

The edge of physics

Canada's Perimeter Institute of Theoretical Physics was intended to become a world leader in the field. **Eric Hand** finds out if it has lived up to its ambitions.



Working at the Perimeter Institute for Theoretical Physics comes with certain perquisites. Whenever recruits arrive at the Toronto airport, for example, they are met by a limousine and driven west along Canada's Route 401 into the rich farmlands of Ontario. Eighty-five kilometres later, the limousine works its way through the streets of the town of Waterloo, and lets them out in front of a sleek building of black, green and glass squares that stands next to a pond in Waterloo Park. Stepping inside, the recruits find wall-to-wall blackboards, working fireplaces, a sauna, multiple dispensers of free coffee and the Black Hole Bistro, which serves free lunches on Wednesdays. And if they say yes to the recruiting pitch, they get a free BlackBerry smart phone — plus the power, even as a postdoc, to invite collaborators for visits of up to 18 weeks in the year.

The building itself is a gleaming architectural marvel rising from the site of a former municipal ice-hockey rink, which had to be demolished to make way. The significance is not lost on Perimeter's director, Neil Turok, a South African-born physicist (see 'A theoretical firebomber') who understands ice hockey's place in the Canadian psyche. The puck has been passed, says Turok. Waterloo will soon be known the world over for theoretical physics. "Part of what Perimeter represents in Canada is this search for self-confidence — the idea that, yes, we can do something better than anyone else," he says.

"What the Perimeter Institute represents in Canada is the search for self-confidence."

— Neil Turok

Besides, says Turok, "Mike thinks hockey is a complete waste of time". Mike Lazaridis, a Turkish-born engineer, is both the co-founder of Research in Motion — the Waterloo-based company that makes the BlackBerry — and a romantic about the transformative power of basic research. A decade ago he gave Can\$100 million (US\$95 million) to start Perimeter, and in June 2008, gave Can\$50 million more.

Lazaridis is hardly the first philanthropist to give money to science. For example, entrepreneur Fred Kavli stumped up US\$7.5 million to help found each of 15 research institutes — in astrophysics, theoretical physics, neuroscience and nanotechnology — that have been established in his name. Such gifts are generally tied to universities with existing facilities, but Lazaridis conjured up something where there was nothing.

Independent institutes aren't new either. In 1930, for example, siblings Louis Bamberger and Caroline Bamberger Fuld contributed US\$5 million from the sale of their department store business — about US\$65 million today — to launch the Institute for Advanced Study (IAS) in Princeton, New Jersey. And ever since, academics have been trying to create similar sanctuaries of pure research, free from the constrictions of teaching, grant writing and university management. But where institutes such as the IAS have a reputation for being "stuffy", as Turok puts it, Perimeter is intended to be "more energetic,

more free-thinking and less project focused".

Turok, who became Perimeter's second permanent director in October 2008, has been making energetic use of the riches at his command. In July, the institute began driving piles into the ground for a Can\$30 million expansion that will double the institute's square footage. And, in a time of recession, Turok is hiring. He already has the largest population of theoretical physics postdocs in the world, with 44. And he is planning to more than double his full-time faculty from 12 to 25. Eventually, the building expansion will allow the current research staff of 85 to triple to 250, including visitors. Stephen Hawking, a former colleague of Turok at the University of Cambridge, UK, is scheduled to preside over a decadal celebration in mid-October, which will provide an excuse to kick-start a campaign aimed at doubling the endowment from its present size of Can\$200 million.

Grand ambitions

In the institute's new five-year plan, which starts in 2010, Turok writes that the overarching goal is to be the world's leading centre for theoretical physics. But the pursuit of that goal actually started in 1999, when an intense, verbal and philosophical dreamer named Howard Burton was still trying to figure out what to do with a freshly minted physics PhD from the University of Waterloo. The 34-year-old Burton didn't seem headed for an academic career. And he was unexcited by the prospect of donning a tie and cranking out financial algorithms in New York City, as so many physicists were doing at the time. On a whim

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The gleaming facade of the Perimeter Institute.

— and perhaps with a whiff of desperation — Burton sent a cover letter to the chief executive of Research in Motion with the tagline: “Please help save me from a lucrative career on Wall Street.”

Lazaridis e-mailed back, telling Burton he was welcome to a regular job at Research in Motion. But might he be interested in this other idea he was pondering?

Intrigued, Burton agreed to lunch at an Italian restaurant in a suburban Toronto strip mall. “I’m talking about doing something big,” Lazaridis told him, according to Burton’s account in his new book, *First Principles* (see page 477). Lazaridis passed Burton a number written on a napkin — the beginning and end of the salary negotiation phase, apparently. “On a tactical level, I think he was feeling me out,” Burton says in an interview from Lyons, France, where he moved with his family after leaving Perimeter in 2007. But Burton was also feeling out Lazaridis, making sure the chief executive wanted some sort of scientific think tank — not another research lab for Research in Motion.

Burton took the job. On his first day of work, he came up with the name ‘Perimeter’, inspired by a walk around the curving edge of Lake Ontario. Next, he started visiting other physics institutes, partly to begin recruitment and partly to absorb the lessons of each. He decided that he wanted Perimeter to have a resident faculty like the IAS. But he also wanted to emulate the nimbleness of the Kavli Institute for Theoretical Physics (KITP) at the University of California, Santa Barbara. So he followed the KITP strategy of staying *au courant* with the hottest

A theoretical firebomber

“I haven’t properly moved,” says Neil Turok in his sparse office at the Perimeter Institute for Theoretical Physics in Waterloo, Ontario, the sharp residual of a South African accent poking through his plummy English tones. “I just literally came here with a suitcase and a bicycle.”

That is easy to believe. In June, nearly nine months after he moved from the University of Cambridge, UK, to become Perimeter’s new director, Turok’s bookshelf contains just two books and a bag of coffee beans. He has had the walls painted a neon green; Turok doesn’t share the previous director’s preference for black. The only real ‘baggage’, as he puts it, that he brought to Canada are the twin obsessions that fill the room’s blackboard.

One of those obsessions is theoretical cosmology: half the board is covered in formulae related to his iconoclastic account of the Universe’s origin. The other, represented by the organizational bubbles and management flowcharts filling the rest of the board, is his stewardship of a growing system of mathematical institutes in Africa. Back in June, he was about to meet with Canadian development

agencies in Ottawa and tell them his most fervent wish: that the next Einstein should come from the developing world. “It’s all about access,” Turok says, “because I believe that there are very many hugely talented people in the world who never realize their potential.”

He knows how eager to learn students from the developing world can be — because he was one.

Turok was born in Johannesburg, South Africa, in 1958 to anti-apartheid activist parents. One of his earliest memories was of a nighttime police raid. As police ransacked his house, his older brother stood to the side and hugged a banned Miriam Makeba jazz record under his nightshirt. In 1962, his father went to prison after a failed attempt to firebomb a post office. Later, says Turok, his mother was imprisoned for putting up a demonstration poster. After his parents got out of jail, the family fled — first to Kenya, then Tanzania and finally to Britain, where his father sold volumes of the Encyclopaedia Britannica door to door. When Turok entered the University of Cambridge, he had none of the means of his wealthy

peers. But he had seen lions.

Turok credits his parents for passing on their intensity. He also inherited an instinct for going against accepted ways of thinking. With his ideas for an ‘ekpyrotic’ Universe that arose out of a fiery collision rather than a bang, Turok has been a bit of a firebomber himself (see *Nature* **458**, 820–824; 2009). But even as he has tried to tear down theories based on the conventional wisdom, he has also been building institutions up.

In 2003, he opened the African Institute for Mathematical Sciences (AIMS) in Cape Town, South Africa. He and his parents — who returned home to become members of parliament in the 1990s — bought a derelict hotel and turned it into a school. AIMS now offers an immersive 9-month course for top students across the continent. A second AIMS in Nigeria is about to open with separate funding. Three more — in Senegal, Ghana and Ethiopia — are being contemplated. Turok says Can\$25 million could support these three and the Cape Town AIMS for five years.

The idea for AIMS arose decades earlier, when Turok was teaching mathematics to villagers in Lesotho before he began university. He recalls speaking to a miner while watching a football match on a dirt pitch. “He said he only liked one thing in school: Shakespeare. Then he recited some.

This to me was amazing. It made me realize that we all have this within us, this deeper side.” At AIMS, Turok wants an Einstein, not a Shakespeare, but the point is still the same. “It’s all about brilliant young people. There are some geniuses among them.”

E.H.



Neil Turok hopes to find the next Einstein in a developing country.

E. HAND

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research via visitors that arrive for short-term programmes and workshops (see *Nature* doi:10.1038/news.2009.699; 2009).

Burton also wanted Perimeter's researchers to tackle overlooked niches of science in the manner of the Santa Fe Institute in New Mexico, which was founded by a group of Los Alamos physicists in 1984 to explore then-obscure notions of complex adaptive systems. So he looked for researchers who were interested in neglected areas of physics such as the root problems of quantum mechanics, a research area he called quantum foundations; and non-string theory approaches to quantum gravity, which seeks a unification of gravity and quantum mechanics.

By 2001, Burton's first recruits were at work in Waterloo's historic post office building.

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In late 2004, his growing crew moved into their new home by the park. And by 2007, he felt he had achieved most of his goals. Burton stepped down as director in June of that year. He had never planned to stay forever, he says. But he could also feel a distinct chill in the atmosphere: he says that Lazaridis, the chairman of Perimeter's board, had stopped trusting and liking him — presumably because Lazaridis had learned that Burton was writing a book about his experiences. A Perimeter spokesman says that Burton's departure was a private matter and unconnected with a book.

Unique set-up

Whatever the reason, Burton still bristles over what he perceives as Lazaridis' excessive control over the institute. He concedes that Lazaridis has given more to Perimeter than has any other source. But he points out the inventor's largesse is nearly matched by more than Can\$100 million in federal and provincial funding. Even the city of Waterloo chipped in, giving Perimeter its park site. Why don't any of these institutions — or any physicists for that matter — have a seat on the board, asks Burton. "Is this a situation where, effectively, it is a rich man's toy?" Lazaridis has had an unusually strong hand in the management of Perimeter, agrees IAS astrophysicist Scott Tremaine, a Canadian who has served on Perimeter's scientific advisory committee. "The usual tradition is that you leave your hands off," he says.

Turok acknowledges that, when he was first offered the job, he thought it a bit strange that the board consisted of lawyers, businessmen and engineers. "Why isn't this governed by a group of scientists?" he asked. But he



Free coffee helps physicists such as Nima Arkani-Hamed (left) work all night in comfortable and relaxed surroundings.

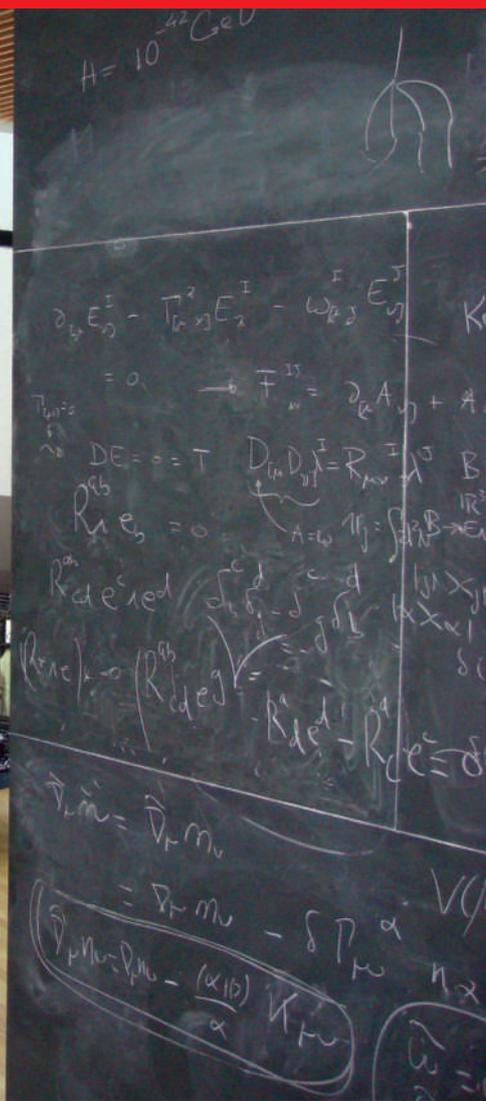
maintains that his relationship with Lazaridis, who declined to be interviewed by *Nature*, is fine — not least because Lazaridis has kept his promise never to interfere with Turok's authority on the strategy and scientific direction of the institute.

By now, says Turok, he actually prefers Perimeter's structure. The make up of the board helps give the place a risk-taking spirit that is more in keeping with a Silicon Valley start-up than an academic venture. And that means Turok can act faster. Since his arrival in October 2008, for example, he has doubled the areas on which researchers focus from four to eight, including a new emphasis on cosmology (see 'On the perimeter'). He has added a 9-month graduate programme to a place that had no teaching. And to remind staff that the coffers aren't bottomless, he has switched to a cheaper brand of the coffee that Perimeter provides for free.

This ability of Perimeter to move quickly — in matters both big and small — is what amazes Raymond LaFlamme, a quantum-information scientist who was plucked from Los Alamos National Laboratory in New Mexico as one of Perimeter's first hires. In 2002, he became director of a Perimeter spin-off: the Institute

for Quantum Computing (IQC) also in Waterloo, which has received a separate injection of nearly Can\$50 million from Lazaridis. The IQC has closer ties to the University of Waterloo, and therefore less independence than Perimeter, and LaFlamme has a telling example of the difference. He still keeps an office at Perimeter, and on a stand inside his office window is the receiver for a quantum-cryptography experiment that detects entangled photons from a transmitter on the University of Waterloo campus a few kilometres away. To allow the photons to reach the detector without destroying the quantum effects, LaFlamme needed to cut out a small piece of the tinted glass in his office window and replace it with clear glass. At a federally funded lab such as Los Alamos, he says, such a request would have been a nightmare. And at the nearby IQC building, where he keeps another receiver, the job took many months. At Perimeter, it took a day. "I went down the hall and talked to the guy in charge of the building. He said, 'Okay'. And — bang — it was done."

And yet — has this entrepreneurial energy led to new physics? Another bold goal of Turok's five-year plan is the expectation of "major scientific breakthroughs". "Everybody



On the perimeter

Neil Turok, director of the Perimeter Institute for Theoretical Physics in Waterloo, Ontario, has doubled the number of research areas that are focused on at the Canadian centre.

Quantum foundations

Concerns the still unanswered mysteries at the heart of quantum mechanics, the theory that describes the peculiar and probabilistic interactions of particles at very small scales.

Quantum information theory

Considers the processing of information held in quantum states that, unlike a classical bit, can exist simultaneously as both a 0 and a 1, and can be used to make unbreakable cryptographic codes.

Quantum gravity

Attempts to reconcile the forces of gravity called for by general relativity at cosmological scales, with quantum forces at very small scales.

Superstring theory

Describes a 'theory of everything' in which incredibly small strings create the fundamental forces of the Universe through their vibrations and interactions in 10 dimensions.

Particle physics

Concerns the interactions of particles at energy scales observed in astrophysical experiments, and created on Earth in accelerators such as the Large Hadron Collider at CERN, Europe's particle-physics laboratory near Geneva, Switzerland.

Cosmology

Considers questions such as: how was the Universe born? What were conditions like in the first seconds? What is the nature of dark matter? And why is the expansion of the Universe accelerating?

Condensed matter

Describes the behaviour of macroscopic materials under conditions achievable on Earth, such as superconductivity. But there are new areas of overlap with quantum mechanics and string theory.

Complex systems

A 'catch-all' category created by Turok to encompass research that lies at the intersection of other theoretical physics areas. This includes statistical physics, complex modelling and dynamic systems. **E.H.**



D. M. BENNETT/GETTY

Mike Lazaridis, head of the company behind BlackBerry phones, founded the Perimeter Institute.

wants a breakthrough," says KITP director and Nobel laureate David Gross, who is both a friend and mentor to Turok. But "you don't order results like that".

That's true, says Turok. But you can increase the odds by packing as much talent as possible into a room, and fuelling everyone with free coffee.

Different approach

The coffee is sometimes needed. Consider an evening in June, for example. The sun is sinking, but Nima Arkani-Hamed and Freddy Cachazo are just getting going. Several empty coffee mugs are scattered on Cachazo's desk.

Arkani-Hamed has just a day before he jets to Rome to present their work at a major string-theory conference, and they are feeling the pressure. Their hope is that, by dusting off a long forgotten corner of particle physics — S-Matrix theory, a model of particle interactions that began to be superseded by more fruitful accounts in the 1960s — they can clarify a very modern notion known as holography, which holds that information about the Universe can be encoded in fewer space-time dimensions than are apparent to us.

"Freddy and I are solving the mysteries of the Universe," Arkani-Hamed announces, only half-jokingly. The exuberant Arkani-Hamed sits at Cachazo's desk, while the more softly spoken Cachazo lounges on a sofa thumbing his standard-issue BlackBerry. One of Perimeter's young stars, Cachazo says he came to Canada from Venezuela partly to escape his country's heat. Arkani-Hamed, a 'distinguished research chair' at Perimeter, is a frequent visitor from the IAS. Keeping themselves going with a stash of cereal kept behind a stack of books, they work through the night, trying to determine the signs of 12 terms in an equation. They finally crack it

at 4 a.m., and leave an hour later for some sleep. It is a small step along what may end up being a blind alley. But it is the kind of effort that Turok wants: undirected, unconventional, ambitious.

Only time will tell whether these two physicists can reach their goal — or whether Perimeter itself will. "Early on," says Tremaine, "I was asked about Perimeter, and I said it might be the most important new institute since the IAS was founded," he says. "I still say that is true. And I still would use the word 'might'."

A few hours after Cachazo wakes up from his all-nighter, a delivery truck accidentally backs into the sprinkler system below Perimeter's car park. A fire alarm goes off. Dozens of

physicists emerge, blinking in the hot, midsummer sun, to discover a dislodged sprinkler pipe spewing a jet of water. Half of its spray hits Perimeter's entrance wall, and the young physicists — some in shorts, some in khakis — hap-

pily soak themselves in the mist. The other half of the jet soaks an Aston Martin belonging to Lazaridis, who is at Perimeter for one of his frequent visits. "Mike's getting a free car wash," says Turok, as Lazaridis ducks into his sports car.

The money man leaves, but the problems of physics remain. After the alarm is silenced, the physicists file back into the building's sun-soaked atrium, passing under a Greek inscription — the same phrase that supposedly hung from Plato's academy: "Let no one untrained in geometry enter here." Cachazo returns to his top-floor office, where the sun is beating in, and resumes work. But the air conditioning isn't working — perhaps because of the fire alarm. The temperature in his office climbs to 30° Celsius. He feels sluggish. His brain is useless. The Venezuelan declares he is ready again for Waterloo's winter: "That's why I moved to Canada." ■

Eric Hand is a reporter for Nature based in Washington, DC.

"Is this effectively a rich man's toy?"
— Howard Burton