



## **Annual Report to Industry Canada**

Covering the Objectives, Activities and Finances  
for the period April 1, 2007 to July 31, 2008 and  
Statement of Objectives for Next Year and the Future

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# Table of Contents

	<u>Pages</u>
<b>Period A. April 1, 2007 to July 31, 2008</b>	
Objectives, Activities and Finances	2-28
- Statement of Objectives, Introduction	
- Objectives 1, 2, 3 with Related Activities and Achievements	
- Financial Statements, Expenditures, Criteria and Investment Strategy	
 <b>Period B. August 1, 2008 and Beyond</b>	
Statement of Objectives for Next Year and Future	29-31

# **Statement of Objectives**

## **Introduction**

Perimeter Institute for Theoretical Physics (PI) has successfully established a major international presence for Canada in theoretical physics. In 2007-8, the Institute achieved several important objectives of its mandate, which is to advance pure research in specific areas of theoretical physics, and to provide high quality outreach programs that educate and inspire the Canadian public, particularly young people, on the importance of basic research, discovery and innovation.

In charting its course, Perimeter Institute set out the following three objectives:

- Objective 1: Establish PI as a premier international centre for foundational physics in accordance with our mission statement.**
- Objective 2: Integrate with the surrounding Canadian academic community and enhance the capability of and national reputation for fundamental physics research.**
- Objective 3: Develop and maintain a vigorous public outreach program geared to Canadians of all ages to promote the excitement of fundamental inquiry and scientific discovery.**

The following pages outline the three objectives in more detail, including how the objectives were met with specific examples of the activities undertaken. These are reported upon for the period April 1, 2007, to July 31, 2008. Moving forward, this yearly report shall be provided to Industry Canada in keeping with the Institute's fiscal year.

## **Objective 1:**

### **Establish Perimeter Institute as a premier international centre for foundational physics in accordance with our mission statement**

Perimeter Institute is devoted to foundational issues in theoretical physics at the highest international levels of excellence. Its scientific research activities are centered around six different research areas, namely, quantum foundations, quantum information, quantum gravity, superstring theory, particle physics, and cosmology.

The Perimeter model involves bringing together researchers approaching similar problems from different angles in order to maximize the cross-pollination of ideas, and increase the probability of breakthroughs in research. The multidisciplinary approach and collaborative atmosphere drive scientific findings – from a growing understanding about giant expanses of dark matter and dark energy that both push and pull our universe to interpretations about the very essence of matter. In between these two extremes, scientists try to explain other phenomena about the world around us – including the strange behaviour of particles at the atomic scale, a strategically important area of basic research that is already giving rise to the manipulation of information using tiny quantum bits or “qubits.”

In order to continue to propel its research excellence to higher levels, Perimeter Institute continuously and aggressively recruits researchers of the highest international calibre to expand its cluster of top scientists to critical mass. The Institute positions itself as a highly attractive destination in the international theoretical physics community by offering a dynamic environment with maximum research freedom and collaboration opportunities second to none. With its active seminar, visitor, conference, and workshop programs, PI offers its researchers more opportunities to interact scientifically with other experts in the productive atmosphere of an award-winning facility – in short, PI ensures that its scientists are able to maximize their greatest research productivity.

The Institute’s successful recruitment of highly qualified scientists, combined with peer-reviewed results, and knowledge transfer to experimentalists and other partners in the research chain, is providing Canada with an essential and competitive foothold in fundamental science and ensures the country will participate in, and indeed come to dominate, important scientific developments.

In pursuing and meeting Objective 1, PI has conducted several activities involving the Research Programs, Recruitment, Visitor Program, Scientific Programming, Partnerships, and Prizes & Awards. Examples of these activities and the progress achieved within the timeframe of this report are detailed below.

## **Activities & Achievements**

### **Research Programs**

#### **Summary of Achievements**

- 85 resident researchers including 9 Faculty, 11 Associate Faculty, 34 Postdoctoral Fellows, and 31 Graduate Students
- Six active research groups with prolific output as follows:
  - 187 publications
  - 2006 citations

### **Research Achievement Highlights**

The following information describes Perimeter's key areas of research and, by way of just a few selected examples, begins to demonstrate the scientific accomplishment and impact on the fields.

#### **Quantum Foundations**

The field of quantum foundations investigates the conceptual and mathematical structure of quantum theory. Broadly, there are three areas of research:

- i. The investigation of novel quantum effects
- ii. The development of an understanding of the conceptual issues raised by the theory (such as the measurement problem and the issue of non-locality) and of interpretations of the theory (such as collapse models, or the pilot wave model) that address these conceptual issues
- iii. Attempts to construct the theory from more basic principles or axioms. Research in quantum foundations connects with quantum information at the more applied end and with quantum gravity at the more fundamental end.

Since July 2007, researchers in quantum foundations at PI have produced 21 scientific articles. Two highlights from Perimeter's foundations research in this period are:

- Matthew Leifer and colleagues proved that the impossibility of broadcasting states (a generalization of the notion of no-cloning appropriate to mixed as well as pure states) is a generic feature of all non-classical theories, not just quantum theory. Their work, "A Generalized No-broadcasting Theorem" (arXiv:0707.0620), was published in *Physical Review Letters*. This is an example of a development that strengthened links between quantum foundations and quantum information, leading to new insights of value in both fields.
- In "A Minimalist Pilot-wave Model for Quantum Electrodynamics" (arXiv:0707.3487), Ward Struyve and Hans Westman developed a pilot wave model for quantum electrodynamics showing, for the first time and contrary to the expectations of many experts, that it is possible to reproduce the predictions of the standard model of particle physics with such an approach.

## Quantum Information

Quantum mechanics redefines information and its fundamental properties. Researchers at PI seek to better understand the properties of quantum information and to determine which information processing tasks may be feasible and which are simply impossible. The field of quantum information science is truly interdisciplinary, bringing together ideas from physics, computer science, and other fields (such as mathematics, engineering, and chemistry), to offer unique insights into the behaviour and capabilities of quantum systems. This research may also lend insights into the nature of quantum mechanics. In the future, quantum computers could represent an important new technology which has the potential to transform our society.

In the report period, Perimeter Institute researchers have published 27 quantum information papers. Two highlights from PI's research include:

- In "Quantum weak coin flipping with arbitrarily small bias" (arXiv:0711.4114), Carlos Mochon provided an elaborate construction to demonstrate that cryptographically secure weak coin flipping is possible using quantum states. This problem had been open for a number of years and been worked on previously by a number of luminaries in the field of quantum information.
- Rolando Somma and his collaborators showed that quantum algorithms can perform an improved version of an important group of classical algorithms known as simulated annealing in two papers: "Quantum Simulated Annealing" (arXiv:0712.1008) and "Quantum Simulations of Classical Annealing Processes" (arXiv:0804.1571). Simulated annealing algorithms are widely used to solve complicated optimization problems, which arise in any sort of resource management context, from airline scheduling to mobile phone bandwidth allocation. Somma and his collaborators have shown that quantum computers can substantially speed up such algorithms.

## Quantum Gravity

Quantum gravity is concerned with unifying general relativity, Einstein's theory of gravity, and quantum theory. At Perimeter Institute, researchers are actively pursuing a broad variety of approaches to this problem including loop quantum gravity, spin foam models, and causal set theory.

The 49 articles produced by the group for the period April 1, 2007, to July 31, 2008 represent substantial progress on several fronts. Two examples of this research follow:

- Fotini Markopoulou and collaborators developed a class of models that demonstrate the emergence of classical space-time from more fundamental quantum degrees of freedom in "Quantum Gravity: A Model of Emergent Locality" (arXiv:0801.0861). In particular, evidence was found for a phase transition, called geometrogenesis, in which the non-local degrees of freedom freeze, resulting in the formation of low dimensional lattices, approximating low-dimensional manifolds.
- "Reconstructing AdS/CFT" (arXiv:0804.0632) by Laurent Freidel presented a new and deeper understanding of the AdS/CFT correspondence, which indicates that this duality should be a general feature of any quantum theory of gravity with a non-vanishing cosmological constant.

## Superstring Theory

String theory is a broad and varied field with strong connections to quantum gravity, particle physics, and cosmology, as well as mathematics. PI's research group is actively working on a wide range of topics including: string cosmology, the string theory landscape, gauge theory amplitudes, gauge/gravity duality, black rings, and strings at singularities.

The scientific output of the string theory group has been strong, not only in the number of publications (46), but also in the visibility of some these publications, with results presented in leading seminars and conferences around the world. Two examples of PI's research results in string theory within the period of this report are:

- In two papers, "Viscosity Bound Violation in Higher Derivative Gravity" (arXiv:0712.0805 [hep-th]) and "The Viscosity Bound and Causality Violation" (arXiv:0804.2168), Rob Myers and collaborators at MIT and Stanford examined a longstanding conjecture, that a hydrodynamic quantity called viscosity must obey a certain lower bound. Interestingly, their work indicates that small violations may be possible but that theories exhibiting large violations of the bound also display other physical inconsistencies. Myers and other researchers are actively working to understand these issues.
- In "Sharpening The Leading Singularity" (arXiv:0803.1988 [hep-th]), Freddy Cachazo found new tools to calculate scattering amplitudes in gauge theories. This research direction aims to develop calculation tools needed to extract new physical results from upcoming experiments at the Large Hadron Collider.

## Particle Physics

Particle physicists at PI are also engaged at this interface and seek to identify nature's constituents and interactions at the most fundamental level, with an emphasis on comparing theoretical ideas with both terrestrial experiments and astrophysical observations. In particular, researchers are involved in identifying how these observations constrain the theoretical possibilities for physics beyond the Standard Model. The future research directions will necessarily be drawn towards more particle phenomenology relevant for the Large Hadron Collider at CERN, which should become operational in the coming year.

The research output of the particle physics group was significant, with 15 new articles published between April 1, 2007, and July 31, 2008. Two highlights among these articles are:

- "Lectures on Cosmic Inflation and its Potential Stringy Realizations" (arXiv:0708.2865) by Cliff Burgess summarizes the multi-year effort in constructing realistic models of cosmic inflation by Burgess and his collaborators. This program culminated in a scenario that is consistent with present observations, but leads to interesting links between inflation and particle phenomenology, which should appear in future experiments. Their model has had a significant impact in the string/cosmology community.
- Recently, Maxim Pospelov has made detailed studies of Catalyzed Big Bang Nucleosynthesis (CBBN), a novel idea that he proposed two years ago to alleviate a persistent discrepancy between theoretical predictions and experimental observations of lithium abundance in the universe. In "Bridging the primordial  $A=8$  divide with Catalyzed Big Bang Nucleosynthesis" (arXiv:0712.0647) and "Primordial Lithium Abundance in Catalyzed Big Bang Nucleosynthesis" (arXiv:hep-ph/0703096), Pospelov and his students provide full calculations of the production of light elements in the hot Big Bang, performed within the

CBBN framework. Pospelov's work on CBBN has had a large impact on different groups around the world and was a focus of a workshop in May 2008.

## Cosmology

Cosmologists at PI combine recent developments at the interface of astrophysics and fundamental physics to shed light on some of the major puzzles in the field: What is causing the observed cosmic acceleration? What is the nature of dark matter? What can be learned from microwave background radiation and large scale structure observations about theories of fundamental physics? Is inflation the correct paradigm of early-universe cosmology?

Cosmologists at PI produced 29 articles in the 2007-2008 period. Two examples of this research include:

- In "Cascading Gravity" (arXiv:0711.2072), a team of PI researchers collaborating with a group at New York University constructed a new class of modified theories of gravity, in which the gravitational force law scales exhibits "weakening" at large distances. The latter can have profound implications for the cosmological constant problem and the origin of cosmic acceleration. Fully understanding the observational implications of such models is a topic of ongoing research at Perimeter.
- "Non-Gaussianities in New Ekpyrotic Cosmology" (arXiv:0710.5172) presented the 3-and 4-point correlation functions and demonstrated that non-gaussianity in density perturbations provides a distinguishing prediction of "ekpyrotic cosmology," a scenario developed by PI's Faculty member, Justin Khoury, and collaborators. Both of these articles appeared in *Physical Review Letters*, recognized as one of the most prestigious publications in physics.

## **Recruitment**

### Summary of Achievements

- Recruited Dr. Neil Turok as Executive Director, to start in the following fiscal year.
- Conducted Faculty searches in quantum foundations and cosmology, leading to the August 2008 announcement of the appointment of Dr. Robert W. Spekkens.
- Recruited two Associate Faculty members, Leonard Susskind (Stanford University, USA) and Adrian Kent (Cambridge University, UK).
- Recruited 19 new Postdoctoral Fellows.

## **Achievement Highlights**

### Executive Director Search

In fall 2007, Perimeter Institute launched a search for a researcher of international standing to lead the next phase of the Institute's development. In May 2008, the Institute announced the hiring of pre-eminent theoretical cosmologist, Dr. Neil Turok. In accepting the appointment, Dr. Turok chose to leave his present position at Cambridge University to become Perimeter's Executive Director as of October 2008.

Dr. Turok has worked in a number of areas of mathematical physics and early-universe physics, focusing on observational tests of fundamental physics in cosmology. Dr. Turok also spearheaded an ambitious program to raise science education across Africa. The search

committee was unanimous in its choice of Dr. Turok as a visionary leader with the ability and ambition to position PI among the elite theoretical physics research institutes in the world. Renowned physicist Stephen Hawking commented, "The combination of Neil and PI is brilliant and holds great promise for the future."

### Faculty Recruitment

The Institute launched two international searches for junior Faculty members in cosmology and quantum foundations. The latter search identified and led to the successful recruitment of Dr. Robert W. Spekkens. The cosmology search considered a number of world class candidates for the second appointment, but elected to postpone the conclusion of this search until after Dr. Turok came into residence.

### Associate Recruitment

Leonard Susskind joined PI's Faculty as an Associate member in October 2007. Professor Susskind is internationally recognized as one of the most highly creative researchers in the field of particle physics. He has received a range of honours and prizes, including election to the National Academy of Sciences (NAS) the American Physical Society's prestigious Sakurai Award, and the American Institute of Physics' Science Writing Award.

### Postdoctoral Fellows

2007-8 saw an extremely successful postdoctoral recruitment season, with 19 of the brightest young researchers across all of PI's fields of research choosing to pursue their research careers here in Canada. These junior researchers moved to PI from leading institutions around the world, including Yale, Oxford, the Institute for Advanced Study (Princeton), the Kavli Institute of Theoretical Physics (Santa Barbara), and Caltech, among others. Over 400 applications were received, demonstrating the Institute's competitiveness and ability to attract highly qualified personnel from around the world to Canada.

PI has played a key role in nurturing outstanding scientific talent in Canada. An important measure of PI's success is its placement of Postdoctoral Fellows into permanent positions following their three year terms at PI. These placements strengthen the academic and research communities both within Canada and abroad. As of this report 43 individuals have completed their postdoctoral training at PI, and 34 postdoctoral researchers are currently in residence. The academic market in physics is extremely competitive, and PI is justifiably proud of placing researchers who serve as ambassadors for both the Institute and Canadian research within the international academic community. Three examples include:

- Robert Raussendorf, who obtained a Faculty position UBC
- Joseph Emerson, who obtained a Faculty position at the University of Waterloo
- Shimpei Kobayashi, who joined the Faculty of Gunma National College of Technology, Japan

## **Visitor Program**

### Summary of Achievements

- 228 Short-Term Visitors
- 20 Long-Term Visitors

## **Achievement Highlights**

### Long-Term Visiting Faculty

PI's ability to recruit the world's leading researchers to Canada was demonstrated this past year as 20 scientists chose Perimeter as their destination during leaves of absence from their home universities. Included among these is Rafael Sorkin, known internationally as the initiator and main proponent of the causal sets approach to quantum gravity. Other long term visitors of note at Perimeter over the past year include: Harvey Brown (Oxford), Katie Freese (Michigan), Chris Fuchs (formerly of Bell Labs), Bei-Lok Hu (Maryland), and Will Kinney (Buffalo).

### **Scientific Programming: Seminars and Colloquia**

Perimeter's eight active, weekly seminar series continued to foster collaborations in Canada and to assemble knowledge from leading researchers around the globe.

### Summary of Achievements

- Presented over 250 scientific talks
- Developed PIRSA (Perimeter Institute Recorded Seminar Archive) as a leading international archive resource for recorded seminars

## **Achievement Highlights**

### Distinguished Speakers

Speakers who have given presentations at PI over the past year included such eminent scientists as Shamit Kachru (Stanford), Joe Polchinski (KITP, Santa Barbara), Andy Strominger (Harvard), Leonard Susskind (Stanford), Gerard 't Hooft (Utrecht), Matias Zaldarriaga (Harvard), and many others.

The colloquium by Nobel Prize winner Gerard 't Hooft was held as a special joint colloquium with the Departments of Physics at the University of Guelph and the University of Waterloo. Notable among the hundreds of talks was Eiichiro Komatsu's seminar, *WMAP 5-year Results: Implications for Inflation*, which was the first seminar world-wide on the new release of data from the Wilkinson Microwave Anisotropy Probe (WMAP) experiment, and which Perimeter transmitted live via an internet broadcast. Perimeter also participates in the *International Loop Quantum Gravity Seminar*, which brings together researchers from 14 quantum gravity groups across Europe, North America, and South America for a weekly live seminar.

### PIRSA (Perimeter Institute Recorded Seminar Archive)

PIRSA is a permanent, free, searchable, and citable archive of video recorded seminars, conferences, workshops, and courses developed by Perimeter Institute to foster knowledge sharing and deliver the most recent cutting-edge research to the international scientific community. PIRSA was launched in 2008. In the short months from inception to July 2008, the site received visitors from 108 countries and almost 100,000 page views. Almost half of PIRSA traffic came from new visitors, demonstrating the ever increasing value Perimeter Institute is playing in providing Canada's digital focal point within the international research community.

## Scientific Programming: Conferences and Workshops

In addition to resident and visiting scientists contemplating and calculating their ideas in a supportive, but often solitary atmosphere, the Institute recognizes that a lively program of high-level conferences and workshops is essential to maintaining a dynamic research centre that stimulates research results and innovation.

### Summary of Achievements

- 43 conferences and workshops held from April 1, 2007 - July 31, 2008
- 11 student-oriented conferences held
- 2264 scientists attended PI conferences and workshops

### Achievement Highlights

#### *Quantum Foundations Summer School (August 2007)*

This school offered 50 top-ranked physics graduate students from around the world and a variety of disciplines the chance to be introduced to the field of quantum foundations. Lecturers invited the students to recognize, analyze, and resolve the conceptual tensions within various frameworks and theories in fundamental physics, where quantum theory is or might be applied.

#### *Experimental Search for Quantum Gravity and Effective Models of Quantum Gravity (November, 2007)*

These international meetings of 47 participants focused on possible experimental tests and their relation to quantum gravity and on modeling the aspects of a fundamental theory of quantum gravity that can affect low-energy physics and/or be experimentally relevant. The workshops created intense exchanges where the different approaches were compared and a common language developed that will be crucial for the future of the field.

#### *Novel Theories of the Early Universe and Origins and Observations of Primordial non-Gaussianity (March, 2008)*

The first workshop brought together 20 international researchers, all of whom were key players in the development of alternative models of the early universe, in particular the ekpyrotic/cyclic models and string/M-theory approaches to cosmology. This meeting included the first seminar worldwide on the latest release from the Wilkinson Microwave Anisotropy Probe (WMAP) after analysis of their 5-year dataset. Perimeter made this seminar available to the international community with a live webcast, as well as by archiving a recorded version on PIRSA. Many of these researchers then also participated in the second workshop, which brought together 30 experts in theories and observations of primordial non-Gaussianity in the cosmic microwave background. Discussions here included exchanging views on the implications of recent WMAP5 results, which provide the most stringent limits on these non-Gaussianities to date.

#### *Quantum Information in Graph Theory: Emerging Connections (April – May 2008)*

This international conference brought together 64 physicists, mathematicians, and computer scientists researching local and non-local properties of graphs and their uses in graph theory and quantum information. Graph theorists, computer scientists, and physicists have each found

new applications of local properties of graphs, but so far most of this research has been conducted separately. This PI-fostered multi-disciplinary meeting covered recent progress and research approaches, identified common goals and research directions, developed a common language for all participants, and led to new collaborations that will no doubt fuel future scientific findings.

### *PASCOS 08 (June 2008)*

*PASCOS 08* was the fourteenth in an international series of interdisciplinary symposia on the interface of particle physics, string theory and cosmology. PASCOS is a broadly recognized international conference series that raised the profile of both Perimeter and Canada in these fields, as well as bringing many leading researchers to the Institute. Attendance was 170.

## **National and International Scientific Partnerships**

Perimeter has developed a number of strategic partnerships both within Canada and at an international level. These partnerships have fostered linkages with other international research groups to enhance the research activities both at Perimeter and abroad and have also strengthened and raised the calibre of research in the broader Canadian community.

### Summary of Achievements

- Entered into partnership agreement with three Australian universities
- Co-organized or sponsored 22 national and international conferences
- Sponsored seven awards, prizes, and scholarships

## **Achievement Highlights**

### Perimeter Institute & Australia Foundations Collaboration (PIAF)

*PIAF* is a 3-year strategic partnership beginning in January 2008 between PI and universities in Australia (Queensland, Griffith and Sydney), which aims to foster international research collaborations between Canada and Australia in the field of Quantum Foundations. The program includes jointly funded and shared Postdoctoral Fellow positions (two were recruited in March 2008), an annual international conference (the first was held in Sydney in February 2008), student exchanges, and research collaborations.

### Debates in Cosmology Partnerships

#### *Origins of Time's Arrow (October 2007, New York)*

*Debates in Cosmology* is a partnership between Perimeter Institute, Columbia University, and the University of North Carolina to organize a series of conferences to focus on key outstanding issues in cosmology and foundational physics. The first of these conferences, *Origins of Time's Arrow*, was held in October 2007 at the New York Academy of Sciences in New York City with 50 participants. The next workshop, *The Multiverse*, was hosted at Perimeter in September 2008.

## PI /APC Partnership

### *Cosmological Frontiers in Fundamental Physics (May 2008, Paris)*

This partnership with the new Laboratoire Astroparticule et Cosmologie (APC) was developed to jointly organize a series of informal workshops to discuss and exchange ideas on recent developments at the interface of modern cosmology and fundamental physics. The second *Cosmological Frontiers in Fundamental Physics* workshop, with 70 participants, was held at the APC in May 2008 and focused on explorations at the intersection between string/M-theory and cosmology, including possible predictions of string physics for observational cosmology.

## PI /UBC/Asia-Pacific Center Partnership

### *Summer School on Particle Physics, Cosmology and Strings (August 2007 and July 2008)*

In an ongoing partnership with the Pacific Institute of Theoretical Physics at UBC and the Asia Pacific Center for Theoretical Physics in Korea, Perimeter organizes an annual summer school to introduce both Canadian and international graduate students to cutting-edge topics in theoretical physics research. The August school in this series brought 68 top students to Perimeter for lectures by world-leading experts on some of the outstanding challenges that await theoretical physicists in the years to come, ranging from preparing for the long awaited Large Hadron Collider experiments to preparing the students for the flurry of cosmological data that will continue to be collected in the next few years. The July 2008 school was hosted at UBC.

## **Prizes and Awards**

### Summary of Achievements

Four major prizes were awarded to Perimeter Institute Faculty and Associate Faculty members:

- Raymond Laflamme, Premier's Discovery Award
- Richard Cleve, CAP-CRM Prize in Theoretical and Mathematical Physics
- Thomas Thiemann, Basilis Xanthopoulos Prize
- Alex Buchel, Early Researcher Award

## **Achievement Highlights**

### *Raymond Laflamme, Premier's Discovery Award (May 2008)*

PI Associate Faculty member Raymond Laflamme received the prestigious Premier's Discovery Award for his contributions to natural sciences and engineering, recognizing individual achievements by the province's most eminent senior researchers. Originally recruited back to Canada by PI, he is a theorist and experimentalist of the highest order in the field of quantum information. Dr. Laflamme and his colleagues currently hold the world record for controlling the highest number of "qubits," or quantum bits, of information under verifiable circumstances - an important milestone toward a new and promising era of quantum based technologies. In addition to this achievement, as well as his many awards and honours, Dr. Laflamme is widely

published throughout the international research community, having written over 120 peer-reviewed papers. His top 15 publications have received over 3300 citations.

## **Objective 2:**

### **Integrate with the surrounding Canadian academic community and enhance the capability of and national reputation for fundamental physics research**

Unlike most developed countries, prior to the creation of Perimeter Institute, Canada did not have an obvious and established focal point for foundational theoretical physics research. PI recognizes that it is both possible and advantageous for the Institute to play such a role while simultaneously pursuing its primary objective of becoming a dominant international centre of foundational physics excellence.

The Institute has taken concrete steps to develop deep and meaningful partnerships with all Canadian research universities to attract, retain, and develop top talent – a rapid example of such scientific synergy is the nearby Institute for Quantum Computing at the University of Waterloo – a top-flight centre that, combined with Perimeter, has already established Waterloo Region and Canada as one of the best places in the world in the exciting new field of quantum computing.

During the reporting period, Perimeter Institute generated harmonious interaction and increased research productivity by propelling several initiatives to foster meaningful interaction with the national academic community. The activities included:

- Integration of PI researchers within the surrounding academic community through cross-appointments and adjunct status at regional universities;
- Partnering with similarly focused research universities throughout Canada to jointly recruit international-calibre scientists;
- Training students from Canadian universities and accommodating them in residence at PI;
- Establishing Memoranda of Understanding for research collaborations with nearly 30 Canadian universities and institutes;
- Offering Affiliate status and research interaction opportunities to 68 faculty members at universities across the country. These initiatives all contribute to PI serving as a focal point for all relevant members of the Canadian theoretical physics establishment, as well as leading in the training and recruitment of highly qualified scientists for Canada.

### **Activities & Achievements**

#### **Attracting and Training the Next Generation of Highly Qualified Personnel**

##### **Summary of Achievements**

- Established a recruitment program for top international students
- Delivered eight high-level courses in collaboration with surrounding universities
- Offered courses remotely via the introduction of Access Grid teaching technology
- Offered summer internships to 12 undergraduate students with supervisory opportunities for PI Postdoctoral Fellows

## **Achievement Highlights**

### **Student Recruitment**

PI launched a new program in 2008 to complement the recruitment efforts of surrounding universities in order to attract top international graduate students to work under the supervision of a PI Faculty or Associate member. In this year's initial phase of the program, 48 applications were received, and a select group of students were invited to visit PI in April. PI plans to expand this recruitment program and will be actively working with the regional universities to enhance and propel the recruitment of top quality students to Canada.

### **Undergraduate Student Internship**

In this ongoing program, Perimeter Postdoctoral Fellows were invited to submit for consideration 2-4 month research projects requiring the assistance of an undergraduate student. Twelve projects with corresponding top international undergraduate students were selected. The success of the program was demonstrated with the publication of work by PI Postdoc Federico Piazza with his summer 2007 undergraduate student Fabio Costa (Universita degli studi di Milano, Italy) on "Causality in pre-geometric theories."

### **Courses**

The Institute offered credit courses both at the undergraduate and graduate levels in collaboration with surrounding universities, as well as special topic courses delivered by distinguished visiting scientists. Courses attracted students from among the eight regional universities, in person and remotely via Access Grid (see below). Furthermore, all courses were recorded and made available for viewing on the PIRSA archive. Highlights from the graduate courses offered within this report's timeframe included *The problem of time in quantum gravity and cosmology* by Faculty member Lee Smolin; *Advanced General Relativity* by PI Affiliate Eric Poisson; *Symmetry Principles in Physics* by Harvey Brown, visiting researcher from Oxford; and *Spontaneous Broken Symmetry* by Robert Brout, visiting professor from Université Libre de Bruxelles. In addition, a leading group of PI Postdoctoral researchers taught PI's first undergraduate course, *New Horizons in Fundamental Physics*, an introduction to some of the most exciting ideas in research conducted at Perimeter Institute, which was attended by approximately 30 students from the University of Waterloo and the University of Guelph.

### **Access Grid**

Installed at PI this past year, Access Grid is an ensemble of technological resources, including multimedia large-format displays, presentation and interactive environments, and interfaces to support group-to-group interactions across the Grid. Access Grid in particular facilitates training at PI, allowing students at surrounding universities to attend PI courses remotely and vice versa. It also more generally facilitates interactions and collaborations with universities across Ontario and beyond.

## **Collaboration on Recruitment Efforts**

### Summary of Achievements

- Creation of two joint cosmology positions with the University of Waterloo
- Continued discussions with McMaster University, University of Guelph, University of Waterloo, and The University of Western Ontario on joint positions (on-going)

### **Achievement Highlights**

The Associate Member program is designed to recruit world-class researchers to Canada and Perimeter with part-time appointments. As well as increasing the diversity and quality of research activities at the Institute, the resident associate program has strengthened and raised the calibre of the faculties of our partner universities in Canada.

## **Conference and Workshop Partnerships**

### Summary of Achievements

- Partnered on 12 joint workshops with surrounding universities

### **Achievement Highlights**

*PI/CITA Mini-Workshops (October 26, 2007, and April 1, 2008)*

This is an ongoing series of meetings between researchers at Perimeter Institute and the Canadian Institute for Theoretical Astrophysics (CITA) at the University of Toronto. The goals of these informal one-day meetings are to share new ideas and encourage research interaction in common fields of interest: cosmology, string theory, particle physics, and quantum gravity. This year saw the eighth and ninth installments of these workshops.

*Southwestern Ontario 4-Corner Condensed Matter Symposium (April 24, 2008)*

This meeting was hosted at Perimeter to encourage interactions between condensed matter physicists from four major research groups in southern Ontario, *i.e.*, University of Guelph, McMaster University, University of Toronto, and University of Waterloo. As well as seminars by local researchers, two keynote seminars were given by leading international researchers, Subir Sachdev (Harvard University) and Collin Broholm (Johns Hopkins University).

## **Affiliate Recruitment**

### Summary of Achievements

- Recruited 9 new Affiliate Members

## **Achievement Highlights**

This program continues to be an unequivocal success in forging research links across the country. Perimeter Institute now has 68 Affiliate members across Canada, enabling members of the national theoretical physics community to interact at the Institute on a regular basis, adding to the critical mass of first rate researchers and increasing research activity and productivity.

### **Objective 3:**

#### **Develop and maintain a vigorous public outreach program geared to Canadians of all ages to promote the excitement of fundamental inquiry and scientific discovery**

Perimeter Institute is not the first international research organization to be involved in outreach activities, but what perhaps sets PI apart from other institutions is its clear acknowledgement that the development and maintenance of a comprehensive and effective scientific outreach initiative is a core strategic priority.

Scientific illiteracy is a major concern throughout most countries, including Canada, while specific mechanisms for supporting science education and awareness are sometimes spotty. There is a major opportunity presented by the rise of PI to have a positive effect on the wider community and to use the Institute's success as a platform to begin to effect some genuine change.

There is also a strong internal cultural component to PI's outreach motivations. Many of its researchers are excited not only about the research at PI, but about having the opportunity to interact with the public in innovative ways. By offering concrete outreach opportunities to research staff, PI is not only leveraging its research expertise to establish a unique outreach program that is integral to its competitive advantage, but it is also providing a concrete means of enhancing the internal culture and atmosphere for its scientists.

### **Objectives**

Perimeter Institute has successfully shared the joys of critical inquiry and scientific discovery with students, teachers, and the general public – demonstrating the value of basic research and innovation. Outreach activities fostered programs and products of the highest international standards and made them available to Canadians and beyond. Examples of these initiatives and the progress achieved within the timeframe of this report are detailed below.

### **Activities & Achievements**

#### **Programs for Students**

##### **Summary of Achievements**

- 68 Canadian students and 70 international students attended the 2007 and 2008 International Summer School for Young Physicists (ISSYP)
- 700 students were reached through “Physica Phantastica” face-to-face sessions with PI's PhD Outreach experts and guest researchers, held in classrooms from coast to coast

## **Achievement Highlights**

### International Summer School for Young Physicists

The Institute continued ISSYP, its flagship program for elite students, inviting youth from across Canada and around the world to Waterloo for intense two-week camps involving lessons in modern physics, mentoring sessions with top scientists, and lab tours in Ontario.

Applications arrived from across Canada as well as from Australia, Brazil, China, Croatia, Ecuador, Greece, Hong Kong, Hungary, India, Italy, Lebanon, Malaysia, Mexico, The Netherlands, New Zealand, Poland, Serbia, Singapore, Spain, Taiwan, Trinidad and Tobago, Turkey, United Kingdom, USA, and Vietnam. The camps provide students, age 16 -17, with deep understanding of cutting-edge topics in modern physics, as well as mentorship by international scientists.

### Physica Phantastica

A variety of enrichment activities for high school students were held on-location in their classrooms. The western and central schools reached within the report period include those in Richmond, BC, Calgary, AB, Edmonton, AB, Balgonie, SK, Winnipeg, MB, Toronto, ON, and Waterloo, ON. A special set of in class presentations also took place throughout Northern Ontario.

## **Programs and Products for Teachers**

### Summary of Achievements

- Developed *Perimeter Explorations*, distributed to 2500 teachers throughout Canada and beyond
- Presented EinsteinPlus Teachers' Workshop to 72 Canadian teachers and 126 international teachers
- Presented on-location Teacher Workshops reaching an additional 346 teachers nationally and 110 teachers internationally at workshops in Boston and Geneva

## **Achievement Highlights**

### Perimeter Explorations

The in-class teaching module, *The Mystery of Dark Matter*, was introduced to physics teachers across Canada and around the world. This resource, including a DVD and teacher's manual, is designed to assist educators in sharing compelling topics in physics with their students. It was unveiled in February 2008 at the American Association for the Advancement of Science (AAAS) Meeting, followed by a Canadian launch at the Toronto District School Board. This product vastly increases the numbers of students and teachers that can be reached by the Institute. An initial target of 2500 North American science teachers was met, impacting over 100,000 students year after year.

## EinsteinPlus National Teachers' Workshop

Teachers also benefit from the Institute's EinsteinPlus National Teachers' Workshop on Modern Physics". These one-week, intensive, residential workshops for international high school teachers focus on key areas of modern physics. EinsteinPlus provides classroom tested materials with strong connections to many high school curricula and the opportunity for participants to learn about some of the latest developments in theoretical physics from researchers at the forefront of their fields. Applications were received from across Canada as well as from Argentina, Bahamas, Brazil, Ethiopia, Guatemala, India, Israel, New Zealand, and the USA.

## Cross-Canada Teacher Workshops

PI offered special day-long and multi-day workshops on location throughout the country, providing teachers with relevant information and concepts that students find accessible and fun to learn. Sessions took place in Vancouver, Calgary, Edmonton, Ottawa, Toronto, Waterloo Region, Montreal, and Halifax. These presentations provide distribution modes for *Perimeter Explorations* content, as well as forums to receive teacher feedback on new content in development by PI.

## **Programs and Products for the General Public**

### Summary of Achievements

- Continued to develop the highly successful public lecture series, expanding reach through agreements with broadcasters and utilization of the enhanced PI website
- Pre-production on broadcast documentary regarding quantum information
- Expanded and enhanced the PI outreach website content

## **Achievement Highlights**

### Public Lectures

The Institute's flagship "Public Event Series" now attracts over 600 people to each popular scientific lecture in Waterloo. The talks are viewed by even wider audiences via television and on-demand over Perimeter's growing website. Lecturers this season included Alain Aspect, Institute d'Optique; John Ellis, CERN; author Michael Belfiore; Neil Turok, Cambridge; Gerard 't Hooft, Utrecht; and a panel discussion with Seth Lloyd, Anthony Leggett, Chris Fuchs, and Leonard Susskind on the topic of quantum information, recorded for the CBC Radio program *Quirks and Quarks*, and broadcast nationally across Canada.

### Quantum Broadcast

Extensive planning was undertaken to prepare a one-hour television documentary targeting the general public around the world with an entertaining and informative look at the subject of quantum theory and quantum information. Raymond Laflamme, PI Associate Faculty member and world renowned expert in quantum information, is the senior scientific consultant on this project. Title Entertainment, a production company with a strong track record of content creation coupled with successful placement into international broadcast markets was retained to detail production and sales efforts.

## Outreach Website

Beyond improvements already made to PI's online public lecture presence, other website enhancements were planned and production started. These new initiatives, when fully implemented, will provide short-form presentations, interactive games, quizzes, and animations to serve average audiences, particularly youth, and raise awareness for the importance of basic research.

## **National and International Partnerships and Relationships**

### Summary of Achievements

- Collaborated with CERN on PI Outreach training of European science teachers
- Delivered a workshop for the American Association for the Advancement of Science (AAAS) conference in Boston for science educators, policy makers, and media
- Trained Canadian teachers in partnership with the BC Teacher's Association, Manitoba Association of Physics Teachers, Calgary Science Network, the Ontario Association of Physics Teachers, and the Science Teacher's Association of Ontario
- Presented two workshops for the American Physics Teachers Association (AAPT) annual meeting in July 2008 in Edmonton
- Provided Perimeter Explorations training to 80 members of the Physics Teaching Resource Agents (PTRA) group, consisting of leading educators from across North America

### **Achievement Highlights**

#### *PI-CERN Teacher Workshop (July 2008)*

This special satellite edition of EinsteinPlus saw Perimeter Institute Outreach staff conducting a teacher workshop on location in Geneva, Switzerland. The workshop served 50 international teachers from across Europe and informed them on research and educational outreach efforts in Canada and elsewhere, particularly relating to a greater understanding of dark matter.

# Overview of Financial Statements, Expenditures, Criteria and Investment Strategy

## Auditor's Report

**ZEIFMANS**  
LLP  
CHARTERED ACCOUNTANTS

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**50 YEARS**  
1959 - 2009

### AUDITORS' REPORT

To the Directors of  
Perimeter Institute

The accompanying summarized statement of financial position and summarized statements of operations and changes in fund balances are derived from the complete financial statements of Perimeter Institute as at July 31, 2008 and for the year then ended on which we expressed an opinion without reservation in our report dated September 26, 2008. The fair summarization of the complete financial statements is the responsibility of management. Our responsibility, in accordance with the applicable Assurance Guideline of The Canadian Institute of Chartered Accountants, is to report on the summarized financial statements.

In our opinion, the accompanying financial statements fairly summarize, in all material respects, the related complete financial statements in accordance with the criteria described in the Guideline referred to above.

These summarized financial statements do not contain all the disclosures required by Canadian generally accepted accounting principles. Readers are cautioned that these statements may not be appropriate for their purposes. For more information on the entity's financial position, results or operations and cash flows, reference should be made to the related complete financial statements.

Toronto, Ontario  
September 26, 2008,

  
Chartered Accountants  
Licensed Public Accountants

# Audited Financial Statements

**PERIMETER INSTITUTE**  
(Incorporated Under the Laws of Canada Without Share Capital)  
**SUMMARIZED STATEMENT OF FINANCIAL POSITION**  
**AS AT JULY 31, 2008**

**ASSETS**

	<b>2008</b>					<b>2007</b>
	<b>Restricted Funds</b>					
	<b>Long-term Endowment</b>	<b>Capital Asset</b>	<b>Research and Outreach</b>	<b>Operating Fund</b>	<b>Total</b>	<b>Total</b>
Current Assets:						
Cash and cash equivalents	\$ 16,264,022	\$ ---	\$ 8,377,285	\$ ---	\$ 24,641,307	\$ 9,196,492
Investments	214,638,903	---	---	---	214,638,903	175,420,864
Government grants receivable	---	---	---	---	---	2,994,000
Other current assets	---	---	210,789	100,199	310,988	308,515
	230,902,925	---	8,588,074	100,199	239,591,198	187,919,871
Other receivable	---	---	78,422	---	78,422	102,328
Capital assets	---	28,132,045	---	---	28,132,045	28,829,559
<b>TOTAL ASSETS</b>	<b>\$ 230,902,925</b>	<b>\$ 28,132,045</b>	<b>\$ 8,666,496</b>	<b>\$ 100,199</b>	<b>\$ 267,801,665</b>	<b>\$ 216,851,758</b>

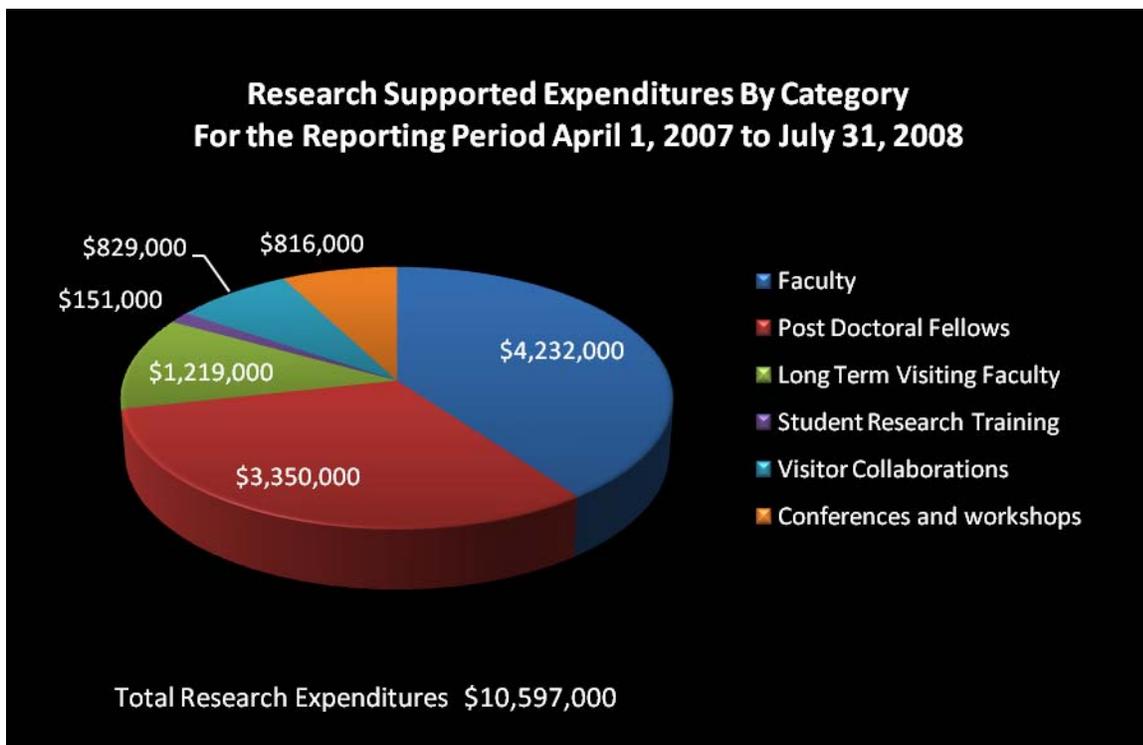
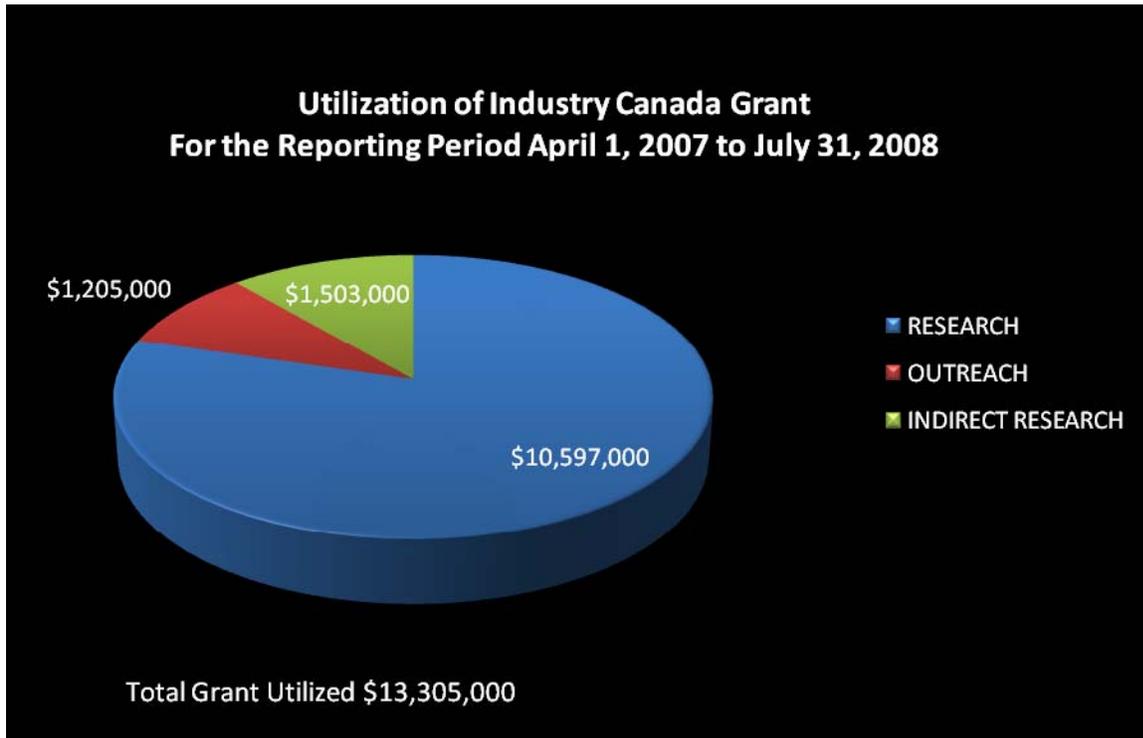
**LIABILITIES AND FUND BALANCES**

Current liabilities:						
Bank indebtedness	\$ ---	\$ ---	\$ ---	\$ ---	\$ ---	\$ 4,130,313
Accounts payable and other current liabilities	2,190,680	462,535	1,064,790	---	3,718,005	2,019,405
	2,190,680	462,535	1,064,790	---	3,718,005	6,149,718
Obligation under capital lease	---	9,482	---	---	9,482	24,582
<b>TOTAL LIABILITIES</b>	<b>2,190,680</b>	<b>472,017</b>	<b>1,064,790</b>	<b>---</b>	<b>3,727,487</b>	<b>6,174,300</b>
Fund balances:						
Invested in capital assets	---	27,660,028	---	---	27,660,028	28,400,675
Endowment	228,712,245	---	---	---	228,712,245	181,927,804
Unrestricted	---	---	7,601,706	100,199	7,701,905	348,979
<b>TOTAL FUND BALANCES</b>	<b>228,712,245</b>	<b>27,660,028</b>	<b>7,601,706</b>	<b>100,199</b>	<b>264,074,178</b>	<b>210,677,458</b>
	<b>\$ 230,902,925</b>	<b>\$ 28,132,045</b>	<b>\$ 8,666,496</b>	<b>\$ 100,199</b>	<b>\$ 267,801,665</b>	<b>\$ 216,851,758</b>

**PERIMETER INSTITUTE**  
**STATEMENT OF OPERATIONS AND CHANGES IN FUND BALANCES**  
**FOR THE YEAR ENDED JULY 31, 2008**

	<b>2008</b>					<b>2007</b>
	<b>Restricted Funds</b>					
	<b>Long-term Endowment</b>	<b>Capital Asset</b>	<b>Research and Outreach</b>	<b>Operating Fund</b>	<b>Total</b>	<b>Total</b>
<b>Revenue:</b>						
Grants	\$ ---	\$ 42,361	\$ 21,248,087	\$ ---	\$ 21,290,448	\$ 9,662,402
Donations	42,884,500	---	---	7,120,664	50,005,164	241,034
	42,884,500	42,361	21,248,087	7,120,664	71,295,612	9,903,436
<b>Expenditures:</b>						
Research	---	2,970	8,717,288	58,030	8,778,288	8,545,116
Outreach	---	---	1,987,117	14,348	2,001,465	1,436,291
Indirect Research and Operations	---	---	3,237,868	116,844	3,354,712	3,172,886
<b>Total Operating Expenditures</b>	---	2,970	13,942,273	189,222	14,134,465	13,154,293
Excess of revenue over expenses (expenses over revenue) before investment and amortization	42,884,500	39,391	7,305,814	6,931,442	57,161,147	(3,250,857)
Amortization	---	(1,728,000)	---	---	(1,728,000)	(1,901,011)
Investment income (loss)	5,535,359	---	---	(7,571,786)	(2,036,427)	9,749,339
Excess of revenue over expenses (expenses over revenue)	48,419,859	(1,688,609)	7,305,814	(640,344)	53,396,720	4,597,471
Fund balances, beginning of year	181,631,912	28,400,675	295,892	348,979	210,677,458	206,079,987
	230,051,771	26,712,066	7,601,706	(291,365)	264,074,178	210,677,458
Interfund transfers	(\$1,339,526)	947,962	---	391,564	---	---
Fund balances, end of year	\$ 228,712,245	\$ 27,660,028	\$ 7,601,706	\$ 100,199	\$ 264,074,178	\$ 210,677,458

## Expenditures by Activity



## **Criteria Applied to Eligible Activities**

In pursuing Perimeter Institute's three objectives at the highest levels of excellence, a wide array of criteria and performance-monitoring and evaluation policies, systems and processes (both internal and external) have been developed over the years and are re-evaluated and updated on a regular basis. These initiatives to measure outcomes, results, and impact include:

### **Performance Monitoring – Internal**

- Annual Reports on research activity submitted to the Director by all researchers for evaluation
- Annual Reports on research activity submitted to the Director by all research groups for evaluation
- Ongoing monitoring of publication and citation records
- Monthly updates and monitoring of progress of all scientific programs
- Post-conference reports and evaluation
- Annual evaluation of all scientific programs
- Mid-term researcher performance reviews
- Postdoctoral Fellow mentorship program
- Visitor research activity reports and on-going tracking of all output
- Monitoring of Postdoctoral Fellow post-PI placement success
- Monitoring of researcher international presence and impact through collaborations and invitations to lecture
- Internal review and evaluation process of all outreach programs and products

### **Performance Monitoring – External**

- Annual reporting to international Scientific Advisory Committee with subsequent performance assessment and recommendations
- Review of all Faculty and Associate hires, renewals, and promotions by Scientific Advisory Committee
- Peer review of publications
- Performance audits as per granting agreements
- External review and evaluation process of all outreach programs and products

## **Investment Strategy**

### **Private-Public Partnership**

Perimeter Institute exists through a cooperative and highly successful public-private approach to investment that provides for ongoing operations while, at the same time, safeguarding future opportunities.

Public partners finance the core research operations and outreach activities and, in keeping with individual grant requirements, receive ongoing updates, reports, and yearly audited financial statements as required to ensure value for money while remaining aware of the Institute's research productivity and outreach impact.

Private funds, including the initial philanthropic donation by Mike Lazaridis to the Institute, are protected in an endowment that is primarily designed to receive and increase donated monies by maximizing growth and minimizing risk in order to contribute to the strongest possible long-term financial health of the Institute.

Following the establishment of the Institute in 2000 with \$120 million in personal commitments from Mike Lazaridis (\$100 million) and fellow RIM executives (\$10 million each), contributions totalling in excess of \$54 million followed between 2002 and 2007 from multiple public sources involving all levels of government. Illustrating a strong resolve by public funders for Perimeter's success, the governments of Ontario in 2006 and Canada in 2007 renewed and increased their commitment to Perimeter Institute by contributing \$50 million each for expanded research and outreach operations over the next five years. These most recent government commitments were matched by a further donation of \$50 million by Mr. Lazaridis in 2008, bringing his personal and private contribution to \$150 million.

Perimeter Institute continues to be an innovative and successful example of a public-private partnership, uniting government and philanthropists in a common quest to secure the transformative potential of scientific research in Canada.

### **Governance**

Perimeter Institute is an independent not-for-profit corporation governed by a volunteer Board of Directors drawn from the private sector and academic community. The Board is the final authority on all matters related to the general structure and development of the Institute.

Financial planning, accountability, and investment strategy are carried out by the Board's Finance and Audit Committee. The Board also forms other committees as required to assist it in discharging its duties. Reporting to the Board of Directors, the Executive Director is a pre-eminent scientist responsible for developing and implementing the overall strategic direction of the Institute. The Chief Operating Officer (COO) reports to the Executive Director and is in charge of day-to-day operations of the Institute. Support of the COO is provided by a team of senior directors and administrative staff.

The Institute's Resident Scientists play an active role in scientific operational issues via participation on various committees in charge of scientific programs. Committee chairs report to the Executive Director.

The international Scientific Advisory Committee (SAC) is an integral oversight body, deliberately created to assist the Board of Directors and Executive Director to ensure objectivity and a high standard of scientific excellence. The SAC meets on an annual basis and submits detailed reports with recommendations to the Board and Executive Director following each meeting. The SAC is composed of eminent scientists drawn from the international community.

### **Financial - Investment and Management of Funds**

The Board of Directors of Perimeter Institute is supported in fulfilling its fiduciary responsibilities with respect to financial management through two Board committees - the Finance and Audit Committee, and the Investment Committee.

The Finance and Audit Committee is responsible for overseeing Perimeter Institute's policies, processes and activities in the areas of accounting, and internal controls, risk management, auditing and financial reporting.

The Investment Committee is responsible for overseeing the investment and management of funds received according to the Institute's Investment Policies that outline guidelines, standards and procedures for the prudent investment and management of funds. To ensure the safeguarding of public money, the policy incorporates specific restrictions surrounding the investment of Industry Canada grant funds in accordance with the terms delineated in the grant agreement.

## **Statement of Objectives for Next Year and Future**

Theoretical physics is one of the highest impact, yet lowest cost, fields in science. Its breakthroughs - such as those due to Newton, Maxwell and Einstein - enabled the creation of new technologies which have literally transformed society. Today, its ideas drive and guide giant international experiments like the Large Hadron Collider, which push technology to its limits and inspire the public about science. Theoretical physics is highly interdisciplinary, contributing key concepts to diverse fields from astronomy to neuroscience, pure mathematics to computer science. It is above all a creative field constantly reinventing itself, discovering deeper insights into nature while broadening its range of application.

Recognizing theoretical physics' fundamental significance and exceptional cost-effectiveness, Perimeter Institute was founded nine years ago in an audacious initiative to vault Canada to a leading position at this frontier of modern science and brand the nation as a world leader in basic research. PI's twin focus on quantum theory and gravity placed it at the apex of 21st century theoretical physics. The Institute's outstanding design and challenging mission attracted talented young researchers and faculty, fostering scientific success and rapidly winning PI a global reputation.

**PI now intends to capitalize on its past success and, over the coming years, aims to become the world's leading centre for research in theoretical physics, becoming a global resource for the field and stimulating major scientific breakthroughs.** PI has already created an exceptional research environment and culture, promoting innovation, cross-fertilization and the emergence of youthful talent. PI is now in a position to assemble a research community consisting of world-leading theorists in a range of complementary disciplines working together to explore the most difficult and important problems in the field.

Perimeter Institute aims to:

- Expand to provide the world's best environment and infrastructure for theoretical physics research by adding over 55,000 square feet to its existing facility in Waterloo. The expanded facility will consist of individual and group research spaces incorporating IT infrastructure as necessary to enable research and training at the highest level, including visualization and analysis of complex calculations and large data sets, and remote collaboration with international colleagues.
- Broaden its team of researchers in order to promote fundamental progress across the full spectrum of physics: from subatomic, to condensed matter, to cosmology, and complex systems, while retaining PI's ambitious focus on quantum theory and spacetime, and their unification. PI's strategically chosen combination of research directions is unique worldwide. The multidisciplinary approach instills a collaborative atmosphere which maximizes cross-fertilization of ideas and increases the probability of breakthroughs.
- Expand the cluster of top resident scientists to critical mass, recruiting Faculty, Associates, Postdocs and PhD students of the highest international caliber. The Institute will continue to position itself as a highly attractive destination in the international theoretical physics community by offering a dynamic environment with maximum research freedom and collaboration opportunities second to none. PI will offer its researchers more opportunities to interact scientifically with other experts in the

productive atmosphere and amenities of an award winning facility – in short, PI will ensure that its scientists are able to maximize their greatest research productivity.

- Fully establish its programme of Distinguished Research Chairs, making PI a second, "research home" to 40 of the world's leading theoretical physicists. Perimeter Institute intends to recruit very high quality researchers who are motivated by pure science and the research environment PI can offer. PI intends to be the destination for these researchers when they want to do a great piece of innovative research or write a great paper.
- Recruit the world's most promising graduate students and prepare them for cutting edge research via Perimeter Scholars International (PSI). This 10 month Masters level course offered in collaboration with partnering Canadian universities will eventually provide highly intensive research training for 50 of the world's most promising young theoretical physicists.
- Engage with experimental and observational centres such as the Large Hadron Collider; the Planck satellite; VISTA, VLT, the SKA and other giant observatories; and LIGO, LISA and other gravitational wave detectors. These huge, costly experiments are driven by theory, and theory is essential to the analysis and interpretation of the vast data sets they produce. By encouraging PI postdocs to visit these facilities and collaborate with observers and experimentalists, PI can help to stimulate new experimental and observational tests of fundamental theory, making its science more relevant and important.
- Host timely, focused conferences, workshops, seminars and courses. PI's flexibility, combined with the goodwill it has generated among the global theory community, places it in an excellent position to host exciting gatherings in cutting edge fields. PI will choose topics of workshops and conferences strategically, by identifying new areas of exceptional promise where a conference, workshop, seminar or school is likely to have a significant outcome.
- Increase its role as Canada's focal point for foundational physics research by increasing the number of PI Affiliates; by making its services, including state-of-the-art visualization for high performance computing, available to all Canadian researchers; by implementing advanced conferencing technologies allowing remote participation in workshops at PI; and by developing partnerships with experimental research institutions throughout Canada, such as SNOlab, TRIUMF and the Canadian Light Source.
- Develop collaboration agreements and partnerships to encourage scientific exchange visits, collaborations and joint activities with leading centres throughout the world in order to promote progress in research areas of common interest. PI has recently signed collaboration agreements with the Centre for Theoretical Cosmology, Cambridge and with the University of Sydney, Queensland University and Griffith University in Australia. Additional agreements are currently being developed with Stanford Centre for Theoretical Physics and CERN Theory Division. Over the coming years, PI will sign additional agreements with other leading institutes worldwide.
- Support the emergence of innovative centers of excellence promoting high level math and physics across the developing world, where a vast pool of talent lies waiting to be

unlocked. By promoting the growth of such centers, PI will be both contributing to the growth of local scientific and technical expertise, which will be essential to those countries' futures, and strengthening the flow of brilliant young people from around the world into theoretical physics, bringing important new energy and creativity into the field. PI is well-placed to become the hub of a global network of centres, branding Canada with a world-leading reputation in a field of fundamental significance to the future of science.

- Continue to build its highly regarded outreach program, focusing on growing the awareness of the importance of basic research and the power of theoretical physics; identifying and nurturing the most promising young scientists and steering them toward careers in theoretical physics research; and engaging in global outreach initiatives by exporting its products and programs to targeted areas internationally.
- Showcase Canada as a country that clearly recognizes that virtually every aspect of our modern technological society historically has roots in the ideas generated by theoretical physics, and that continued investment in such basic research places Canada in prime position to benefit from the technologies of tomorrow.