While the internship model has not been formalised, the department and NSERC Chair in Design Engineering has been instrumental in developing industry partnerships to support Design Project students. MME aims to further develop the academic depth of learning, formalize and actively promote the experiential component of its GDD programs, and incorporate selected students into the JobMine employment cycle by introducing co-operative education to the existing GDD program.

Old Calendar Description (where applicable):
Graduate Diploma in Design Engineering

New Calendar Description (where applicable):
Graduate Diploma in Design Engineering
Graduate Diploma in Design Engineering / co-op option
Graduate Diploma in Design with Co-op option

Background:

The Graduate Diploma in Design (GDD), originally the Professional Master of Engineering Design Certificate, was developed in 2007 following the awarding of the Waterloo Chair in Design Engineering. The GDD is available to those Master of Engineering (MEng) students who select four of the eight MEng courses to be the following GDD core and elective requirements:

- ME 680 Advanced Design Engineering (core)
- ME 681 Advanced Design Engineering- Design Project 1 (core)
- ME 682 Advanced Design Engineering- Design Project 2 (core)
- One Design Specific Elective from the following list:
  - ME 538 Welding Design, Fabrication & Quality Control
  - ME 555 Computer-Aided Design
  - ME 559 Finite Elements Methods
  - ME 561 Fluid Power Control
  - ME 566 Computational Fluid Dynamics For Engineering Design

Currently, Design Project (DP) courses act as quasi-internships, where academic content is associated with industry engagement. While students are not formally employed, their courses require students to engage in highly authentic and complex design-based project work within an industry environment. While the internship model has not been formalised, the department and NSERC Chair in Design Engineering has been instrumental in developing industry partnerships to support Design Project students. MME aims to further develop the academic depth of learning, formalize and actively promote the experiential component of its GDD programs, and incorporate selected students into the JobMine employment cycle by introducing co-operative education to the existing GDD program.

It is noted that the GDD programs currently attract students with varied backgrounds, including working professionals, foreign-trained professionals, and recent returning graduates. It is anticipated that only foreign-trained professionals and returning graduates would be eligible for co-op, as working professionals would not be able to accommodate a full-time study/work sequence. The anticipated annual intake into co-op studies is between 5 and 15 students.

Summary of the changes:

The proposed co-op addition to the GDD is optional for the student participating in this program. Qualified students will have two co-op options: 4- and 8-streams. If they are interested in 4-stream then they have to submit an application by August 1st before the start of their program. For 8-stream option the application submission and selection will be in their first term and by December 1st. Selected students are introduced to the Co-operative Education & Career Action (CECA) to be included into the JobMine employment cycle. Upon successful placement, the student will go on a work term using one of the following sequences:
Qualified student interested in the co-op option must submit an application by August 1st for 4-stream and by December 1st for the 8-stream and meet the following requirements:

- student will be interviewed by the department before they are recommended to the Co-operative Education and Career Action (CECA) for approval. Interviews will take place prior to the end of August or December for 4-stream and 8-stream options, respectively.
- student should submit the followings with their application and prior to their interviews:
  a. any previous Professional Engineering Licensure documents or licensure status
  b. design Portfolio (past design projects experiences including capstone projects....)
- an excellent command of the English language

After a student has confirmed a co-op work term position the following will be required:

- Change of Program Form to switch to the co-op program
- Change of Enrolment Form indicating co-op work term
Handling of Final Assessment Reports related to academic program reviews and follow-up Two-Year Progress Reports.

Introduction
Waterloo’s Senate Undergraduate Council (SUC) and Senate Graduate and Research Council (SGRC) have among other responsibilities, a fiduciary duty is to consider all aspects relating to the academic quality of undergraduate studies and graduate studies, respectively, within the university. As described in Waterloo’s Institutional Quality Assurance Process (IQAP), documentation emerging from the cyclical program review process includes: (1) a Final Assessment Report, which summarizes the self-study, external reviewers’ report, program response and implementation plan, and (2) a Two-Year Progress Report, which reports on progress related to the implementation plan. This document outlines a process for vetting these reports through SUC and SGRC.

Process
All undergraduate program reports are handled by SUC. Likewise, all graduate program reports are handled by SGRC. For augmented reports (combined undergraduate and graduate), in any given year, half will go through SUC and the other half through SGRC to share the workload.

For Final Assessment Reports two SUC or SGRC members will be asked to review the report. For Two-Year Progress Reports, one SUC or SGRC member will be asked to review the report, although at the SUC/SGRC Chair’s discretion, a second reviewer may be sought.

Reviewers of FAR and Two-year reports will consider a series of guiding questions (see below) in coming to their recommendation to SUC or SGRC. Furthermore, before reporting to SUC or SGRC, reviewers are encouraged to ask questions and share their observations as well as any concerns they have identified with the program under review (usually through the chair of the program). Any revisions should be completed by the chair of the program prior to bringing the report for approval at a SUC or SGRC meeting.

Guiding questions for Final Assessment Reports
Does the Final Assessment Report:
1) Identify the significant strengths and weaknesses of the program as described by either the program and/or the visiting team?

2) Include a credible implementation plan that not only addresses the substantive issues identified from the program review process but also identifies clearly:
   - What actions will follow from specific recommendations?
   - Who will be responsible for acting on those recommendations?
   - Who will be responsible for providing resources?
   - Priorities for implementation and realistic timelines for initiating and monitoring actions?
Guiding questions for Two-Year Progress Reports

Does the Two-Year Progress Report:

1) Clearly describe progress achieved on the various action items in the implementation plan?

2) Explain convincingly any circumstances that would have altered the original implementation plan?

3) For items that are behind schedule, propose an amended implementation schedule that is reasonable and credible?

4) Does the report address significant developments or initiatives that have arisen since the program review process, or that were not contemplated by the program review process?

Reviewers, should they request it, will be provided access to the confidential documents informing the reports (e.g. self study, reviewers’ report, program response), but consulting these documents is not expected unless there is a need to clarify some aspect of a Final Assessment Report or Two-Year Progress Report. All members of SUC and SGRC will have the opportunity to review the Final Assessment Report or Two-Year Progress Report ahead of the meeting in which the report will be considered and so will have the necessary information to engage in discussion.

To promote transparency and foster integrity in the review process, whenever possible, reviewers should not be members of the faculty/ Affiliated and Federated Institutions of Waterloo (AFIW) from which the reports originate.

Normally, the associate dean (undergraduate studies or graduate studies) in the faculty (or equivalent in an AFIW institution) where the program resides would be asked questions during an SUC or SGRC meeting when then report is being discussed. However, responses from any member of SUC or SGRC who can offer insight, are welcome. The department chair or school Director (or their chosen delegate) of the program being considered could be invited to attend the SUC or SGRC meeting by the associate dean to act as a resource person.

SUC’s and SGRC’s responsibility will be to focus on the overall credibility and feasibility of the report and the proposed plan of action – seeking to uncover, for example, unexplained disjunctions between the reviewers’ recommendations and the department’s response – as opposed to the minutiae of course content and curriculum structure.
Meaning of Approval at SUC or SGRC

For both Final Assessment Reports and Two-Year Progress Reports, SUC or SGRC should ultimately be able to assess whether the report is (a) satisfactory; (b) satisfactory but with minor concerns; or (c) unsatisfactory due to major concerns.

In considering whether to approve a Final Assessment Report, SUC or SGRC will focus on the above guiding questions for FARs or Two-Year Progress Reports.

For a Two-Year Progress Report, endorsement of the report by SUC or SGRC indicates that SUC/SGRC is satisfied with the progress to date on the implementation plan based on the answers to the guiding questions, and that SUC or SGRC has confidence that remaining action items will be appropriately addressed on the established timelines.

A Final Assessment Report or Two-Year Progress Report that is deemed “satisfactory” by a majority vote of SUC/SGRC will be submitted to Senate for information, normally without additional comment. Should the discussion at SUC or SGRC reveal issues of minor or major concern (as indicated by vote), SUC/SGRC shall forward the pertinent minutes of the meeting to the head of the program in question (and their resource person if one acted as their delegate) to advise of the concerns identified at SUC or SGRC and to invite a response which may include amendments to the original report, along with the appropriate endorsement by the faculty dean or AFIW head. The report then comes back to SUC or SGRC for reconsideration and a final vote. A report considered unsatisfactory is not forwarded to Senate, but is instead returned to the head of the program with a request for further work. A program chair at this stage may request an unsatisfactory report be provided to Senate, in which case Senate shall be provided the report with a description of the areas of concern identified.
Final Assessment Report of
Bachelor of Arts (Studio Art, Art History and Visual Culture, Film Studies and Visual Culture),
Master of Fine Arts (Studio Art)

December 2015

Introduction
In accordance with uWaterloo’s Institutional Quality Assurance Process (IQAP), this final assessment report provides a summary and synthesis of (i) the external review of the three BA programs in Studio Art, Art History and Visual Culture, and Film Studies and Visual Culture and the MFA program in Studio Art, (ii) the program (department) response to the external review, and (iii) an implementation plan for improvements that lists specific actions, timelines, required resources and responsibility.

The Fine Arts Department was last reviewed in 2007. Although self-studies were prepared separately for the graduate (2006) and undergraduate (2007) programs, the two programs were reviewed by external reviewers at the same time in the fall of 2007. Recommendations from the last program review have resulted in improvements in curriculum, courses, admissions processes, library resources, space for students, involvement of faculty beyond the department and Faculty of Arts, and strategic faculty and staff appointments.

Self-Study Process and Site Visit
The Chair of the Department of Fine Arts assumed primary responsibility for guiding the self-study process. Each faculty member, except those on sabbatical, was assigned one or more major sections of the self-study to complete. Staff were also involved in contributing to the self-study. Institutional Analysis and Planning provided the usual wide array of data required to support the self-study. The Centre for Teaching Excellence conducted three workshops with Fine Arts faculty members to create the UDLEs (in 2009) and GDLEs (in 2013-4) mapping charts. Student opinion was solicited through surveys. For current students, survey questions were appended to the Fall 2013 course evaluation forms for four key Fine Arts courses in Fall 2013. For undergraduate and graduate alumni, the department worked with the Office of Advancement. Current undergraduate and graduate students were also interviewed by the external reviewers as part of the review process.

The Department of Fine Arts submitted their self-study to offices of the Associate Vice President, Academic and Associate Provost, Graduate Studies on August 25, 2014. In addition to
The site visit was conducted November 20-21, 2014. The external members of the review team were Alex Poruchnyk, School of Arts, University of Manitoba and David Merritt, Department of Visual Arts, Western University. The internal member was Dr. Vivian Dayeh, Department of Biology. The review team met with program administrators and departmental faculty (including sessional faculty) and staff, graduate and undergraduate students, as well as the Faculty Dean and Associate Dean (Undergraduate Studies), the Associate Provost, Graduate Studies and Associate Vice-President, Academic. The reviewers also visited numerous studios, resource centres, lecture theatres, art galleries and faculty and administrative spaces.

The external reviewers’ report was received on January 2, 2015 and the department’s response and implementation strategy, with timelines, responsibilities and resource needs assessment was received on April 29, 2015 and approved by the Dean of Arts on May 15, 2015.

This final assessment report is based on information extracted, verbatim in many cases, from the self-study, the reviewers’ report and the program response.

**Fine Arts Programs Under Review**

**Bachelor program**

In 2011 the Department activated entirely new undergraduate curriculums in studio, art history and visual culture, and film studies and visual culture to keep pace with the changing nature of art scholarship and practice and the study of art and the visual image. The current bachelor programs are (i) Studio Practice, (ii) Art History and Visual Culture, and (iii) Film Studies and Visual Culture which are available through a variety of different bachelor programs (see below). The department has plans to merge the latter two programs in the near future into a new program called Visual Culture, a move strongly endorsed by the External Reviewers who indicated that the “planned Visual Culture designation will serve to align studies in this program with a growing number of programs adopting similar methodological approaches and nomenclature in Canada and internationally. It will also clearly differentiate the focus of the degree from film studies programs currently available through other universities in the region.”

The currently available Bachelor programs are:

- Three-Year General Fine Arts
- Four-Year General Fine Arts
- Honours Fine Arts (note all Honours Fine Arts programs offer students a choice in year 4 of either the Studio stream or the Studio Practicum stream)
• Honours Fine Arts, Arts and Business Regular
• Honours Fine Arts, Arts and Business Co-op (note that the Fine Arts Department does not have a department co-op program. Fine Arts students participate in co-op through this plan.)
• Joint Honours Fine Arts (note all Joint Honours programs are taken with another discipline program at the University of Waterloo)

The program also offers two minors (Fine Arts Studio Minor and a Visual Culture in a Global Context Minor) as well as two specializations which can be taken in conjunction with a Fine Arts major plan (Fine Arts - Teaching Preparation Specialization, and the Professional Practice Specialization);

**Master of Fine Art Program**

The Master of Fine Art is the sole graduate offering, and is offered in four fields:
• Painting
• Sculpture
• Electronic imaging (digital)
• Drawing

However, hybridity across these fields and other fields (e.g. performance, sound art) also occurs, consistent with the nature of much contemporary art practice. Note: the MFA is still generally considered the terminal degree in Fine Art (although doctoral programs are increasingly on the rise).

**Strengths and Challenges**

**General**

**Strengths**

• Department’s continued commitment to excellent pedagogy by offering a diverse, innovative and flexible curriculum that embraces a range of media and approaches to the study of studio practice and visual culture and by enhancing the student experience generally, as well as continuing to maintain a high level of research pursued by each member of faculty.
• Committed faculty and sessional instructors who are active practicing artists and scholars of significant repute and who bring their professional experience and critical acumen into the classroom environment.
• Strong faculty-student interaction
• Program-related support appears efficiently maximized in light of the relatively tight human and physical resources currently available to the program
Challenges

- Faculty have heavy teaching loads (5 courses/year) as well as significant service demands related to administering and delivering the intricacies of both undergraduate and studio graduate programs, as well as the extra contact hours associated with the teaching of studio courses, 2.5 hours per course twice a week (with only limited technical support).
- Staff complement (administrative assistants and technicians) remains small vis-à-vis the size of the student body and the complexity of the programs offered in Fine Arts, especially considering the MFA in the departmental offerings.
- Until more recently, the location of the Department in East Campus Hall on Phillip Street, on the periphery of the main campus, resulted in isolation from the rest of the Faculty of Arts and the university as a whole. However, this situation is changing rapidly with the construction of the new Engineering buildings, as well as new student housing east of campus.

Specific to the BA

Strengths

- Experiential learning opportunities: (i) undergraduate students in the final year of the honours studio program develop an independent body of work and participate in the honours graduation exhibition held in the University of Waterloo Art Gallery (UWAG), (ii) availability of visiting artists, curatorial opportunities, field trips, work in local galleries and art institutions, workshops, and course trips abroad.

Challenges

- The recent 40% increase in undergraduate student enrolment in Fine Art programs is stretching available resources. Space resources are sufficiently limited that the external reviewers recommended the “department consider restricting undergraduate enrolment until more campus space comes available.” Total undergraduate enrollments in 2007/08 were 1434; in 2013/14 they were 2015. Note that this data includes headcounts only, academic courses only, excludes Co-op, PD and work report courses and represents only the primary class components for each fiscal year. In 2007/08 14 sessional appointments were made. In 2013/14 18 sessional appointments were made.
- Sessional instructors carry a significant portion of the course delivery in the Department, representing up to 40% of the teaching in the program over the past seven years.

Specific to the MFA

Strengths

- Experiential learning opportunities: (i) Each MFA student has the opportunity to exhibit their solo thesis exhibition in UWAG or another appropriate professional space, (ii) Shantz internship for MFA students offers exceptional opportunity for study abroad.
- Research and scholarly record of core faculty members is strong, and there is a notable diversity in the secondary and tertiary fields among the core faculty research areas.
• MFA students have a Pedagogy elective available to them, where under faculty supervision, students have the opportunity to design and deliver their own course material in their second year in the program. This also allows MFA students to build a teaching dossier prior to looking for a placement in another university or college.

Challenges
• The MFA program at the University of Waterloo is amongst the smallest in the country, with only four students admitted each year for a total of eight students across the five-term program, due to various reasons: space, financial resources, technical and administrative support, already pressing demands on the faculty.

Summary of the External Reviewers’ Findings
The Reviewers were unanimous and unequivocal in their support of the Fine Arts Department and its undergraduate and graduate (MFA) programs. The three-person review committee was “genuinely impressed with the energy and dedication of the faculty, staff and students” and acknowledged the breadth and depth of pedagogy and research within the Department. In particular, the committee was impressed with the creative and intellectual development that is central to the programs, delivered through a core academic structure buttressed by a diverse range of professional practice and experiential learning requirements and opportunities. The Committee emphasized the high national and international profile, strength and relevance of the faculty and sessional instructors, as well as their dedicated commitment to pedagogy. Furthermore, the reviewers “found the culture of the Department open, collegial, and respectful, with a remarkably consistent spirit of community and sense of common cause among the faculty, staff and students [that] enriches student experience and clearly sustains the program’s healthy retention numbers, as well as its attractiveness to recruiting students and faculty”.

The External Reviewers did note, however, that the Department of Fine Arts faces substantial challenges. While the Department is no longer “technology starved” as it was described in the 2007 Program Review, lack of sufficient administrative and technical support, pressure on existing space, and faculty workload are hampering the Department’s ability to sustain the same level of vitality as it moves into the future.

The external reviewers reported on their findings using the evaluation criteria set out in Waterloo’s IQAP. They found the University of Waterloo undergraduate and graduate Fine Arts program consistent with the Faculty of Arts mission and academic plans. The external reviewers found the Fine Arts undergraduate degree level expectations to be appropriately developed throughout the curriculum from introduction, reinforcement and mastery.

Admissions requirements for the undergraduate and graduate programs seem to be appropriate. Admission to the MFA program is an Honours degree in Visual Arts or its equivalent from a recognized university or art college, and a minimum of an 80% average and these requirements are consistent with comparable MFA programs in Canada.
In light of the 2011 changes to the curriculum in the undergraduate Fine Arts program, the external reviewers noted the “value of comprehensive mechanisms introduced for guiding students through their degree milestones and program requirements...”. The external reviewers did make a number of recommendations concerning curriculum improvements to reduce redundancies and gaps, however, and these are noted specifically below as part of the program response documentation. Following from the 2007 review, the department has made significant advancements in adding and integrating new technologies in the studio curriculum, and according to the external reviewers, this is progressing very well. With only minor exception the external reviewers found the variable modes of program delivery to be effective and consistent with the programs’ learning outcomes.

For the undergraduate program, assessment methods are consistent with the learning objectives for its students as set out in the self-study document and with similar programs across North America. Undergraduate studio work in the program is generally assessed on a project assignment basis and typically includes evaluation of communication skills in seminars, critiques, reports and other written assignments. Art History/Film Studies/Visual Culture courses generally assess achievement through essays, reports, exams and quizzes.

The Graduate program has set out clear learning outcomes measured against a well-stepped five-term framework of professional study as students progress in their program. Assessment of students’ written, oral and visual performance takes place at measured intervals in each semester over this period and culminates in the oral defense of a professional body of work presented in a thesis exhibition. Students’ professional achievement is also assessed in the context of a pedagogy seminar and subsequent in-class teaching situations. These methods are appropriate and consistent with Fine Art MFA programs in North America.

The external reviewers expressed significant concerns around the workload issues for faculty and staff and questioned the sustainability of the current situation. Based on information in the self-study, the “current technical and administrative support positions for the Fine Arts program in the University place it at the lowest tier among comparable Fine Art Department programs in Canada” – a concern that could eventually “impact the quality, level of ambition and safe conduct of students’ work in the program.” The program is well-supported by the university library, however, and the departmental Visual Resource Centre and the University of Waterloo Art Gallery. With respect to the latter, the reviewers noted “the fragility of its operations given an operating budget and staff resources that appear minimal in relation to most similarly mandated galleries across the country.”

Student feedback from the survey and meeting during the site visit generally reflected well on the program, and students provided critical insights into program improvements which informed the reviewers’ report. Course evaluation scores, averaged for classes of all sizes, support students’ overall satisfaction with Fine Art courses over the past three years.
Student quality is high for both undergraduate and graduate students based on retention rates and degree completion times. In fact, for the MFA program, the reviewers commented that “all students who entered the MFA program have successfully graduated with their degree since 1998 with the exception of one withdrawal.” Given the preceding, the reviewers were “surprised by the relatively small number of applicants seeking admission to the program over the past two years.”

The alumni survey responses from students who completed undergraduate degrees indicated a wide breadth of careers, both related and in some cases, unrelated, to professional occupations associated with graduation from a Fine Arts program. Graduates of the MFA program since 2007 have had a high degree of success, reflecting very well on the professional preparation their program provides. The reviewers noted that most all of its graduates are continuing to work as artists over this period, with many acquiring full-time or sessional employment teaching at the post-secondary level.

Program Response to External Reviewer Recommendations
Responses to 22 specific recommendations from the external reviewers follow. These responses include timelines for implementation of changes, responsibility for follow-through and indication of what resources are needed and how they will be provided. Responses are provided under 3 major categories: resources, curriculum, and teaching and assessment.

Resources:
- **Recommendation 1:** “the Appraisal Committee felt there was much to celebrate and champion in the Fine Arts program and strongly recommend the Department continue to find ways to promote its distinct strengths and uniqueness on campus, as well as within the region and larger cultural community”.

  **Response:** The Department instituted a faculty administrative position in public relations about three years ago and has strengthened its communication efforts through its websites, Facebook, Akimbo, etc. UWAG employed a part-time Audience Coordinator for two years which significantly increased UWAG’s profile (and, by extension, the Department’s) regionally and nationally. Unfortunately, this position was not ongoing. Plans for moving forward:

  1. The Department plans to create a ‘splash-page’ that runs parallel and is linked to the official UW site. The intent is to appeal to the art-focused audience that is the Department’s primary audience. **Responsibility:** Digital Media faculty members. **Timeline:** December 2016.
  2. The Department will continue to enhance its profile by posting visiting artists’ talks, student exhibitions, MFA thesis exhibitions, etc. on its website and Facebook page. **Responsibility:** Visual Resources Curator and Digital Media faculty member. **Timeline:** in place and ongoing.
  3. Re-establishment of the Audience Coordinator on a permanent, part-time basis, for both
4. Assured ongoing funding for the Department to advertise its programs, 4th-year and MFA exhibitions in *Canadian Art’s School Guide*, *Border Crossings* and Akimbo (a national listserv for the national art community) to hit target audiences. **Responsibility:** Dean of Arts.

- **Recommendation 2:** “the University, Department and University of Waterloo Art Gallery work together to determine the most effective means possible to place appropriate public signage identifying the location of the Gallery to the campus and larger community.”

**Response:** Lack of signage for UWAG and Fine Arts has been an ongoing issue, pre-dating the last Program Review, with no evident progress made since then. This circumstance is an obvious detriment to public outreach, with UWAG so conveniently located off busy Philip St. **Responsibility:** Dean of Arts; Plant Operations and Vice-President Administration and Finance.

- **Recommendation 3:** “the reviewers strongly recommend that the University work with the Department to find the means to increase technical support for the Fine Arts program. We would consider the addition of at least one 0.5 technical position critical to current program delivery. We also recommend the Department explore the feasibility of hiring appropriately skilled and trained graduate students or senior undergraduate students to aid with wood and metal shop supervisions”. For the print studio, the Reviewers wrote: “The reviewers were surprised to find the technically intensive printmaking shop relying on volunteer technical support. This arrangement suggests the Department has had to turn to provisional measures to support delivery of their program and raises in our eyes significant questions regarding the sustainability and appropriateness of such arrangements”.

**Response:** Hiring of graduate and/or senior undergraduate students in these roles is not feasible according to the University’s safety policies. The Department has identified areas in critical need of technical support: ceramics, metal, and print. Two 0.5 positions would address the deficiency.

- 0.5 technician in Ceramics and Metal: Currently the Ceramics Professor provides all technical support. For metal, the Department currently hires a technician on an hourly basis to ensure appropriate support for technical instruction and safety for courses that involve metal, as well as for senior undergrads and MFA students working with metal.
- 0.5 technician in Print: Currently the Department relies on a volunteer to provide technical support in the Print Studio, as well as on the Print Professor. This arrangement is logistically and pedagogically untenable with the significant increase since 2011 in enrollments in print courses and students working in print at the senior undergrad and MFA level (in conjunction with our new hire in Print and the consequent revitalization of
Recommendation 4: “the university considers the means of increasing Fine Arts studio space to meet the demands of recent enrolment and teaching area expansions. During the Appraisal Committee visit there was mention of possible future annexation of spaces in ECH currently occupied by other programs. In the reviewers’ view, this would be an ideal solution. In the interim, we feel the department consider limiting undergraduate enrolment growth until more campus space comes available.”

Response: Since the last review, the undergraduate program in Fine Arts has grown by 40-45% (see Table 23A in the self-study).

- 2014-15 marked the largest senior Honours cohort (43) in the Department’s history, and as a consequence, Fine Arts improvised; rather than working in open shared studio spaces, ten 4th-year honours students were tucked into borrowed space around ECH. The appropriate means of pedagogy has become untenable. The Department and Dean’s Office continue to make concerted attempts to secure more space.
- Faculty-wide Plan Standardization and the lowering of the honours average to 70% is likely to have a significant impact, increasing pressure on the current space.
- The current (shared) MAC lab is now beyond capacity and the conversion of a drawing studio for the creation of the lab has meant the remaining drawing studio is also at capacity. A ‘clean drawing room’, furnished with computers, multi-media equipment (see Reviewers’ suggestion, pp. 9-10) and drawing tables would address this need. The new undergraduate initiative between Fine Arts and Computer Science and the continued growth of the Stratford programs will further increase pressure on this type of studio space.
- The MFA program has also been inhibited by lack of space; we are now in a situation of needing to grow the MFA program by two students a year, to use properly the endowment provided by Keith and Win Shantz. However, there is no space to accommodate any more graduate students and the Reviewers have noted that the existing MFA space is mediocre at best compared to other institutions.

The Reviewers’ recommendation to limit undergraduate growth until space can be found runs counter to the mission of the Department, Faculty and University. Responsibility: Dean of Arts; Associate Provost, Resources. Timeline: Ongoing.

Recommendation 5: “the Department considers revising the Experiential Learning course requirements to allow intern students the possibility of repeat assignments with employers and sufficient time to follow through on initiated projects.”

Response: Currently, students can repeat internships at the same institution. Fine Arts is considering enhancing the length of the internships so students can work on more involved, meaningful projects. Longer term, the Department is committed to expanding
the internship opportunities for undergraduate students and has identified national and international internship opportunities as a focus for fundraising and advancement. Additional administrative support is required before any expansion can take place; currently a faculty member handles all of the administration. **Responsibility:** Chair; Dean of Arts. **Timeline:** December 2016 for minor adjustments to local internships; December 2018 for longer term opportunities.

- **Recommendation 6:** “The Faculty of Arts and Fine Arts Department work together to find a way to offset the current workload of the Department Administrative Assistant, particularly during peak program enrolment periods.”

**Response:** The job description for the Fine Arts administrative assistant is 9 pages long; the position embraces undergraduate and graduate matters, building issues, enrollments, course trips, chair, exhibition, visitor and exhibition assistance, and much more. A comparative study revealed that Fine Arts at UW is underserved in terms of administrative support positions vis-à-vis comparable Fine Arts departments in Canada (see table 1.1, p. 13 in self-study). The level of administrative assistance has not kept pace with the increased student population in Fine Arts. Expansion of any aspect of either the undergraduate or graduate program is also predicated on the need for additional administrative support. (This is particularly urgent in the case of the MFA given the terms of the Shantz internship funding.) **Responsibility:** The Dean of Arts. While the addition of a 0.5 or 1.0 permanent position would be ideal, other options are being considered in light of budgetary constraints. **Timeline:** In place.

- **Recommendation 7:** “The Department considers extending the weekly visits of a main campus librarian to the Visual Resource Centre to advise students in their broader research needs to promote the acquisition of information skills through in-class bibliographic instruction at both the undergraduate and graduate level.”

**Response:** This initiative seems entirely plausible. **Responsibility:** Chair of Fine Arts, Dana Porter liaison librarian and the Fine Arts Visual Resources Curator. **Timeline:** In place.

- **Recommendation 8:** “The Visual Resource Centre work with the University to enable Fine Art students to gain access to its holdings from remote locations.”

**Response:** This is potentially feasible. **Responsibility:** Chair of Fine Arts, Dana Porter liaison librarian and the Fine Arts Visual Resources Curator. **Timeline:** December 2016.

- **Recommendation 9:** Concerning UWAG, “The University review its art collection holdings and consider hiring a third party consultant to undertake a systematic inventory and assessment, including appraisals and condition reports, in order to determine policies appropriate to the handling, storage, display, and insuring (or potential deaccessioning) of its contents.”
Response: At present, UWAG has no administrative assistance except at a very minimal level provided by OSAP work-study students. This, combined with UWAG’s very small budget, precludes a proper assessment of the permanent collection. A third party consultant will result in highlighting the strengths of the collection – notably the strong focus on late 1960s/early 1970s Canadian Modernism. Responsibility: Dean of Arts; Vice-President, Administration and Finance.

- **Recommendation 10:** “The Department considers the feasibility of providing Fine Arts student interns with the opportunity of working with UWAG and the University permanent collection to develop appropriate interpretative signage for each piece from the permanent collection currently installed around campus.” (p. 20)

Response: This is feasible. The UWAG Director/Curator has already worked with one student intern in 2014 to do an initial assessment of the permanent collection. Responsibility: Fine Arts Experiential Learning Liaison (Department member) and UWAG Director/Curator. Timeline: December 2016.

- **Recommendation 11:** “The Department work with the University to resolve issues associated with the implementation of the new UW Enrolment system in the Fine Arts program. The current system has placed inordinate pressures on the faculty and staff, frequently requiring manual enrolment of its students.”

Response: The Department is supported by the Arts Undergraduate Office in its ongoing dialogue with the Registrar’s Office to overcome the hurdles that impede students’ ability to enroll easily in their Fine Arts courses. While progress has been slow, some procedures have begun to be implemented. Similarly, the current scheduling system does not effectively serve the specific nature of Fine Arts studio pedagogy. While the Chair of Fine Arts has succeeded in maintaining ability to schedule courses, there is no guarantee this autonomy will continue into the future. Responsibility: Chair of Fine Arts, Associate Dean of Arts, Undergraduate, and Registrar’s Office (Systems and Scheduling). Timeline: December 2016.

- **Recommendation 12:** “The Department limit further enrolment growth until such time that faculty workloads can be relieved through a reduction of required teaching loads or the creation of a further faculty position.”

Response: Faculty in Fine Arts teach 5 courses a year plus graduate supervision in a program that demands, by its very nature, high faculty-student interaction. This load is very high compared to other programs at UW and is at the highest end for Fine Arts programs in the country. Student demand on the existing courses is high and the Department is already reliant on sessional instructors to ensure enough courses are available. 2011 Fine Arts instituted an extensive overhaul of the curriculum,
allowing faculty to go from teaching 6 courses a year to 5. Limiting enrolment growth is inconsistent with the mission of the Department, Faculty of Arts, and University thus we continue to identify ways to offset the pressure on the current faculty. Responsibility: Chair; Associate Chair Undergraduate Studies; Dean of Arts and Associate Vice-President, Academic. Timeline: December 2016.

- **Recommendation 13:** “The Committee recommends that the University examine its promotion criteria in view of encouraging progress through the ranks and better reviews in supporting of faculty promotions, particularly promotion to the rank of full professor.”

  **Response:** At least one faculty member is planning to apply for full professorship in 2016. For some, the potential impact of high teaching loads and faculty service on research output have discouraged them from considering moving forward. Responsibility: Dean of Arts and Vice-President, Academic.

**Curriculum**

- **Recommendation 14:** “The committee strongly supports the Visual Culture program plan as it moves towards consolidation as an interdisciplinary degree with a home base in the Fine Arts Program. We recommend it going forward with developed and formally instituted protocols to guarantee the commitment of faculty, space, and resources necessary to sustain its viability over the long term. We further recommend the institution of a governing body constituted by core faculty to coordinate and guide its optimal and ongoing delivery as an integrated program.”

  **Response:** Plans for implementing the revised Visual Culture program are well underway and will become effective, with the Plan Standardization initiative, in Fall 2016. Responsibility: Visual Culture Working Group: (Prof. Joan Coutu and Prof. Boyana Videkanic). Timeline: implementation, Fall 2016.

- **Recommendation 15:** “The appraisers recommend the Department examine the feasibility of implementing a Studio and Visual Culture Major Degree stream to respond to increased student demand for academic plan representative of a balance of courses drawn from the Studio and Visual Culture programs.”

  **Response:** Currently a student cannot officially get a joint degree in Studio and Visual Culture because both programs are housed in the same department, although numerous students have completed the appropriate courses to get such a degree (the students’ diplomas and transcripts will say a major in either Studio or Visual Culture, but not both). Responsibility: The Chair and Associate Chair, Undergraduate, Fine Arts will initiate conversations with the Associate Dean, Undergraduate and the Registrar’s Office to determine a solution. **Timeline:** December 2016.
• **Recommendation 16:** “In revisiting their current studio course offerings, we recommend a Department Curriculum Committee review of the content of current course offerings with eye to further minimizing students’ experience of blind spots and redundancies of course content encountered by students’ in their progression through the program.”

**Response:** Redundancies are sometimes the perception of students, although the Department has kept an eye on potential overlap in FINE 100 and some of the 200-level courses. The Department Curriculum Committee is currently refining the curriculum implemented in 2011 to address ‘blind spots’, especially adding more technical courses in 3rd year and integrating the Arts and Business co-op students more effectively. **Responsibility:** Chair; Associate Chair, Undergraduate Studies. **Timeline:** implementation, Fall 2016.

• **Recommendation 17:** “the Department continues its enhancement of professional practice workshops for the MFA students in order to assure their access to a broader set of professional skill sets.”

**Response:** The Department has increased the number of workshop opportunities for both undergraduate and graduate students. Grant writing and academic writing workshops have also been provided solely for the graduate students. The Department would like to formalize and expand these opportunities yet such opportunities are particularly vulnerable to funding issues. **Responsibility:** Chair, and Associate Chair, Graduate Studies; Faculty of Arts, including Advancement. **Timeline:** December 2016.

• **Recommendation 18:** “The Department restores offering the course Topics in Museums, Galleries and Curatorship (FINE 330) and considers making the course a requirement of the Professional Practice Specialization stream. We also recommend the Department consider renaming this Specialization stream to reflect its focus on gallery practices and to provide more explicit identification to potential employers after students graduate.”

**Response:** FINE 330 still exists and the plan is to run it on a fairly regular basis but this is conditioned upon sessional financing. The Professional Practice Specialization requires enhancement. **Responsibility:** Department Undergraduate Curriculum Committee. **Timeline:** implementation, Fall 2016 with other refinements to undergraduate curriculum.

• **Recommendation 19:** “the Department considers adding a media course to the core requirements of drawing and sculpture in the studio major program to balance students’ interdisciplinary skill sets of its students.”  (p. 21)
Response: This has become part of the discussion of the current Curriculum Committee. Responsibility: Department Undergraduate Curriculum Committee. Timeline: implementation, Fall 2016.

Teaching and Assessment:

- **Recommendation 20:** “The Department continues to develop the MFA Pedagogy course, particularly in the areas of pedagogical theory and through workshops in student engagement strategies and critiquing approaches and the development of teaching philosophies.”

  Response: This process is well underway. Responsibility: Associate Chair, Graduate, Fine Arts. Timeline: December 2016.

- **Recommendation 21:** “The Department considers adding MFA professionalizing workshops (paralleling those offered in the undergraduate program).”

  Response: See Recommendation above, under Curriculum. The Department would like to formalize and expand the existing experiential learning opportunities. Responsibility: Associate Chair, Graduate Fine Arts; Faculty of Arts, including Advancement. Timeline: December 2016.

- **Recommendation 22:** “As an alternative to the 20 still image documentation current required in support of MFA applications, we recommend the Department consider making explicit allowances for applicants to submit documentation of time-based media (i.e. media, video, sound, performance, installation etc.). This would fall in line with the broadened interdisciplinary orientation of the program and more effectively align with the goals of its evolving program”.

  Response: This was an oversight in the Department’s website and has already been corrected.

Additional Recommendation:

Although not included in the concluding list of recommendations, the External Reviewers also suggested the Department consider parallel direct-entry admission into the undergraduate program. Such an initiative would attract “the most competitive and strongly identified applicants possible to the undergraduate program [and] would bring an enhanced profile and cultural benefits to the Department as a whole”.

Response: The Department has considered this possibility, for the reasons above and to augment further admissions to the Faculty of Arts generally. However, the pressure on existing resources makes such an initiative untenable, which the External Reviewers acknowledge.
Final Assessment Report of:
Geography and Environmental Management (Bachelor of Environmental Studies)
Geomatics (Bachelor of Environmental Studies)
Tourism (Master of Environmental Studies) and
Climate Change (Master of Climate Change)

December 2015

Introduction
In accordance with Waterloo’s Institutional Quality Assurance Process (IQAP), this final assessment report provides a summary and synthesis of (i) the external review of two Bachelor of Environmental Studies programs (Geography and Environmental Management and Geomatics), the Master of Environmental Studies program in Tourism and the Master of Climate Change program in Climate Change; (ii) the program (department) response to the external review; and (iii) an implementation plan for improvements that lists specific actions, timelines, required resources and responsibility.

The Department of Geography and Environmental Management offers the following undergraduate programs leading to a Bachelor of Environmental Studies:

- Geography and Environmental Management - Three-Year General
- Geography and Environmental Management - Four-Year Honours (Regular and Co-op)
- Honours Geomatics (Regular and Co-op)
- Honours Geography and Aviation (Regular)

The Geography and Aviation program has been recently reviewed separately, together with the Science and Aviation program.

The graduate Geography programs administered jointly with Wilfrid Laurier University (MA, MSc, MES, PhD) through the Waterloo-Laurier Graduate Program in Geography (W-LGPG) are being reviewed separately. Graduate programs included in the current review are:

- Master in Climate Change (MCC), a coursework based degree that began with its first
class in the fall term of 2013

- Master in Tourism (MES) degree, offered in cooperation with the Department of Recreation and Leisure Studies in the Faculty of Applied Health Sciences. The department moving is to phase out this program due to persistently weak enrollments. No new Tourism students are being admitted in Fall 2015, although the Department of Recreation and Leisure Studies intends to admit a few students this fall and review the future of the program from their end. The reviewers evidently also determined this program was in trouble in their comment “we do not understand why the Master is Tourism is still an option. It does not seem to be a viable program”.

This report is one of three academic program reviews that have been prepared this year by GEM. In addition to the current report, GEM programs being reviewed include:
- the graduate programs offered by the Waterloo – Laurier Graduate Program in Geography; and
- the aviation degrees (Geography and Aviation, and Science and Aviation)

The last review of undergraduate and graduate programs administered by the department (including W-LGPIG) was undertaken in 2007. Eighteen recommendations were made, resulting in numerous improvements to curriculum (undergraduate and graduate), departmental web pages, student orientation, student recruiting, research and experiential learning opportunities for senior undergraduate students, oversight of space issues and computing resources.

Department of Geography and Environmental Management

From its 2013 strategic plan, the Department of Geography and Environmental Management is “committed to the discovery, innovation, dissemination, and application of geographic knowledge focused on the complex interactions within and between the human and natural environments. The Department embraces the goals of excellence in geographic research and excellence in geographic research-led teaching in undergraduate and graduate degree programs. It also seeks to stimulate and engage the sharing of geographic knowledge across the Faculty, University, and the wider global community.”

As of January 2014, the Department had 10 full professors, 12 associate professors, four assistant professors, and one continuing lecturer. There are currently 22 cross-appointed faculty to the Department. The cross-appointment is used primarily to allow these faculty to sit on graduate student committees.

The Department’s research and teaching activities fall into three broad areas: Earth System Science, Environment and Development, and Geomatics. Several cross-cutting research and teaching themes, such as climate change, are woven through all three of the theme areas. The
Department’s reputation in Geomatics, GIS, Remote Sensing, Environmental Management, Economic Development, Tourism and International Studies distinguishes it from most other Geography programs. Unique to Geography at Waterloo are two new academic plans (Geomatics; Geography and Aviation) as well as two joint academic programs with Nanjing University. Compared with other universities, the program at Waterloo provides breadth equal to other large undergraduate programs in Geography in Canada. Approximately 700 undergraduate students are enrolled in the various programs offered by the department, the second highest in the province, with over half of the undergraduate students in Geography in the co-op program. For graduate programs – including those that are part of W-LGPIG – Waterloo also has the second largest Geography graduate program in the province (39 at WLU, 70 at Waterloo).

The department’s QS rankings indicate that it has moved up through the past four years. Ranked in the 151-200 range in 2011, the department moved into the 101-150 range 2012, the 51-100 range for the years 2013 and 2014 and the top 50 in 2015.

Self-Study Process and Site Visit
The self-study was prepared by faculty and staff members of the Department of Geography and Environmental Management, with the chair of the department assuming primary responsibility for guiding the process. Statistical data related to faculty and student numbers, and finances were provided by IAP. In addition, departmental data on students were used to generate some of the tables, particularly in the sections on graduate students. An alumni survey was completed in 2013, by 111 individuals who graduated during the 2007-2014 period. Other information was obtained from publications of the Ontario Universities' Application Centre, the Canadian Association of Geographers, the Association of American Geographers and from web sites at UW and other universities.

The Department of Geography and Environmental Management submitted their self-study to offices of the Associate Vice President, Academic and Associate Provost, Graduate Studies on June 12, 2014. The site visit was conducted April 13-14, 2015. The external members of the review team were Professor Nigel Roulet, Chair and Professor of Biosciences, Department of Geography, McGill University and Professor Scott Lamoureux, Professor, Queen’s University, Department of Geography. The internal member was Professor Anindya Sen, Associate Chair, Graduate Studies, Department of Economics.

The review team met with program administrators and departmental faculty and staff, graduate and undergraduate students, the Faculty Dean and Associate Dean (Undergraduate Studies), the Associate Provost, Graduate Studies, the Associate Vice-President, Academic and representatives from the library and co-operative education. The reviewers also toured the Faculty of Environment buildings and the main map library.
The external reviewers’ report was received on June 10, 2015 and the department’s response and implementation strategy, with timelines, responsibilities and resource needs assessment was received on August 20, 2015 and approved by the Dean of Environment on August 19, 2015.

This final assessment report is based on information extracted, verbatim in many cases, from the self-study, the reviewers’ report and the program response.

**Programs**
The external reviewers noted that the learning outcomes for the programs under review were clearly laid out, and also commented on the “stronger emphasis at the University of Waterloo’s Geography on educating graduates for employment.... and the programs associated with the co-ops seems to be very well developed and successful.”

**Undergraduate:**
The objectives of the Geography and Environmental Management and Geomatics programs are well expressed through UW’s eight Undergraduate Degree Level Expectations (UDLEs). The overarching programmatic objective is best captured in the first of the UDLES, namely to “have knowledge and critical understanding of the key concepts, current advances, theoretical approaches and assumptions in the field of Geography and Environmental Management and its various specializations (Earth System’s Science; Development and Environment and Geomatics).” From the alumni survey, the majority of students agree that the Department’s undergraduate program learning outcomes are being realized. However, results suggest that the Department needs to consider implementing strategies to enhance student awareness of cultural diversity; to provide specific transferable skills and to provide additional field work opportunities.

**Graduate:**
The self-study articulates the six Graduate Degree Level Expectations (GDLEs) for both graduate programs.

The overarching programmatic objective of the Master of Climate Change (MCC) Program is to provide an academic environment that promotes open critical interdisciplinary inquiry of the scientific and socio-political complexities of climate change, and prepares highly qualified graduates for ethical, innovative and professional practice in diverse climate change careers in government, civil society, business and local/international development.

The overarching objective of the Master of Environmental Studies in Tourism is to provide a constructive, critical, and interdisciplinary education that prepares graduates in careers in government, business, tourism and recreation planning, and consulting.
Programs Under Review – Strengths and Challenges

Undergraduate programs - general

Strengths:

• Students have a broad diversity of courses to support their programs and interests. GEM offered 66 undergraduate courses in 2013-14.
• Students report a consistently high level of satisfaction with courses that they take in the Department as well as overall high level of satisfaction with the teaching performance of instructors. Furthermore, a high percentage of the courses are taught by tenured or tenure track professors.
• The Department encourages a vibrant learning community via seminars and conference opportunities, and opportunities to interact with graduate students as well.
• Students continue to show strong interest in the co-op programs
• The Department’s honours programs are becoming increasingly attractive to foreign applicants.
• Both the co-op GEM and co-op Geomatics programs have higher retention rates than the regular versions of these programs, and numbers are increasing over time
• Co-op employers give GEM and Geomatics students a rating of at least very good, with approaching half, in each case, assigning an excellent rating.
• Co-op students are largely satisfied with their co-op experiences. During the reporting period, three-quarters of the Department’s co-op students (75.9%) rated their employees at least 8, on a 10-point scale
• Post-graduation outcomes are favourable for both GEM and Geomatics students – the majority of graduates continued their academic career following graduation, with 89% attending either a graduate or professional school. Most indicate working in an occupation that is closely related to their undergraduate program.
• Specific to Geography and Environmental Management:
  ➢ There is growing interest in the GEM program by international students (5.3% were of international origin in 2007/2008, 10.7% in 2013/2014)
  ➢ Genders are evenly represented

Challenges:

• Both the regular GEM and regular Geomatics programs have retention issues Part of this could be explained by the transfer of students to other programs within Geography and Environmental Management
• specific to Geography and Environmental Management:
  ➢ Interest from high school students has become flat in recent years
• specific to Geomatics
  ➢ Females are not well represented in Geomatics enrollments, although the proportion of females has increased slightly over time (from 10.5% to 14.7%;
Total applications to Geomatics have declined over the seven years (from 80 in 2007/2008 to 70 in 2013/2014), although annual fluctuations are observed. However, despite declining applications to the Geomatics program, first-year enrollment has increased, due to admission of students deflected from Computer Science.

From their meeting with Geomatics students, the reviewers heard that there was little guidance for course selection.

Graduate programs – general

**Strengths:**
- Graduate students are supervised by top-ranked, successful faculty, as measured by awards from various academic, research, or other organizations; significant funding from a variety of sources; peer-reviewed publications and other indicators of productivity; memberships in various editorial boards; executive roles and memberships in professional associations; etc.
- Programs attract international students, who enrich the program.
- The Department encourages a vibrant learning community for graduate students with numerous opportunities for graduate students to participate in conferences (including international), seminars, workshops, various public events and exposure to international scholars as visiting faculty.
- **specific to Master of Environmental Studies - Tourism**
  - Quality of students coming into program has been very good
  - A number of students in the program have gone on to pursue doctoral studies, either at Waterloo or at other institutions.
  - The reviewers commented that “Plans for growth appear particularly timely given the recent announcement of major climate-policy initiatives in central Canada.”
- **specific to Master of Climate Change – Climate Change**
  - The professional internship option provides an opportunity for experiential learning
  - The MCC student cohort exhibits extraordinarily great diversity in any metric which can be used to assess diversity. It includes a large proportion of internationally trained students (6/13) and gender balance (6 males, 7 females).
  - While the MCC Program has yet to graduate a student, initial employment prospects appear promising. Of the 13 students in the program, 10 have secured internships

**Challenges:**
- **specific to Master of Environmental Studies - Tourism**
  - Enrollments are weak – program will be phased out in Faculty of Environment
- **specific to Master of Climate Change – Climate Change**
International students have difficulties identifying and securing internship opportunities in Canada.

External Reviewers’ Report
The reviewers were generally favourably impressed with the programs under review but there were several areas that were specifically mentioned in their report as being problematical.

“Since almost all professors in the program are traditional teacher-scholars, we were unable to assess at least fifty percent of their activities. We were not able to form any opinions of the great undergraduate experience that often comes from being an undergraduate in a strong research department. ... We had little opportunity to form much of an impressions of the strengths in human geography. This puts the reviewers at a bit of a loss on what to suggest may be fruitful avenues to explore.

The final general aspect of our review that was unexpected was the almost complete lack of representation from the Geography Tourism Masters program. ... the general lack of details in the written report in comparison to the other graduate programs we reviewed, and the complete lack of any discussion during our two day visit, indicates to us that this program exists in name only. Without champions and supporting faculty we see little value of continuing with this program.”

The latter issue noted by the reviewers concerning the Tourism Masters program stems largely from plans to discontinue the program due to low enrollment. Even though the Department has not admitted any new students to this program for the fall of 2015, Applied Health Science’s Department of Recreation and Leisure Studies is still admitting Tourism Masters students. The final fate of the Tourism masters program will be determined following discussions with the Department of Recreation and Leisure Studies in the coming year.

Regarding admission criteria, the reviewers indicated those for the undergraduate programs were “fine” but “were very confused by the graduate admissions and the criteria for admitting students. ... the report and our discussions did not lead us to have a lot of confidence that GEM was striving to get the top students”.

The reviewers’ comments on the undergraduate curriculum led them to state that it reflects “to a large extent the current state of the discipline of Geography, or at least several thematic areas of Geography quite well. Clearly, to us the Geomatics program is probably the most complete and rigorous program in Canada.” With reference to physical geography, they observed that students graduating from the GEM programs earned a BES rather than a BSc and wondered as a result whether the lack of mandatory basic science courses in the curriculum (calculus, algebra, chemistry, physics, biology) put these students at a disadvantage in applying for graduate
positions at other institutions where physical geography was more strongly underpinned by basic science at the undergraduate level.

The human geography theme area also prompted comment on several issues. “First, there was no coherent presentation of a program through curriculum mapping. It was not clear what the goals and objectives of the human geography offering were, or what a human geographer graduating from the University of Waterloo looks like.”

Regarding the theme of the geospatial analysis of public health, the reviewers noted that with the exception of one recent addition to the Faculty, “[N]one of the existing human geographers seem to have a particular strong emphasis in health geography”. They further commented that “Waterloo uniquely has an emphasis on many dimensions of public health, which should have a very strong geographical component. Given the strength in Geomatics at Waterloo this might be an area worth exploring.”

Concerning resources, the reviewers paid a significant compliment to the Department’s staff and faculty in that the reviewers “were very surprised to not hear a long list of complaints about how under-resourced the GEM was”, which was not a reflection of having all the desired resources, but learning to do an excellent job with the resources at hand. Minor space concerns were raised, which the reviewers noted was a common complaint in universities in general.

The reviewers indicated that the “additional criteria” for graduate programs as described in the guidelines for reviewer “seem to be fine” and their comments regarding the Tourism program and Climate Change program have been articulated earlier in this report. The reviewers noted that, with respect to a possible Master in Geomatics program, “GEM has the faculty and the expertise to mount a high-end graduate program that we believe few other institutions could match” and they recommended this initiative be approached as a “co-op graduate program because we believe these students would be very attractive in industry and could, given the emergence of this field in the mainstream economy, could be business innovators.”

The reviewers concluded their report with a series of 11 recommendations that provided the basis for the program response.
Program response and implementation plan

Recommendation 1: We recommend that GEM consider a strategic visioning of the Department as a whole, to define future plans and identify priorities for faculty positions, undergraduate and graduate teaching programs, and resources.

Response: We agree with this recommendation. Discussions around the future of the department are ongoing. Currently, we are reviewing our experiential learning activities, our undergraduate recruitment activities, and the overall research and teaching focus of the department, with a particular emphasis on human geography. These activities will continue over the next year with the specific goals of: reviewing and revising the undergraduate and graduate curriculum, clarifying and improving our experiential learning activities, and arriving at a plan for future hiring, with a focus on human geography. These activities will be led by the department chair and associate chairs.

Recommendation 2: Undergraduate student advising and mentorship should be broadened within the department to include a wider range of faculty and on a more frequent basis.

Response: We will take this recommendation under advisement. The department has two associate chairs and two staff who are available to advise students on academic and curriculum matters. We are not aware of any complaints from students regarding a lack of access to academic advising. Further, we are concerned that other faculty in the department do not have sufficient knowledge of policies, procedures, and curriculum requirements to provide accurate and uniform advice. Over the next year, we will review and discuss our current academic advising activities with student representatives to determine if adjustments are required to improve the service we provide. This activity will be led by the department chair and associate chairs.

Recommendation 3: We strongly recommend the Department seek to improve communication with undergraduate students related to course enrollment. Determining Department course offerings prior to student registration would eliminate many challenges faced by students in meeting their program requirements. Additionally, given the complexity on offering courses due to the co-op programs, we recommend the Department consider multi-year course planning to improve student access to courses.

Response: We agree with this recommendation. We currently advise students of our term-by-term course offerings one year ahead of time. However, the specific scheduling of these courses in each term is handled by the Registrar’s Office, with notice of the schedule given about two months prior to the start of that term. This scheduling of classes and times is beyond the control of the department. We will review our communication of course offerings
to students to improve the availability of this information and lengthen advance notice of course offerings. This activity will be led by the chair and associate chairs over the next year.

**Recommendation 4:** The program in Human Geography is in a transition period and we recommend initiating a review and visioning for the program to reflect the current faculty complement. We anticipate elements of the geography of health would be well supported by the expertise in the group, and natural linkages could be developed to the Geomatics and other units in the Faculty and across campus.

**Response:** We agree that the Department is in transition with respect to its strengths in Human Geography. We would note, however, that the Department’s combined strengths in the human and physical dimensions of climate change place are noteworthy, and the ways in which social science and natural science are integrated around this theme reflect an important aspect of Waterloo’s Geography programming, and that is Human and Physical Geography do not exist as two silos. That said, we agree that a review and visioning exercise is needed, with a particular focus on human geography, and this has been underway for the past year. These will continue with a view to outlining a vision for the Department that will guide future hiring. This activity will be led by the department chair and associate chairs.

**Recommendation 5:** The program in Geomatics has rapidly developed and appears poised for further growth. Increased promotion to incoming undergraduate students with interests in computing may further increase enrollments.

**Response:** We agree with this recommendation. We have recently struck a committee for undergraduate recruiting. This committee will develop a strategy that will include raising awareness of geomatics amongst high school students. Additional resources from the Dean’s Office may be required for promotional activities, such as the revival of the “Geomatics Roadshow” or the preparation of promotional materials. This activity will be led by the department chair, working with the undergraduate recruitment committee.

**Recommendation 6:** Development of a Masters program in Geomatics appears to hold strong potential. The existing faculty complement could support an advanced program that would be uniquely positioned to train students for research and development aspects of Geomatics. A co-op offering would be a logical consideration given the university strengths.

**Response:** We agree with this recommendation. Discussions regarding the development of a masters in geomatics have taken place in the past. The department will consult with the Dean of Environment to explore the feasibility of developing a co-op masters in geomatics.

**Recommendation 7:** The new Masters of Climate Change program has already built a strong international attraction and had positive feedback from students. Maintaining the “lead” of
this program in a rapidly developing sector in Ontario and globally will require continuing to innovate in order to attract high quality students. We recommend considering the development of co-op and research program streams to better meet student career goals and to make sure that student expectations are being matched effectively.

Response: We agree with this recommendation. Over the next year, we will explore and discuss the possibility of adding a co-op stream to the MCC program. This initiative will be led by the Director of the MCC program, working with the department chair and associate chairs.

Recommendation 8: The Masters of Tourism appears to be at a crossroads, with declining enrollments and a change in the faculty complement that makes the viability of this program questionable.

Response: We agree with this observation. GEM has already decided to discontinue offering the Masters in Tourism. The Department of Recreation and Leisure Studies has decided to admit students to the Tourism program for the fall of 2015. However, they will review their commitment to the program over the next year. We will coordinate with them as they make that decision.

Recommendation 9: Based on feedback, we feel that the Department needs to invest in expanding cultural and related support for the programs that attract a sizable international cohort (2+2, Masters of Climate Change).

Response: We will take this recommendation under advisement. The Faculty of Environment has a full-time Coordinator of International Education who works with international students, and especially the 2+2 students, to support their adjustment to the Canadian academic environment. We will work with the Dean of Environment to review the activities of the coordinator and address any perceived needs.

Recommendation 10: Graduate student application review and acceptance practice in the Department appears to be heavily weighted towards support staff with limited academic oversight. The volume of applicants and the screening process should be reviewed to increase faculty involvement.

Response: We disagree with this assertion and recommendation. Support staff facilitate the review of graduate applications, but they do not make decisions with respect to the admission of graduate students. The final decision regarding the admission of each applicant is made by the potential faculty advisor of that student and the Associate Chair – Graduate Studies, under the supervision of the Associate Dean – Graduate Studies.
**Recommendation 11:** Support staff in the Department are in the process of developing documentation for best practices and procedures to enhance the continuity of staff support. We recommend continuing to support this positive initiative.

**Response:** We agree with this recommendation. This activity will be ongoing, under the supervision of the department chair.
Two-year progress report  
Department of Management Sciences  
October 2015

In 2013, Dr. Oded Berman (University of Toronto) and Dr. Mark Daskin (University of Michigan) completed their review of the Masters and Ph.D. programs as well as the undergraduate Management Sciences Option at the Department of Management Sciences. They offered a positive account of the department’s strengths in terms of the diversity its faculty and the strong mix of theoretical and applied research programs. They also offered several recommendations that helped the department achieve its strategic plan.

This two-year progress report outlines the department’s achievements and future in response to the recommendations suggested by the reviewers.

Recommendation 1: The department lacks adequate financial support for graduate students, in particular for Ph.D. and MASc students, and more financial support is required.

Funding is one of the perennial issues in terms of faculty research activities and financial support for graduate students. We are pursuing several ways to increase funding. In the annual review process, faculty members are encouraged to seek more than one funding source (e.g., more than an NSERC Discovery grant). We have also established some contacts with industry through the activities of our recently established Industry Liaison position. With this effort, the research funding in the department has increased during the past few years by 25%, from $887,146 in 2011/12 to $1,111,487 in 2013/14. As newly hired faculty members establish their research programs, we expect research funding to increase in the future.

Recommendation 2: The department should not trade the quality of students for increasing the number of graduate students.

During the past few years, the department has tried to increase the number of graduate students, especially Canadian and Permanent Resident (CPR) students. However, we did not lower our graduate admission standards, even if we experienced a difficulty in meeting CPR targets. We are pursuing different tactics to increase the number of graduate students without sacrificing the quality. For example we are introducing new specialization within our graduate programs to respond to market needs. Data Analytics is one of them.

As mandatory funding may have contributed to the difficulty in attracting more students, we are trying to attract more research funding (discussed above). In addition, we started a rolling admission process in which top CPR applications are considered as soon as they apply.

Recommendation 3: The faculty’s current workload of four courses per year seems to be out of line with that of the rest of the Faculty of Engineering, and efforts need to be made to bring the teaching load in line with other departments in the Faculty of Engineering.
One of the reasons for maintaining the four-course course load was the introduction of the BASc in Management Engineering in 2007 and the time it took to hire faculty for it. Once the hiring is done and steady state is reached, the teaching load will be adjusted. We currently provide partial teaching relief for faculty who are newly hired, or who are heavily involved with administration and or special projects.

**Recommendation 4:** The class size of some core courses is too large for graduate students. Teaching students with diverse background in the same classroom for core courses is nearly impossible. The department should either create foundational courses for students with deficient backgrounds before the start of the fall term, or create a more advanced version of core courses for Ph.D. and MASc students.

Some core courses (MSCI 603, 605, 607 and 609) have a class size of 60 – 70 students, which is partly due to increased graduate student intake and to increased enrollment from other departments that offer certificate programs (e.g. Management Science certificate by the Department of Electrical and Computer Engineering). These courses provide a common base for the different areas within the department and are required for all students, regardless of background. Students with adequate background are exempted to pursue more advanced courses.

With proper TA support, the courses are handled well. With the availability of more teaching resources and if the department sees a need, different sections may be created.

**Recommendation 5:** The differentiation of MASc, MMMSc and Ph.D. programs is important in the long run. Additional coursework at the Ph.D. level is highly desirable.

The reviewers recommended a reduction of the number of required courses for the MASc to 5 courses to align with other programs in the Faculty of Engineering. We used to have the same course requirements for both MMMSc and MASc programs: students should complete 8 courses to complete the program. In 2013, we reduced the required number of courses for MASc program from 8 to 5 courses, enabling them to spend more time on research. The MMMSc students still need to take 8 courses to complete the program. Ph.D. students should complete 6 courses which include three core courses (MSci 603, 605 and 607). Students with the proper background get exemptions from these core courses, and they can end up taking only 3 courses to fulfil the Ph.D. course requirements. This number is in line with the requirements of other Ph.D. programs in the Faculty of Engineering.

**Recommendation 6:** Students should be offered a greater diversity of course offerings, so that students who want to focus their four electives in one of the three areas of the department could more readily do so.

We currently offer about 20 graduate courses per year for on-campus masters and Ph.D. students, and about 10 graduate courses for online master’s students. In addition, supervisors often offer reading courses in their specialization areas, these course offerings are not reported in the graduate statistics. By initiating new diploma programs, such as Data Analytics, we hope to increase the number of graduate course offerings.
**Recommendation 7:** The department is well poised to create a Ph.D. internship program which often leads to funded research opportunities and provides students with valuable practical experience.

We don’t offer a formal Ph.D. internship program. However, many students do often get internships through funding programs such as the Mitacs Accelerate program.

**Recommendation 8:** The department needs to develop comparative measures and metrics of student success, such as placement information.

The department, in collaboration with the alumni office, is trying to collect and provide such information. We have a project in place to use this information for promotional purposes. In addition, some faculty have student placement information on their websites.

**Recommendation 9:** With the unique and diverse faculty, the department can explore new specialization areas such as healthcare, sustainable energy and smart grids and data or business analytics.

Our faculty members are actively involved in all of the suggested areas in terms of research and teaching. We started by creating a specialization in Data Analytics, with possibly more to follow. This was in response to increasing demand for data analysts in industry. By taking three courses in data analytics in addition to the four core courses, student can graduate with a Masters of Management Sciences with a Diploma in Data Analytics. We anticipate the diploma program to start in Fall 2016.

**Recommendation 10:** The undergraduate Management Science option should provide courses on stochastic modeling and simulation.

Currently we offer MSci333 (Simulation analysis and design), MSci431 (Stochastic models and methods) and MSci531 (Stochastic processes and decision making). Students pursuing MSci Option can take either MSci431 or MSci531 as an elective course.

**Recommendation 11:** Partnership with other disciplines such as psychology should enable the faculty in the relevant area to better recruit students and faculty colleagues.

Several faculty members are partnering with faculty in other departments in graduate student supervising and collaborative research. We haven’t explored a joint faculty appointment yet.
MEMORANDUM

December 16, 2015

TO: Mike Grivicic, Assistant University Secretary, Senate Graduate and Research Council

FROM: Heidi Mussar, Assistant Director, Graduate Financial Aid & Awards

RE: Agenda items for Senate Graduate & Research Council – January 2016

Items for Approval

a) MSW Award of Excellence – operating
The MSW Award of Excellence, valued at $300, is given to students with the highest achievement who are graduating from the Master of Social Work program at Renison University College. One award is given to a student completing the full-time program and one award is given to a student completing the part-time program. Selection is made by a Committee in the School in the Fall term.

b) Stieber Family Graduate Scholarship in German Studies – trust
An award valued at $5,000 will be provided to a student entering year one of the Intercultural German Studies Program, the regular German MA or the German PhD program in the department of Germanic and Slavic Studies in the Faculty of Arts. Recipients will be selected based on academic excellence (min. 80% overall average in their last degree) and should have a good knowledge of German language and an interest in expanding knowledge of German-speaking countries and engaging in cultural transfer. An award application is not required; selection will be made based on the student’s application for admission to the graduate program. This fund is made possible by a generous donation from the Stieber Family.

The $20,000 Gift is being provided in the form of cash donations of $5,000 per year from 2015 to 2018.

c) Risk Management, Economic Sustainability and Actuarial Science Development in Indonesia (READI) Training Award – research account
The READI Project’s objective is to establish Indonesia as a regional centre of actuarial excellence, to increase the number and quality of Indonesian actuarial science graduates and to strengthen the actuarial profession in Indonesia. Working with key universities, the project will strengthen teaching and research in support of actuarial science. This award will contribute to strengthened actuarial science teaching capacity. Thus, award recipients must have an outstanding academic background and be committed to the development of actuarial science teaching in Indonesia, including an enthusiasm to pursue actuarial accreditations. The award is limited to candidates who are eligible to be granted a Canadian Study Permit. Funding for this award is being provided by the Department of Foreign Affairs, Trade and Development of the Government of Canada (now known as Global Affairs Canada). The value of the award and the terms of payment vary depending on the student. The award and its components other than international travel are only valid for study at the University of Waterloo, in Waterloo, Ontario, Canada. Recipients must have been offered unconditional full-time entry into the Master’s of Actuarial Science program. Recipients of this award must be full-time lecturers, or have been recruited to become full-time lecturers of one
of the participating universities of the Risk Management, Economic Sustainability and Actuarial Science Development in Indonesia (READI) Project. Students must have the approval of the rector of their university to be on leave for the duration of study. Recipients are expected to be bound by the normal Indonesian Directorate General of Higher Education protocol for such awards including the terms of indenture following return to their post.

There is no competition and no applications are solicited for this award; as a result, this will not be posted on the graduate studies website.

d) Paul Bridger Graduate Award in Advanced Applied Science – endowment
An award valued at $2,000, will be provided annually to a full-time graduate student enrolled in a Doctoral program in the Faculty of Science on the basis of academic excellence (minimum 80% cumulative average) and an interest in advanced areas of multidisciplinary research with the potential to shape future technology. Interested students should submit an application which can be obtained from and returned to the Administrative Assistant - Graduate & Research, faculty of Science by May 1st. This fund is made possible by a donation from Paul M. Bridger (BSc, Applied Physics, 1994).
The gift is comprised of a $50,000 endowment plus $4,000 to remain as spendable to cover the initial 2 years of the award while income is being earned on the principal.

e) Dr. Brian Rudrick Memorial Graduate Award in Applied Philosophy – trust
At least one award will be provided annually to full-time graduate students in the Department of Philosophy in the Faculty of Arts. Preference will be given to doctoral students who are completing an Applied Research Placement. The value and number of awards will depend on the number of eligible student applicants and their proposed expenses during their Applied Research Placement. If such suitable candidate does not apply, the department Graduate Committee will invite doctoral and master’s students who are pursuing research in applied philosophy to apply. Students are awarded on the basis of academic excellence and the likelihood of a student incurring additional expenses due to the nature or location of their Applied Research Placement. Interested students should submit an application to the Department of Philosophy at least one month prior to the start of their Placement. This fund is made possible by a generous donation from the estate of Dr. Brian Rudrick.

The gift, valued at ~$32,000, is in the form of cash from the estate of Brian Rudrick.

Items for Information
f) Hertha Brichta Award for German Studies – endowment
Previously approved at SG&RC in February 2006, the award agreement is being amended. The Department of Germanic & Slavic Studies would now like to remove the eligibility requirement limiting the award to Canadian citizens or permanent residents. This removal will allow international students to be considered for this scholarship.

Existing Award Description:
AWARD DESCRIPTION (posted on website)

Herta Brichta Award for German Studies ($1,000). This prize is normally awarded annually to a graduate student who is registered in either the MA or PhD program at the University of Waterloo or an outstanding applicant to one of these programs. Students who have achieved excellent results in her/his academic studies during the previous calendar year and who are Canadian citizens/permanent residents are eligible. Students must be nominated by a faculty member in February. The prize will be adjudicated by the German faculty of the Department of Germanic and Slavic Studies.

New Award Description:
An award valued at $1,000 is normally awarded annually to a graduate student who is registered (or will be) in either the Master’s or Doctoral program in the department of Germanic & Slavic Studies in the Faculty of Arts at the University of Waterloo. Students who have achieved excellent results in her/his academic studies during the previous calendar year are eligible. Students must be nominated by a faculty member in February. This prize will be adjudicated by faculty members in the Department of Germanic & Slavic Studies. This award was made possible by the generous estate gift of Mrs. Herta Brichta.