Institute for Applied and Interdisciplinary Mathematics

Proposal for the Academic Initiatives Fund, October 2005

1. Vision and Priorities

I-AIM: to create a new multidisciplinary centre for applied and interdisciplinary mathematics

There is growing consensus that the grand challenges in science and technology need to be addressed by interdisciplinary teams. As mathematics provides both the language that allows science to be quantifiable and the tools for understanding complex structures, it is vital to such teams. On the other hand, scientific and computational advances have created the need for a new type of interdisciplinary mathematician. This need has been identified all over the world. Governments and professional societies have issued reports on the sea change towards interdisciplinary research and education, universities have opened new centres and programmes, conferences and new journals are being devoted to Interdisciplinary Mathematics.

In the words of one senior American academic, those who are not developing a capacity in modelling, simulation and computational science will not be involved in serious science fifteen years from now.

We aim to create a new institute in order to foster such novel science and education at the University of Toronto. It is issued the long-term competitive edge of the institution.

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Research imperatives

A 2005 report of the U.S. President's Information Technology Advisory Committee stresses the critical importance of computational science to scientific leadership, economic competitiveness and national security:

> *" Computational science is now indispensable to the solution of complex problems in every sector, from traditional science and engineering domains to such key areas as national security, public health and economic innovation. Advances in computing and connectivity make it possible to develop computational models and capture and analyze unprecedented amounts of experimental and observational data to address problems previously deemed intractable or beyond imagination."*

It goes on to recommend that:

> *"Universities must significantly change their organizational structures to promote and reward collaborative research that invigorates and advances multidisciplinary science. They must also implement new multidisciplinary structures and organizations that provide rigorous, multifaceted educational preparation."*

This is I-AIM!

I-AIM will constitute a new paradigm for attacking major interdisciplinary problems.

It will build targeted research teams with specific high-profile goals. I-AIM will quickly move to establish *critical mass* with 3 new joint appointments each in the broad areas of

systems biology and **biophysics** and 2 new positions in **computational science**. With its nucleus of permanent faculty and a grand, visionary challenge to catalyze participation from multiple disciplines I-AIM will draw together the mathematical scientists and their experimental colleagues across the university and provide multiple benefits on all levels of our academic endeavour.

To paraphrase a distinguished chair-holder at the university when consulted about one of the major research goals outlined in this proposal; "That is a great idea! The data (for mapping cell structures) is coming in over the next five years. If you wait until then to build the in-house expertise, it will be too late."

Educational imperatives

The new institute will create a new breed of scientist, one in which scientists from various disciplines obtain training within a mathematical environment; one in which mathematicians obtain and appreciate scientific literacy by working in situ on one of the major research challenges, immersed in the atmosphere of the facility. The scientists trained in this facility will be ones which professional mathematicians will refer to appreciatively as being very good mathematicians; the mathematicians trained in this facility will be people about which scientists will comment that “she really does understand the science.”

2. Three Pillars

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An institute of this magnitude and impact cannot be built from scratch. At the University of Toronto, we already have in place the necessary prerequisites. The newly envisioned institute I-AIM will be firmly grounded on the 3 pillars of the mathematical community that are currently located on campus.

Mathematical Scientists across the University of Toronto

University of Toronto hosts the strongest collection of mathematical scientists in Canada. Yet this fact is largely lost on the rest of the country, as the researchers are dispersed over more the 21 departments, 4 faculties and 4 campuses. To date connections between such researchers have been formed mainly by serendipity, with few resources dedicated to nurturing these essential links. The exorbitant start-up costs for each individual venture have deterred all but the most determined form embarking on this foray.

The report of the site selection panel for the Fields Institute (1993) stated that

> *"There are several very strong centres of applied mathematical work at Toronto, including the engineering faculty, computer science and the Canadian Institute for Theoretical Astrophysics (CITA). Thus, there is excellent potential . . . to build interdisciplinary bridges of the kind contemplated."*

Indeed the whole is far less than the sum of the parts. The purpose of I-AIM is to provide a nexus at which the full potential for this world-class resource is realized.

The Department of Mathematics

The recent External Review of the Department (Y.-T. Siu, Harvard, P. Constantin, University of Chicago, N. Kamran, McGill) perhaps says it best.

> *The Department of Mathematics at the University of Toronto is manifestly the leading mathematics department in Canada. . . . Over the past several years, the Department has succeeded in strengthening its position within the group of five or six top-ranked mathematics departments among publicly funded universities in North America through a series of spectacular hirings. . . . The quality of these appointments is stellar, and shows that the department is consistently hiring the best regardless of their fields of research. It is manifest that the proximity and successful interaction with the Fields Institute has been a significant asset in attracting excellent new faculty to the Department.*

The new interdisciplinary institute will draw on this invaluable pool of talent.

The Fields Institute for Research in the Mathematical Sciences

The Fields Institute, while not part of the University, will provide an important resource for the international aspirations of I-AIM; indeed, the relationship will be one of true symbiosis. I-AIM will provide instant access to internationally acclaimed faculty in mathematical interdisciplinary research areas who have the international connections and scientific expertise to bring the best and the brightest to Fields for special semester long programs and ongoing workshops and seminar series; in doing so, it will enhance Fields' reputation in groundbreaking interdisciplinary areas. In return, Fields' activities will highlight the wealth of talent and depth of scientific research that takes place on the campus and enhance the university's attractiveness when recruiting in these hotly contested fields. In total, Fields is an incredible resource that will lend instant credibility and international recognition to the new research venture.

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From the outset, the authors of this proposal have coordinated closely with Dr. Barbara Lee Keyfitz, Director of the Fields Institute, to ensure that I-AIM's mission and activities are complementary to those of the Fields Institute. The latter, although located on the St. George campus, is a seven-university consortium with no permanent faculty or degree programs, whose main activity is to host revolving one-year (and shorter) programs of a topical nature, selected to balance the needs of the regional, national, and international communities in pure and applied mathematics. By contrast, I-AIM will create a deep and lasting research and educational base that is internal to the University of Toronto.

3. I-AIM and Stepping Up

The Arts and Science academic plan strongly endorses the concept of I-AIM that is referred to in Section 3.8.3.7. I-AIM addresses the priorities of the Faculty of Arts and Science as detailed below.

Enhancing the student experience. The brightest students are naturally drawn to exciting new areas and research challenges. Often, the process of acquiring the necessary background and expertise is overwhelming. I-AIM will provide the vehicle where they can learn both domain knowledge and the analytic techniques in context. Co-supervised research teams at the graduate level will rapidly train students, bringing them to the cutting edge and providing them a competitive advantage upon graduation.

The University has recently established a new Undergraduate Specialist Program in Bioinformatics and Computational Biology which considers I-AIM to be a crucial component of its academic perspectives, as described in the Program's founding documents.

Undergraduates will benefit by research opportunities that will be provided in the labs through NSERC USRAs and 299Ys.

The Industrial Problem Solving Workshop will provide a tremendous opportunity for students to engage in real industrial problem solving under the guidance of experts, acquiring both experience and contacts in industry.

Enhancing interdisciplinary, interdepartmental, interdivisional, and cross-campus collaborations. I-AIM is a manifestly interdisciplinary venture; it involves some 85 teaching faculty spread over three Faculties and a dozen departments. The initial research challenges addressed by I-AIM are biological and mathematical modelling, but the ubiquity of the language and techniques will bring the other mathematical scientists into the mix. In fact, the long term mandate of I-AIM will be to create an incubator facility into which mathematical scientists from across the university will come to attack the hard scientific challenges of the coming decades - the proposed systems biology challenge is to be seen as exemplary, not limiting. Colleagues from MIT and ATT have said it best: If you want them to play together, you have to make a place for them to do so.

Bringing together undergraduate and graduate activities with research opportunities. Graduate students will work on problems with faculty and postdoctoral fellows on interdisciplinary research challenges. The excitement of these ventures will enter the undergraduate classroom through their courses, and undergraduates will be brought into the research ventures through USRAs and 299Ys.

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Connecting the University with the broader community.

Mathematics and applied mathematics community. The tremendous vitality of the University of Toronto's applied and interdisciplinary mathematics community is largely invisible within the Canadian mathematical community, partly because there is no formal institutional home at the University for such work. I-AIM will address this problem, raising the profile of *applied* mathematics at the University and showcasing the variety and depth of work taking place here.

I-AIM will facilitate the recruitment of faculty and students with interests in interdisciplinary mathematical work, and increase their success in obtaining grants and developing and sharing industrial connections.

I-AIM will also strengthen contacts with researchers in relevant fields throughout North America by bringing in seminar speakers, workshop participants, and other visitors. The research vitality of the labs will raise the profile of this community of scholars to one of international envy.

Industry. Industrial partnerships will stimulate research of societal relevance through cross-fertilization and generation of novel perspectives and ideas. They also contribute significantly to the training and placement of students, and can play a pivotal role in securing governmental support for I-AIM.

I-AIM's space and human capital will allow it to function as an incubator for spin-off companies founded by our members; precedents include Karthika, RiskLab, and Sigma, in the data security and financial analysis sectors. It should be emphasized that these success stories occurred ***in spite of the tremendous start-up costs!*** If we wish to promote more such ventures, then we must facilitate the process. I-AIM will do precisely this.

The public. I-AIM will institute an annual public lecture by a distinguished scientist, with enough drawing power to capture the imaginations and bring a broad swath of the public together with the I-AIM community.

Improving equity and diversity. I-AIM addresses the gender gap and hard science phobia, by establishing partnerships between hard sciences and the life sciences, where under-representation of women has tended to be less extreme. The team-oriented approach will also be a significant attraction for a wider cross section of students.

3. Specific Initiatives

Research Imperatives

As discussed in the beginning, there are certain research imperatives that need immediate attention if Canada is to remain abreast of modern scientific advances at the deepest and most fundamental level. What must be emphasized here is that these are *not isolated initiatives*. Rather, they have been chosen precisely because:

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1) It is absolutely essential for the university to develop real strength in these areas if it is to remain competitive over the coming decades.

2) Each area already has significant strength on campus on the application side, but has identified the need for new theoretical muscle on the modelling, analysis and computational side, to address the major challenges it faces. The envisioned cross appointments are focused on providing this critical new strength.

3) The three areas will have real commonality, not only by being conceptually related but precisely in the language and the tools needed to address the issues.

4) The nexus of strengths developed through this research grouping will provide the core and the glue that will attract the mathematical scientists across the university to collaborate and exchange fundamental mathematical ideas and analytical and computational tools across domains.

The Systems Biology Initiative.

Biology is undergoing a phase transition that is driven by the availability of massive sets of observations of the components of life. However, data does not explain itself, nor does it make itself useful on its own. Many of us feel that we are currently facing roadblocks due to the paucity of explanatory, quantitative and predictive models that would allow us to express and integrate ideas and support the formulation of insight. In particular, we identify three related areas in which progress has been lacking due to the absence of such models:

The integration of models at multiple scales - ranging across explicit numerical simulations in molecular dynamics, cellular automata that capture aspects of microscopic structure, coupled differential equations or flux-balance networks that may describe metabolic

pathways where the details of concentration and rates are known, Boolean networks where they are not, and many others - is an underappreciated problem that requires a concerted, trans-disciplinary effort. On the life-science side we require quantitative models to be made accessible and we need to define the interfaces through which they could be connected. On the theoretical side we need to build theories how such integration could be best achieved, guidance on how to reason when the models are incomplete, and expertise in the construction of the algorithms and large computational systems that may support such integration to name only a few.

Biological systems are self-organising and robust. It is an underappreciated problem that we need to formalize constraints that derive from this fact and apply them to our models. On the life-science side, we need contributions from the study of concerted genetic regulation and of the dysregulation of cellular pathology and pathophysiology. On the theoretical side, we need insight based on the understanding of trajectories in large state spaces, on advances in control theory, on game-theory that discusses choice and ambiguity to name only a few.

There are fundamental problems with data mining that go beyond the statistical formalisms. It is an underappreciated problem that only semantic models can ultimately distinguish random or incidental associations from meaningful relationships. On the life science side we need the insight of domain experts to describe the biological systems and diseases they are working with in ways that are amenable to computational analysis, and we need the datasets that contain the observations of interest to us. On the theoretical side we need the tools of knowledge engineering to help us organize concepts, we need the insights of statisticians and researchers in machine learning to extract and infer associations, we need work on complex data objects, such as medical images to access the data, to name only a few.

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Broadly speaking, these three areas address the data, the algorithmic and the computational modelling aspects of a very large challenge.

I-AIM will recruit 3 top researchers with a background in the theoretical aspects of systems biology that can catalyze the discussion between mathematicians and scientists who wish to contribute to the program, as well as strongly pursuing their own research interests.

The Biophysics Initiative.

It is important to realize that systems biology is at its foundation a molecular science and a large component of the vision described above is in fact the domain of biophysics.

Again, as exemplars for many, the following areas are a part of the University's current research portfolio, but constrained in their development by the lack of mathematical contributions. Imaging technologies are being developed on multiple scales and becoming increasingly important in our efforts to link molecular composition with observable behaviour. These are a rich source for inverse problems, i.e. the attempt to deduce the complex underlying structure from a finite, often noisy set of observations. The protein-folding problem - the self-organized assembly of biological molecules into active catalysts and nanoscopic machines - merits novel computational approaches based on the large-scale systematic collection of protein structure data. And we need better support for the challenges posed by nanoscale experimental setups, exploiting phenomena such as

stochastic resonance and analyzing the domain where continuous treatments break down due to the finite numbers of interacting components in molecular clusters.

These are highly interdisciplinary fields, drawing on statistical mechanics, stochastic dynamics, partial differential equations, continuum mechanics and fluid dynamics. Mirroring the systems biology initiative we can broadly group the areas described above into modelling, algorithmic and data analysis domains, which will provide foci for a recruiting effort that aims to attract 3 top researchers with a background in the theoretical aspects of biophysics who can catalyze the integration of their particular fields of expertise with the experimental community, ideally contributing to fundamental issues arising from the broader Systems Biology program.

The Computational Science Initiative.

Scientific computation and numerical simulation provide a new methodology in science and engineering whose importance can scarcely be overestimated. Current groups on campus employ this methodology to design everything from molecules to aeroplanes and telescopes, to reconstruct three dimensional data from two-dimensional observations, and to model the spreading of disease, environmental contaminants, climate change, the evolution of matter in the universe. Other groups are active in the development of reliable general-purpose numerical software to accurately approximate and visualize the solutions of these important mathematical models.

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The University of Toronto has several groups that use and develop scientific computing to conduct world-class research in specific application areas. This expertise is often not accessible to other groups working on computationally intensive problems, which may have a similar mathematical structure. For example, large-scale optimization problems that historically have been the bailiwick of engineers are becoming an important tool in the field of proteomics.

Future progress in many important disciplines in science and engineering depends on continued improvements in computational simulation capability, which is driven by algorithmic advances (as well as advances in hardware). For example, a fundamental understanding of nanomaterials, nanostructures, nanodevices, and nanosystems requires new capabilities in large-scale simulation. Similarly, improved projections of regional climates and prediction of natural disasters will require ultra-high-resolution simulations on next generation high-end computing platforms.

As computational science moves forward, it becomes increasingly dangerous to have algorithms that are not totally reliable. Furthermore, the development of computational algorithms by researchers who are application driven has reached certain limits that may only be overcome by contributions from applied mathematics, i.e. mathematicians and computer scientists whose primary focus and education is in computational science but with an interest in applications in science and engineering. More specifically, we need algorithms that are guaranteed to have certain properties under certain conditions, and it usually requires quite advanced mathematics to develop such algorithms. To move computational science forward, we need researchers who can bring the theory and application of computational science together.

I-AIM will recruit 2 top researchers with a background in applied mathematics and computational science who can contribute breakthrough ideas to bridge the gap between the theory and practice of computational science and position the university for future developments involving large scale computational simulations.

New Research Paradigm.
I-AIM will develop and mastermind a structured program with the ultimate goal to develop a predictive model of a human T-cell as Leitmotif and focus for the exploration of the areas stated above. In the spirit of interdisciplinarity, this program will not only apply theory to domains in which it is now underrepresented, it will also stimulate new theoretical developments by clearly identifying problems that currently have no satisfactory solution strategy. And it is our intent to make this program represent a distinct "University of Toronto Paradigm" of how to go about this structuring task in principle. Joint mini-workshops will identify work packages within and across the individual domains of expertise at the University; ad hoc groups will define structure and interfaces to assemble progress in concept and method from individual disciplines; core faculty members of I-AIM will provide a constant driving force, but the most important effect is to catalyze the contribution of a consortium of researchers towards a common, visionary goal, each according to their proper interests and priorities.

Such research would currently not be representable in either pure/applied mathematics or life science departments, yet the lack of such approaches is currently the most important bottleneck in the advancement of theoretical contributions to the life sciences.

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Supporting activities

I-AIM Principal Investigator Program
Active engagement in a new discipline can have significant transactional costs associated with the start-up. The I-AIM Principal Investigator Program is designed to facilitate collaborative, interdisciplinary research and accelerate productivity. This Program is modelled on the success of the RiskLab. Within the I-AIM research initiatives, faculty members will design professional-level projects for a cohort of interested collaborators that introduce them to concepts in their respective domains, supplemented by seminars on an as-needed basis. For example one theme of such seminars could be the introduction to concepts of molecular biology, taught specifically for accomplished scientists without any specific previous training in this field.

I-AIM/Fields Distinguished Visitors program
The lifeblood of any research institute is a constant infusion of new ideas; this is particularly the case in emerging areas. The Visitors program will attract the top people in the field to Toronto for long term visits, to introduce new approaches first hand, and to stimulate long-term international research partnerships.

I-AIM Postdoctoral program
We propose to implement a system of postdoctoral fellowships, allocated on similar terms as the graduate stipends through the Graduates and Fellows Committee. Three fellows are to be appointed per year, with fellowship duration of roughly two years and the stipend

covering 60% of salary cost. The competitive nature of these fellowships will help ensure quality and their rapid adjudication through an internal committee will allow channelling resources into exploratory avenues flexibly and rapidly, when they have the largest benefit.

Graduate Fellows
Top graduate students are readily attracted to emerging areas of research, but often find the start-up cost is too high. I-AIM will train graduate students *in situ*, obtaining the domain area knowledge from the experts while learning the language, theory and applications of the tools of analysis. Working alongside graduate students for other projects will reinforce the commonality of problems and suggest new methods of solution. New courses will be introduced which will be geared to teaching domain expertise and introducing analytic tools in context.

Based upon previous experience with mathematical finance and cryptography, it is anticipated that the new facility will easily attract an additional 30 graduate students and postdoctoral fellows, and place them in key research positions in local industry, providing a competitive advantage for Canadian industry.

Undergraduate research opportunities
New team-taught courses will be developed for advanced undergraduates and graduates. For instance, we plan a course on **"Current Directions in Computational Biology"**. The course will be directed towards students in the life sciences as well as in mathematics, statistics or computer science. To address the needs of students with very different backgrounds, the lectures will be supplemented by separate tutorials that bring the theoretically oriented students up to date on concepts of molecular and cellular biology and familiarise biologically oriented students with the tools and methods of applied mathematics. If successful, this model will be used for other interdisciplinary courses.

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The committee will act as a clearinghouse for catalysing and placement of undergraduates into summer research internships.

Interdisciplinary Seminar Series
I-AIM will introduce a new interdisciplinary seminar series to profile emerging areas and stimulate collaborative research. This will provide the natural venue to promote new ventures as the research challenges shift from scientific discipline to another, and new ones come online.

Industrial Problem Solving Workshop
In conjunction with Fields, I-Aim will begin a new "Industrial Problem Solving Workshop" like RPI's "Mathematical Problems in Industry"(now in its eighteenth year). These are "mathematics modelling camps" where participants arrive and spend one to two weeks in residence with R&D representatives from industry. The participants are given a real-world problem to model and work together to provide theory-driven solutions. These programs are quite successful, and have led to a number of new projects between academia and industry. A significant critical mass of contributing faculty is required to make such programs a reality; this has not been the case outside I-AIM.

Industrial Seminar Series
I-Aim will begin, in conjunction with Fields, a new monthly seminar series geared for researchers in industry. This will mimic their highly successful series in Mathematical Finance, and be targeted to the mathematical biotech industry. This series will not be successful without the introduction of the new research initiatives proposed by I-AIM, with its core of dedicated faculty.

Public Lecture Series
I-AIM will introduce an annual public lecture series by a distinguished scientist, with enough drawing power to capture the imaginations of the public and promote the value and depth of research that takes place within the university community of mathematical scientists.

5. Goals, Priorities and Benchmarks

The success of the Institute will be measured by the following quantitative and qualitative criteria.

- Quality and quantity of publications in the emerging research areas by graduate students, postdoctoral fellows and faculty; benchmarks will measure depth and impact of research.
- Emergence of new interdisciplinary research collaborations among fellows and affiliates of the Institute.
- The quality of the applicant pool for graduate, postdoctoral and Distinguished Visiting Fellowships.
- Career trajectories of Graduate students and Postdoctoral Fellows.
- Engagement of undergraduate students in research.
- Formation of community partnerships for dialogue and research.
- Success in attracting research funding for Institute affiliates.

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6. Concluding Remarks

To quote one senior academic "Why do it? Because this just **ha**s to be done." If we want to go head to head with MIT and Harvard, then we have to **choose to do it.** We have the unsurpassed access to the data and the medical establishment in Toronto. We have some of the top ranking internationally acclaimed researchers in the mathematical sciences and theoretical mathematics who are ready and willing to play. We have the experience in coordinated attacks on new ventures through MMF and Karthica. Now is the time for U of T to choose to ante up or fold its hand.

Faculty enthusiasm for the institute has been enormous: the proposal is supported by some 85 teaching faculty (see Appendix A) from more than a dozen departments in the Faculties of Arts and Science (54), Medicine (10), and Applied Science & Engineering (21).

In order to stay abreast of the modern revolution, it is critical to invest in the computational sciences. This has already been recognized in the United States, where bidding wars are happening over the best mathematical biologists. The team which has been working towards making I-AIM a reality is energized by the passion to be directly involved in some of the most exciting scientific challenges of the future. The potential is here. The groundwork has been done. Now is the time to act.

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List of Appendices

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Appendix A: Faculty Support

The scope and shape of I-AIM continues to evolve, but the intellectual relevance of applied mathematics across the university is reflected by the widespread interest and broad support that this initiative has garnered. The following 85 faculty members have expressed strong support for the concept and their interest in affiliation with I-AIM. They include 19 members of the Department of Mathematics, 28 additional faculty from Arts and Science, 20 members of the Faculty of Applied Science, 10 members of the Faculty of Medicine, 7 from the School of Graduate Studies, plus the Director and Deputy Director of the Fields Institute.

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Peter Abrams, Zoology
Robert Almgren, Computer Science and Mathematics; Mathematical Finance Program
Richard Bailey, Geology and Physics
Ian Blake, Electrical and Computer Engineering
Richard Bond, Canadian Institute of Theoretical Astrophysics
Allan Borodin, Computer Science
Andreille Brouwer, Electrical and Computer Engineering
Paul Brumer, Chemistry
Egnar Brownweitz, Mathematics
Markus Bussman, Mechanical and Industrial Engineering
Ray Carlberg, Astronomy and Astrophysics
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Wayne Enright, Computer Science
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Andrey Feuerverger, Statistics
Bruce Francis, Electrical and Computer Engineering
Simon Fraser, Chemistry
Jim Friesen, Banting and Best Department of Medical Research
Clinton Groth, Institute for Aerospace Studies
Jorn Hansen, Institute for Aerospace Studies
David Hogg, Medicine and Medical Biophysics
Kentaro Hori, Mathematics and Physics
Victor Ivrii, Mathematics
Ken Jackson, Computer Science
Sebastian Jaimungal, Statistics
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Velimir Jurdjevic, Mathematics
Raymond Kapral, Chemistry
Barbara Keyfitz, Fields Institute
Boris Khesin, Mathematics
Keith Knight, Statistics
Lev Kofman, Canadian Institute for Theoretical Astrophysics
Lisa Kramer, Rotman School of Management
Frank Kschischang, Electrical and Computer Engineering
J. Douglas Lavers, Electrical and Computer Engineering
Peter Lewis, Biochemistry and Medicine
Daniel Lidar, Chemistry
Hoi-Kwong Lo, Electrical and Computer Engineering and Physics
Manfredi Maggiore, Electrical and Computer Engineering
Steve Mann, Electrical and Computer Engineering
Peter Martin, Astronomy and Canadian Institute for Theoretical Astrophysics
Joaquim Martins, Institute for Aerospace Studies
Christopher Matzner, Astronomy
Robert McCann, Mathematics
Jerry Mitrovica, Physics
Michael Molloy, Computer Science
Stephen Morris, Physics
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[illegible]rman Murray, Canadian Institute of Theoretical Astrophysics
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Richard Peltier, Physics
Gerald Penn, Computer Science
Ue-Li Pen, Canadian Institute for Theoretical Astrophysics
Erich Poppitz, Physics
Mary Pugh, Mathematics
Jeremy Quastel, Mathematics and Statistics
Charles Rackoff, Computer Science
Joe Repka, Mathematics
Jeffrey Rosenthal, Statistics
Tom Salisbury, Fields Institute
Ted Sargent, Electrical and Computer Engineering
Costas Sarris, Electrical and Computer Engineering
Jeremy Schofield, Chemistry
Luis Seco, Mathematics
Theodore Shepherd, Physics
Michael Shub, Mathematics
Francis Skinner, Medicine - Neurology, Physiology, Biomaterials and Biomedical Engineering
Boris Steipe, Biochemistry, Molecular & Medical Genetics; Proteomics & Bioinformatics
Catherine Sulem, Mathematics

Frank Tall, Mathematics
Christopher Thompson, Canadian Institute for Theoretical Astrophysics
Elisabeth Tillier, Medical Biophysics
Michael Tropak, Hospital for Sick Kids
Shahrokh Valaee, Electrical and Computer Engineering
Balint Virag, Mathematics and Statistics
Stuart Whittington, Chemistry
Shoshana Wodak, Biochemistry, Structural Biology, and Medical Genetics
Yanqin Wu, Astronomy and Astrophysics
Christopher Yip, Biomaterials, Biomedical & Chemical Engineering, Biochemistry
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Appendix B: Time Frame for Program Development

Preparation:

- Obtain new space for the Institute and renovate as necessary
- Recruit first I-AIM Fellows (3 PDFs, 5 graduate fellows)
- Hire assistant and halftime systems administrator
- Search for 3 new positions: 2 in systems biology, 1 in biophysics.

Year 1:

- Introduce two new interdisciplinary graduate courses
- Increase complement of I-AIM Fellows (6 PDFs, 10 graduate fellows)
- Search 3 new positions: 1 in systems biology, 1 in biophysics, 1 computational scientist
- Establish weekly interdisciplinary seminar including high profile external speakers
- Define topical inititaives roadmap in workshop and working groups to forge research collaborations and partnerships
- Begin undergraduate summer research placements
- Establish joint monthly colloquium series with the Fields Institute
- Develop fundraising strategy for long term support of the Institute and computational resources, including granting councils, NRC, OFI, CIAR, and private donors
- Unified webpage listing for Toronto area seminars of related interest

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Year 2:

- Increase complement of Fellows to new space
- Add 3 new pdfs, 5 additional graduate students
- Introduce two new interdisciplinary graduate courses
- Search 2 new positions: 1 in biophysics, 1 computational scientist

Year 3:

- Undergraduate curriculum recommendation completed in time for next academic year;
- Continue fundraising efforts and other activities as above.
- Review and assess I-AIM development and outcomes

Year 4:

- Undergraduate certifications in computational science and in applied mathematics in place;
- Continue all major program activities.
- Review and assess I-AIM development and outcomes

Year 5:

- Continue all major program activities;
- Review and assess I-AIM development and outcomes

Appendix C: Space requirements and capital costs

In accordance with the activities outlined above, we request the following space allocations and funds for the associated development costs, (a) for a central location that is conveniently accessible by faculty from the diverse departments affiliated with I-AIM, (b) that supports our mandate of embedding this interdisciplinary approach in existing academic structures, (c) that provides a visible focus for students and colleagues who are interested in our activities, and (d) that allows us to colocate a critical mass of collaborators to generate a scientifically productive environment. **Ideally I-AIM would be located in the first floor of the Fields Institute Building.** I-AIM will require:

- A common space for use as lounge, seminar space and meeting room, supporting formal presentations and unstructured interactions ("tea room")
- Office space for the I-AIM members whose roles are described above. After ramp-up in the first year we anticipate the institute to house up to 42 members:
    - The Director of I-AIM;
    - One administrator and one half-FTE systems administrator;
    - 15 graduate students;
    - Postdoctoral Fellows;
    - 8 full-time Faculty;
    - 6 spaces for visiting Fellows;
    - 2 spaces for internal faculty; these will be used on a day-by-day basis by I-AIM faculty who visit the institute in the course of their collaborations
- A mail and photocopy room; required to support the day-to-day operations of the Institute.
- A storage room; required to support the day-to-day operations of the institute e.g. to store posters / exhibits for use in recruiting activities, poster-boards and secure archiving of personnel records and applications.

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As for other capital costs, budget allocations for furnishings and consultations are being requested, as well as a fibre connection to the University's backbone with Gigabit capacity and wireless ports. Gigabit connectivity will support distributed storage schemes as well as real-time visualisation of large-scale computations, wireless connectivity will facilitate networking in the dynamic environment we anticipate.

Appendix D: OTO and operating budget request

OTO funds are requested to establish I-AIM as the autonomous workspace it needs to be. This includes funds for

- Constructions and renovations: based on the space and infrastructure requirements specified above, we have estimated a development cost of $1,283,000. This figure is based on the University's experience with similar projects and detailed in the Appendices below.
- Workstations: the Director, assistant, systems administrator, students and PDFs each require a personal workstation. In addition 2 workstations will be held available as terminals and network access points on a short-term rotating basis. Accordingly we budget 41 workstations at an average cost of $3,500 ($73,500)
- Office Equipment: to support normal operations of I-AIM as an academic institute, we need to provide telephones, a photocopier, a shredder for personnel related documents, a central printer and a telefax. These items are budgeted at an avergaed cost for 41 seats at $41,000.
- Development of promotional media: to enhance its profile, advertise its activities to the scientific community and support its recruitment activities, the Institute will have a Web-page and a printed brochure designed at a budgeted cost of $15,000 for both.

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Operating funds are requested to support I-AIM academic activities. This includes:

- Office operating costs: we request a sum of $5[illegible] annually per person (40 people) to cover telephone and Internet connectivity, mail and courier costs, photocopying consumables, storage media and supplies;
- Institute operating costs: we request a sum of $10,000 annually to cover miscellanous items such as hospitality, recruitment activities, staff travel and contingencies;
- Cleaning and maintenance costs of $ 10,000 annually;
- A seminar budget of $25,000 annually to cover travel costs for invited speakers;
- An Annual Retreat budget of $15,000 to cover space and audiovisual costs, travel for two external speakers, catering, and insurance;
- A Topical Workshop budget for 3 workshops annually at $12,000 each to cover space and audiovisual costs, travel for three external speakers, catering, and insurance;
- A summer school budget of $20,000 annually to contribute to preparation, advertising, space and audiovisual costs, administration; travel for one keynote speaker, catering, social activities and insurance;
- A conference travel budget averaged to $3,000 annually per faculty member, administered by the Director, to support applications from the I-AIM faculty, graduate students and postdoctoral fellows for conference travel to present research results;

Salaries are requested for the following positions, budgeted as stated and including an estimated 4% annual increase of base salary and benefits;

- The I-AIM Director, cofunded at 0.5 FTE (0.5 of $120,000 annually of base salary and benefits)
- Up to 8 I-AIM Faculty, to be ramped up over the first three years of operations, funded at 2 x 1.0 FTE (2 x $100,000 annually of base salary and benefits)
- An Administrative Assistant at 0.5 FTE (0.5 of $30,000; annually of base salary and benefits) to support the Institute's Director and the executive committees and administer the Graduate Program.
- A System Administrator at 0.5 FTE (0.5 of $80,000 annually of base salary and benefits) to support the high-performance computing facilities of I-AIM participants in the form of maintenance, liaison, and education of users (e.g. training of different team members on software developed by another collaborating partner).
- Up to 15 PhD students, to be ramped up over the first three years of operations (10 x $23,000 annually of base salary and benefits);
- Up to 8 Postdoctoral Fellows, to be ramped up over the first three years of operations (6 x 0.6 of $50,000 annually of base salary and benefits);

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Appendix G: Projected Budget

	AIF Financial Request - 3nd Round, 2005-06						
Proposal Name	**Budget request ***	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Subtotal**
I-AIM	**OTO**						
	Equipment						
Institute of	Workstations (41 at 3,5k)	144					144
Applied	Office (41 at 1k)	41					41
Interdisciplinary	**Operating**						
Mathematics	Web Site and Brochure	15					15
	Construction/renovation						
	(development pro forma attached)	1,283					1,283
	Subtotal OTO	1,483	0	0	0	0	1,483
	BASE						
	Salaries and Stipends						
	Director (0.5 FTE)	60	62	65	67	70	325
	No. of Faculty Members	*3*	*6*	*8*	*8*	*8*	
	Faculty base	*100*	*104*	*108*	*112*	*1*	
	y salari	300	4	865	900	936	3,625
	Postdo	*3*		*8*	*8*	*8*	
	base sti	*45*	*47*	*49*	*51*	*53*	
	PDF Stipend am		281	389	405	421	1,631
	No. of Graduate Students	*5*	*10*	*15*	*15*	*15*	
	Graduate stipend	*23*	*24*	*25*	*26*	*27*	
	Graduate Stipend Program	115	239	373	388	404	1,519
	Admin. Assistant	30	31	32	34	35	162
	Systems Admin. (0.5 FTE)	40	42	43	45	47	217
	Academic activities						
	Seminar series	25	25	25	25	25	125
	Annual retreat	15	15	15	15	15	75
	Topical Workshops	36	36	36	36	36	180
	Summer Schools	20	20	20	20	20	100
	Conference Travel	9	18	24	24	24	99
	Operating						
	Office operating	20	20	20	20	20	100
	Institute Operating	10	10	10	10	10	50
	Cleaning and Maintenance	10	10	10	10	10	50
	Subtotal Base	1,004	1,630	2,141	2,219	2,300	8,258
	Totals OTO + Base	2,487	1,630	2,141	2,219	2,300	9,741
	Notes						
	All figures in 1000 $ CDN						
	* **One-Time-Only (OTO):**	Funds for activities that do not require continuing support from year to year.					
		One-time-only items are reversed in the next year's budget.					
	Base:	Expenses that occur year after year for the same amount.					

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Appendix H: Development cost breakdown

Space requirements

	DESCRIPTION	No. of Rooms	No.Seats	NASM/St	NASM
	ACADEMIC				
1	Office: Director	1	1	18.00	18
2	Office: Visitors	4	8	13.00	104
3	Office: PHd	5	15	4.00	60
4	Office: PostDocs	4	8	13.00	104
5	Office: Faculty	4	8	13.00	104
6	Office: Admin. Assitant	1	1	13.00	13
7	Photo/Mail room	1	na	13.00	13
8	Small storage space	1	na	8.00	8
9	Tea Room (multi functional)	1	25	2.00	50
10	Kitchenette (access to)	shared	shared	na	na
	TOTAL	22	41		4
			(excl. Tea Room)		

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Development cost summary

(These numbers are activated by assumptions)

	DESCRIPTION	DRAFT budget
B	MAIN CONSTRUCTION CONTRACT	$561,249.18
C	LANDSCAPING, ROADS, SIDEWALKS	$0.00
D	OTHER PROJECTS	$75,000.00
E	INFRASTRUCTURE SERVICES	$22,500.00
F	CONSULTANTS	$136,893.56
G	FURNISHINGS (LOOSE)	$219,350.00
H	EQUIPMENT	$13,500.00
J	SOFT COSTS	$121,791.07
K	ALLOWANCES	$31,770.00
L	PROJECT CONTINGENCIES	$101,024.85
	TOTAL	**$1,283,078.66**

Development cost details

(This development pro forma is based on, but not identical to, the Faculty planning templates)

	DESCRIPTION	Units	Space/Unit Cost	DRAFT budget
A	ASSUMPTIONS			
	Net Assignable:renovated (SM)	474		
	COST PER SM		$1,184.07	$561,249.18
	COST PER SF		$110.00	
	Approvals			
B	MAIN CONSTRUCTION CONTRACT		*forward*	$561,249.18
1	General Conditions		5.00%	$28,062.46
2	Sitework		1.00%	$5,612.49
3	Concrete		3.00%	$16,837.48
4	Masonry		5.00%	$28,062.46
5	Metals		2.00%	$11,224.98
6	Wood & Plastics		10.00%	$56,124.92
7	Thermal & Moisture Protection		6.00%	$33,674.95
8	Door & Windows		10.00%	$56,124.92
9	Finishes		15.00%	$84,187.38
10	Specialties		5.00%	$28,062.46
11	Equipment		5.00%	$28,062.46
12	Furnishing (Built-in Only)		5.00%	$28,062.46
13	Special Construction		0.00%	$0.00
14	Conveying Systems		0.00%	$0.00
15	Mechanical		10.00%	$56,124.92
16	Electrical		10.00%	$56,124.92
17	IT Connectivity		8.00%	$44,899.93
	Sub-Total		100.00%	$561,249.18
C	LANDSCAPING, ROADS, SIDEWALKS		-	$0.00
D	OTHER PROJECTS			$75,000.00
	Secondary Effects		not included	not included
	Hazardous Removal		-	-
	Code Compliance			$75,000.00
	Other		-	-
E	INFRASTRUCTURE SERVICES			$22,500.00
	Central Plant			
	Hydro			
	Sewer			
	Water			
	IT Infrastruc	4	$250.00	$10,[illegible]
	Fibre		$7,500.00	$7,5[illegible]
	Telephone	19	$250.00	$4,750
	Other			
F	CONSULTANTS			$136,893.56
	ASSUMPTIONS		$561,249.18	
	Architect		15%	$84,187.38
	Engineers		3%	$16,837.48
	Disbursements		2%	$11,224.98
	Construction Management		3.50%	$19,643.72
	In-House costs (code)			$5,000.00
G	FURNISHINGS (LOOSE)			$219,350.00
	Administrative station	1	$2,500.00	$2,500.00
	Faculty private	25	$3,500.00	$87,500.00
	Faculty shared	13	$2,000.00	$26,000.00
	Student shared	5	$1,000.00	$5,000.00
	storage cabinets	41	$250.00	$10,250.00
	lateral filing cabinets	41	$400.00	$16,400.00
	hooks 10.00	41	$200.00	$8,200.00
	Public Spaces Lounge seats/tables	20	$300.00	$6,000.00
	sofa/arm chair	12	$700.00	$8,400.00
	tables (meeting)	6	$2,000.00	$12,000.00
	guest chairs	52	$150.00	$7,800.00
	task chairs	41	$300.00	$12,300.00
	shelving standard per standard office	13	$1,500.00	$19,500.00
H	EQUIPMENT			$13,500.00
	AV requirements Learn. Environ. partial	1.00	$10,000.00	$10,000.00
	AV requirements wireless	1.00	$3,500.00	$3,500.00
J	SOFT COSTS			$121,791.07
	ASSUMPTIONS		$561,249.18	
	Applicable taxes		9.70%	$54,441.17
	Fees		1.00%	$5,612.49
	Insurance		3.00%	$16,837.48
	Permits Construction		8.00%	$44,899.93
K	ALLOWANCES			$31,770.00
	Project Opening			$10,000.00
	Security: Door Access System	4	$3,600.00	$14,400.00
	Security: Intrusion System	-		
	Signage: Interior	41	$70.00	$2,870.00
	Signage: Exterior A	1	$3,000.00	$3,000.00
	Signage: Exterior B	3	$500.00	$1,500.00
L	PROJECT CONTINGENCIES			$101,024.85
	ASSUMPTIONS		$561,249.18	
	Construction Contigency		5%	$28,062.46
	Design Contingency		5%	$28,062.46
	Cost Escalation		6%	$33,674.95
	Other (NA compliance)		2%	$11,224.98

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