

# Final Assessment Report

## Computational Mathematics (MA)

### November 2016

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#### **Summary of the Program Review:**

In accordance with the University Institutional Quality Assurance Process (IQAP), this final assessment report provides a synthesis of the external evaluation and the internal response and assessments of the MMath program delivered by the Centre for Computational Mathematics in Industry and Commerce (CCMIC). A self-study (Volume I) was submitted to the Associate Provost, Graduate Studies Office on November 16, 2015. The self-study presented the program descriptions and learning outcomes, an analytical assessment of this one program, and program data including the data collected from a student survey along with the standard data package prepared by the Office of Institutional Analysis & Planning (IAP). Appended were the course outlines for all courses in the program and the CVs (Volume II) for each full-time faculty complement hired for CCMIC.

Two arm's-length external reviewers (Volume III), (Dr. Antoine Deza, Professor and Canada Research Chair, McMaster University and Dr. Steve Ruuth, Professor of Applied and Computational Mathematics, Simon Fraser University) were chosen by the Associate Provost, Graduate Studies, in addition one internal reviewer (Dr. Tara Collington, Associate Professor) was selected by the Associate Provost, Graduate Studies.

They reviewed the self-study documentation and then conducted a site visit to the University April 26-27 2016. The visit included interviews with the Vice-President, Academic & Provost; Associate Provost, Graduate Studies; Dean of Math; Math Associate Dean of Graduate Studies, Director of the Centre for Computational Mathematics in Industry and Commerce (CCMIC), a Graduate Officer, Faculty Members, staff and meetings with a group of current graduate students.

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

#### **Program characteristics:**

The Faculty of Mathematics has significant strength in numerous areas of computational mathematics and scientific computing across its five academic units, including discrete and continuous optimization, numerical methods for partial differential equations, numerical linear

algebra, computational statistics, symbolic computation and cryptography. In January 2005, the Faculty of Math established the Centre for Computational Mathematics in Industry and Commerce (CCMIC) to provide educational opportunities for students in the Faculty as well as to serve as a forum for collaborative research activity within the Faculty and the University in all areas of Computational Mathematics.

Soon after the creation of the undergraduate Honours program in Computational Mathematics, it was felt that there was a need to expand Computational Mathematics on the graduate level. The program received approval in 2007 from the Ontario Council on Graduate Studies (OCGS) and the first cohort of graduates began in Fall 2008.

### **Summary of strengths, challenges and weaknesses based on self-study:**

#### **Strengths**

- Breadth of program
- Diverse choice of courses and diverse topics of research to choose from
- Degree is unique in Canada; other similar programs do not offer the same broad spectrum of computational mathematics subjects that Waterloo's Faculty of Math is able to
- Short in length; only a year-long program is very popular with the students, as many do not wish to spend an additional two years before entering the workforce.
- Affiliation with Faculty members from Mathematics, Engineering and Science

#### **Challenges/Weaknesses**

- Funding for students less than other programs in Faculty of Math; especially true for international students who pay higher tuition fees
- Short length of program prevents students from learning more about subjects they are interested in; can also prevent from doing any substantial research development
- Decreasing number of domestic applicants as well as women
- Popularity of online courses, which are currently not offered as part of the Masters program
- Lack of co-operative (co-op)stream or internships
- Difficult for students to differentiate computational mathematics from mathematics and computer science
- Lack of space; no room for Teaching Assistant (TA) office hours or to mark assignments
- Lack of control over offering and scheduling of graduate courses; all graduate courses offered through other departments/schools

- Support staff position is part-time contract position; turnover is very high and hiring and training takes a long time

### **Opportunities**

- Grow program through increased enrollment
- Adding a coursework option
- Adding specializations to the program
- Creation of a PhD program

### **Summary of key findings from the external reviewers:**

Dr. Deza and Dr. Ruuth found the Computational Mathematics program to be an “outstanding, interdisciplinary program that addresses the needs of industry and academia for advanced computational and mathematical training.” They believe that the University of Waterloo is “an ideal host institution due to its excellence in the computational and mathematical sciences, and its established links with co-operative education and industry.” They also found the CM-affiliated members to be very enthusiastic about the program.

### **Program response to external reviewer recommendations:**

#### **Recommendations**

1. *The reviewers support the ongoing initiatives to create course-based, and co-op Master’s programs.*

#### **Response**

Pending approval, starting Fall 2017 incoming graduate students will have the opportunity to enroll in the program as course-work students. This means they will take 8 courses instead of the regular 6, and they will not be required to do a project. In addition, pending approval, starting Fall 2017 students will be able to enter into the co-op option. Strong students, as determined by their grades, will be allowed to enroll in co-op starting January 1<sup>st</sup>. The grade cut-off is expected to be around 80%, but the precise cut-off will depend upon the amount of demand by the students in the program. They would be expected to start their work term either in the Summer term, or for an 8-month work term for the Summer and Fall term, followed by a term back on campus. At the request of CECA, the program is committed to accepting no more than 10 co-op students into the program. It was felt by CCMIC and CECA that 10 students could be accommodated by the existing demand by employers, and any more than that would require job development on the part of CECA. The plan is that this number will

be increased slowly over time, as CCMIC and CECA better understand the demand from students and employers.

- 2. We recommend that the half-time administrative position be made permanent in order to achieve stability and institutional memory. Staff is a critical point of contact for such a non-departmental based program.*

### **Response**

The current staff contract position is expected to expire in July 2017. There are currently ongoing discussions between the Director for the Centre for Computational Mathematics in Industry and Commerce (Kevin Hare) and the Dean of Math (Stephen Watt) about how to better serve the needs of the Centre. It is expected that a plan on how to solve this issue will be in place before July 2017.

- 3. We recommend enhancement of the visibility of the program at the Faculty level, and increased efforts to highlight the program in promotional material and outreach activities.*

### **Response**

The Centre intends to do more targeted recruiting and will plan outreach activities targeting their own undergraduates for recruitment. The graduate committee is also investigating how to better recruit students from outside of University of Waterloo. One option is to specifically target undergraduate conferences typically attended by students that may be interested in the program. The Centre also anticipates that the introduction of co-op will make the program more attractive to higher quality students. Recruitment will be an ongoing project for the Centre.

- 4. We recommend increasing flexibility within the curriculum by adding one more course to the list of core courses, leading to a choice of 4 courses for 6 possibilities.*

### **Response**

The Graduate Committee met February 8<sup>th</sup>, 2017 to discuss this recommendation. The final opinion of the committee was that there are currently no courses that could be added to the program that would not compromise the breadth of the program. All other courses within the program (in the list B) are too specialized, or too tangential to the core of computational mathematics to be considered breadth. It was decided that we would not increase the list of core courses from 5 to 6.

- 5. We recommend exploring the possibility of adding specializations to the program to improve job placement in a competitive environment. The Director and Graduate Officer should*

*follow up with the Associate Dean and take any necessary steps to approve changes in the program description in the calendar to allow for this.*

### **Response**

The Centre is supportive of the idea of allowing specialization within the program. However, due to recent changes to the program, it is felt that it would be better to wait and see how the new co-op and course work Master's programs proceed before adding new specializations. This suggestion will be revisited for discussion after the first year of the course work/co-op offering of the Master's program. It is expected that a decision and plan of action will be developed by Spring 2018.

6. *We recommend involving Computational Mathematics in Faculty or University-wide computation-intensive initiatives.*

### **Response**

The Centre agrees in principle that it would be good to be involved in faculty or university-wide computational initiatives. Those involved plan to meet over the next two years to determine how the Centre can play a more active role within university initiatives.

**Recommendations that were not selected for implementation:** 1. *We recommend continued work on strengthening the interaction with industry.*

### **Response**

The Centre agrees that there should be better connections with industry. However, there is currently a lack of support from the affiliate members for the Centre to play an active role in making connections to industry. Additionally, the Centre does not have plans to market itself to industry as a potential research collaborator as it is felt that this is best done through the Office of Research, and through the individual faculty member.

7. *We recommend that the position of Graduate Officer be recognized and incentivized. This might involve a partial course release or stipend.*

### **Response**

The current Graduate Officer believes that the workload is not sufficient to justify further compensation. However, this should be monitored in the future, as this may change due to the introduction of co-op and coursework students. This would change should a PhD program be created.

\*Recommendation of creation of a PhD is not listed as one of the formal recommendations listed at the end of the report. The reviewers state that there is “*considerable support expressed by CM [Computational Mathematics]-affiliated members for the development of a PhD program in Computational Mathematics...we believed that this is in the long-term interest of the unit and the Faculty to have discussions on the possibility of a PhD in Computational Mathematics. However, in the near-term the programmatic focus for Computational Mathematics should be on the introduction of its new course-based Master’s and its new co-op programs.*”

**Response**

The Centre responded that although they are very supportive of the idea of creating a PhD program, it is felt that it would be best to wait and see how the new co-op and course work Master’s programs work before adding new programs to the Centre.

**Implementation Plan:**

	Recommendations	Proposed Actions	Responsibility for Leading and Resourcing (if applicable) the Actions	Timeline for addressing Recommendations
1.	Course based & Co-op Masters	Create and run the course based and co-op masters	Director of CCMIC	Creation – Completed Students to start in Fall 2017
2.	Support Staff	Decision to be made concerning ongoing support for the centre	Director of CCMIC and Dean of Mathematics	July 2017
3.	Enhanced visibility of the program	Investigation to be made by graduate committee on how to do this	Graduate Committee of CCMIC	Ongoing
4	Increased flexibility of the core	Discussions of issue, and implementation if appropriate	Graduate Committee of CCMIC	not pursuing
5	Adding specialization to the CM program	Discussions of issue, and implementation if appropriate	Graduate Committee of CCMIC	Spring 2018
6	Involvement of CM in University wide computation-intensive initiatives	Investigation to be made by the Steering Committee on how to do this	Steering Committee of CCMIC	Spring 2018



The Department Chair/Director, in consultation with the Dean of the Faculty shall be responsible for monitoring the Implementation Plan.



**Date of next program review:** \_\_\_\_\_ **2022** \_\_\_\_\_  
Date

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**Signatures of Approval:**

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Chair/Director \_\_\_\_\_ Date

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AFIW Administrative Dean/Head (For AFIW programs only) \_\_\_\_\_ Date

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Faculty Dean \_\_\_\_\_ Date

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Associate Vice-President, Academic \_\_\_\_\_ Date  
(For undergraduate and augmented programs)

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Associate Provost, Graduate Studies \_\_\_\_\_ Date  
(For Graduate and augmented programs)