Submission to Productivity Commission review of innovation in science and technology

Professor J. H. Rubinstein, Chair National Committee for Mathematical Sciences

Introduction

The mathematical sciences play an important role in economic activity, from scientific and technological research and development, to developing and analysing financial instruments and markets, to aiding in collection and analysis of data in drug and treatment evaluation in medicine, to assisting in the search for the genetic basis of diseases, to the optimisation of various industrial processes, such as transport and logistics. In this submission, a number of case studies are given to provide a snapshot of some current and recent innovation projects undertaken by mathematical scientists, to illustrate the range of areas in which contributions are being made.

A National Review of Mathematical Sciences is being finalised at present. We discuss some of the issues raised in this review, including difficulties of SMEs in gaining access to mathematical scientists and administrative arrangements with universities, such as intellectual property, which are seen as barriers for closer cooperation between business, universities and CSIRO.

A brief summary of some of the main problems facing the mathematical sciences in Australia is given. We feel that this is important to the long-term health of innovation and research and development in Australia and so is relevant to the current Productivity Commission enquiry. Many countries are concerned with maintaining their competitiveness in the mathematical sciences.

Finally, information is given about some institutions and methods used in Canada, to foster better opportunities for industry to benefit from advanced mathematical sciences. The network MITACS draws together public investment in research, private development and implementation of research outcomes. More details are given in Appendix 2 of this document.

Case studies

Australia has a long tradition of strong interactions between departments of mathematics and statistics and industry. There are a number of centres of mathematical modelling and more specialised centres in optimisation and statistical consulting centres which give advice to a variety of clients in industry, government and university research projects. CSIRO has a very active and growing Division of Mathematical and Information Sciences. An interesting activity of the mathematical community has been the mathematics in industry study group, where industries are invited to bring suitable projects along to workshops where groups of mathematical scientists work intensively with industry representatives. This has been successful in ongoing collaborations and is summarised in an appendix to this submission.

The case studies presented are divided into several groups. The first relates to the mining industry. Australia has a very highly developed network of companies providing services to the mining industry, often of a highly innovative nature. For example, Australia is a world leader in software for 3d visualisation for mine planning and operations and optimisation of the design of open-cut pits. Optimisation is a key part of efficient production and involves sophisticated mathematical techniques. Logistics is also included in this set of case studies, since transport is a crucial component of the industry.

The second set of case studies are concerned with medicine and health services. This is a growing area of demand for advanced mathematical services, from optimisation and queueing theory to look at patient movements in hospitals, to data mining in bioinformatics, to drug design. A noteworthy case is the spectacular success of the start-up company Silicon Genetics, founded by Andrew Conway, which was recently sold to Agilent.

The final set of case studies includes a short comment by Jack Gray who is a leading financial advisor and was previously an academic mathematician. Jack brought attention to an article on one of the most innovative companies in the world in fund management. Their techniques have been the subject of much attention recently and several groups in Australia are building trading systems using sophisticated mathematical and statistical techniques. The article is included as Appendix 4. The head of this group, Dr James Simons, is very concerned with the shortage of suitable people in the U.S. We are seeing similar issues in Australia, where for example, BHP-Billiton is outsourcing advanced mathematical problems to India and Russia, due to lack of suitable people in Australia. There are several Australian companies, which use advanced mathematical and statistical techniques for automated trading. There is a strong demand from large financial institutions such as banks and insurance companies, for people with excellent mathematical science skills at the PhD level. The second case study concerns the strong role that CSIRO has played in the success of the lens making company SOLA International. Finally there is a case study about a missed opportunity, which also highlights the `brain drain’ affecting the mathematical sciences in Australia.

MISG - bridging the divide between mathematics in Australian universities and industry.

The mathematics-in-industry study group (MISG) is an interesting attempt to bring together university mathematicians and statisticians with industry representatives to focus on problems suggested by industry. A brief account of other research-centre like activity is given in the Appendix 1.

Since 1984, Australia and New Zealand mathematical scientists have had the opportunity to interact with industry through the Mathematics-in-Industry Study Group (MISG).
The model for such an activity was originally based on activities at

the University of Oxford, but the MISG has been running in Australia and New Zealand for sufficiently long to have developed its own culture and traditions.
The annual MISG meeting lasts for five days: the first day is largely devoted to the introduction of problems to be studied. Participants self-select to contribute to work on one or more problems and on the last day, a summary of progress made and prospects for future work is presented for each problem.
Clients from outside the university sector (including private and public sector enterprises of all sizes) are invited to submit problems for consideration by the MISG.
The soliciting of problems is a major task for MISG organizers: many enterprises that would benefit from mathematical and statistical modelling and analysis are unaware of the potential value of collaboration with mathematical scientists.
Proceedings of the MISG are subsequently published, and sometimes the MISG work leads to ongoing collaborations with research or research training opportunities for university departments, or to consulting by research groups or individuals.

Review of Mathematical Sciences and impediments to innovation.

The review team had the opportunity to talk to a number of SMEs. Several issues came out in most of these discussions, as impediments for closer cooperation between academic mathematical scientists and this sector of industry;

- Intellectual property is a major issue – universities and academics were quoted as believing that an idea represented IP, whereas industry people see this as only the very beginning of the research and development process. Universities are seen as possessive and rigid about IP. Moreover Universities have problems recruiting suitably trained people with real knowledge of R and D in industry to assist with negotiations.
- SMEs often do not have the capacity to find the right academics with the right skills to assist in R and D projects. Another issue raised was the difference in `time-scales' between academic work and industrial pressures. Academics have teaching, supervision and administrative responsibilities, which make timely responses often difficult.
- A serious issue is a shortage of mathematical sciences students with the right mix of communication, team work, computational and IT skills. As examples, BHP-Billiton, CSIRO Division of Mathematics and Information Technology, Australian Bureau of Statistics and the Pharmaceutical industry generally report serious problems in recruitment of PhDs especially in Optimisation and Statistics.

Since Australia has a university system in which the mathematical sciences are funded at a particularly low level, providing appropriate training in communication, team work, computational and IT skills is not possible. In fact, the review has noted that the **average** decline in teaching and research staff positions in the GO8 Departments of Mathematics and Statistics from 1995-2005 is 30%, with higher levels of reduction in the smaller and regional universities. Moreover some departments have abandoned tutorials and are still facing further cuts due to financial pressures. So turning this around will not happen unless a major change occurs in the funding arrangements.

A number of leading mathematical scientists have emigrated in the last decade, including national leaders in areas such as continuum and fluid mechanics, optimisation, statistics and analysis. This is a very serious situation and we hope that the forthcoming national review will lead to a re-evaluation of the position of mathematical sciences in Australia.

1. Mining and logistics.

Some contributions by mathematical scientists to BHP-Billiton

- Project Falcon airborne gravity gradiometer.

Mathematical scientists replaced time-consuming computational schemes that correct for gravitational perturbations produced by terrain with highly efficient techniques based on the fast Fourier transform.

- Underground mine operations.

Without care in deciding the life-of-mine extraction schedule, geotechnical and accessibility factors may prohibit the extraction of areas with ore in the future. A mixed integer programming formulation incorporating these issues, enables BHP-Billiton determine an extraction sequence that is optimal for the entire life of mine.

- Multi-pit blended-ore mining operations.

The mine planner is faced with difficult decisions regarding both the extent of ultimate pits and the design and precedence of mining phases in each pit. Existing commercially available software was found to be inadequate and the design of mining phases in blended-ore operations largely depended on the expertise and experience of the particular mine planner rather than being an objective and repeatable procedure.The BHP-Billiton mine planning optimisation group has developed a mixed integer programming based mine planning optimisation software tool called Blasor, the only such tool presently available that is specifically designed to optimise the life-of-mine development plan, including the ultimate pit and mining phase designs, for blended-ore multi-pit operations.

- Petroleum exploration and production.

Deterministic modelling for petroleum exploration and production processes rely critically on sophisticated mathematical techniques and numerical algorithms. On-going activities in marine controlled source electromagnetics (CSEM) for identifying hydrocarbons in seismic bright spots are based on boundary value problems involving Maxwell's equations at low frequencies. Finite-difference, finite element and boundary integral equation methods as well as the more sophisticated perturbation methods for fields around slender bodies are used in delineating the reservoir responses during a survey. Final interpretation of the survey data however involves elaborate 3-D inversion of the surficial data, and due to a lack of information, regularization techniques from the theory of integral equations are applied to uniquely specify solutions.

Mathematics and the Mining and Milling Industries

Contributed by Professor Peter Hall, The Australian National University and The University of Melbourne

The story below was related to me by engineers and scientists working in the mining and metal-milling industries. It tells of the work of a remarkable CSIRO mathematician, Dr Frank de Hoog, who has made very substantial contributions to mineral and metal processing methods, not just in Australia but also internationally. His research has led directly to many hundreds of millions of dollars in export earnings for Australia.

In particular, Frank's mathematical work has resulted in significant improvements to chemical-based mineral separation in the aluminium industry, and to improved management of metal-milling quality. In the latter context he has developed a theory of buckling, involving models for residual stress. To indicate why this is important, it is helpful to note that escalating price constraints force milling companies to produce steel and aluminium sheets that are ever thinner, yet have to perform the same function as much thicker sheets. The strength of the sheets is proportional to thickness, but the tendency for the sheets to buckle is proportional to the inverse of the cube of thickness; therein lines the challenge. Frank's mathematical theory gives accurate predictions of the ways in which different parameter configurations affect buckling, and enables sheet-metal millers to modify their production lines in real time, so as to substantially improve the quality of Australian-made sheet.

In the same vein, Frank's mathematical work also leads to significant improvements in the way metal sheet is stored, in coils. Here, appropriate `winding policies' for producing the coils, using Frank's mathematical formulae to minimise stress, allow manufacturers to maximise the quality of sheet when the coils are unwound.

One Australian scientist, who has worked for several of the companies to which Frank has contributed mathematical advice, estimates the value of this work as `conservatively...into the hundreds of millions of dollars.' The depth, as well as the breadth, of Frank's mathematical expertise has multiplied the value and influence of his research; he has won the Australian Mathematical Society Medal for his theoretical research.

Frank has set mathematics to work to solve many other problems, besides those discussed above. I would single out, for special mention, Frank's work on the Kelsey Jig, a machine for centrifugal processing of minerals. At the time the story was first related to me, by Chris Kelsey in 2002, the Jig was being used to process one quarter of the world's total production of tin. Today it recovers more than half a billion dollars worth of ore worldwide, each year. This figure is expected to double by 2008.

The Kelsey Jig is the only commercial centrifugal jig in the world. It is employed to produce chromite, cobalt, copper, gold, iron, lead, nickel, platinum-group minerals, tantalum, tin and zinc. Although manufactured in Australia, it is used in more than a dozen countries.

While working for Bougainville Copper some 25 years ago, Chris Kelsey became aware of inefficiencies in the process of recovering gold from ore. He saw that machines that used chemical-based froth flotation processes were unable to extract a high percentage of the precious metal. This led Chris to investigate more effective, gravity-type systems. He was aware of the limitations of conventional jigs; such devices were unable to operate successfully in the fine-size range. He appreciated the need to increase the gravitational effect, using centrifugal forces. From these insights, the Kelsey Jig was born.

During the development process, Chris and one of his partners learned of the mathematical expertise available in CSIRO. It was in this connection that he first made Frank de Hoog's acquaintance. He was later to describe the occasion as `one of those fortunate meetings that happen very rarely in life, where synergy helped us create, over the years, a gravity separation device which is recognised in the mining industry as having the highest separation efficiency of any gravity device worldwide.'

The mechanisms that make a jig work, and especially the interactions among those mechanisms, are particularly complex. Frank overcame these challenges, and developed a realistic and tractable mathematical model, which addressed all the important operations. These results gave Chris Kelsey a fundamental, and practical, understanding of the potential performance of his jig, and enabled operating parameters to be determined.

That early work was to be the start of a long-term relationship between Chris and Frank. Their collaboration was essential to taking the Kelsey Jig from a concept to the runaway export-success that it is today. Many of the complex mathematical problems that Frank had to solve related to high-G fluid dynamics, pulsed shock waves and attenuation. (Current versions of the Jig exert forces up to 40 times that of gravity.)

Chris Kelsey's own remarks are an enthusiastic endorsement of the value to the venture of Frank's mathematical work:

As a result of Frank's work and determination we [were] able to fast-track development, reduce costs, and stay within the boundaries of practical application... Were there monetary benefits to this country? Undoubtedly this product has brought foreign exchange to this country, when you consider that for every large unit bought overseas around $500,000 is received...and that around 90% of this product is Australian made. The most significant monetary benefits, however, must be to the mining operators, certainly in many millions of dollars.

The success of the Jig has won Chris an Australian Innovation Hero Award. Today, design of the fourth-generation Kelsey Jig is well under way. Its physical parameters are still determined by the mathematical model established more than 20 years ago by Frank de Hoog. Its sales abroad will earn substantial export income for Australia, and its operation within Australia will ensure profits for our mining industry.

Extracting wealth from minerals- mathematics is essential

Contributed by David Lee, Emeritus Professor, University of South Australia

'Minerals and energy production and processing are now relatively larger in the Australian economy than at any time since federation' according to Alan Wood (The Australian, 20th May 2006) reporting on a recent address to treasury officials by Ross Garnaut. Modern mining, and the technology it uses, depends heavily on advanced mathematics, from the algorithms which support the signal processing of exploration data through the optimal design of mines to efficient materials handling systems at the production and export stages. Australian mathematicians have been active in supporting the advancement of the mining and its associated specialist software industry.

Consider the development of a new underground mine or major expansion of an existing mine such as Callie in the Northern Territory. A new shaft is a $100 million decision; the question is whether it is better to extend a decline and truck haul system deeper or install a vertical haulage shaft and if so what is the optimal location and depth of this shaft. The answer is informed by advanced mathematical network and geometric analysis embedded in a program developed by a mathematics team at Melbourne University. This team has explored a number of optimisation questions for the underground mining industry over the last decade and has developed software to optimise mine layouts which has already been used in more than 10 mines through Australia. Underpinning this new software is mathematical research which has lead to significant theoretical advances in the construction of three-dimensional networks with the gradient and turning circle constraints encountered in underground operations. Savings, where comparative designs were available, have been of the order of 10% on a life of mine basis. But equally, with the current shortage of experienced mining engineers, savings relate to enhanced productivity of the design engineers supported by such tools. Furthermore, these design tools allow management to explore alternative development options on an objective basis. Note that costs of development and operations in underground mines are so large that even a 10 metre reduction in the length of haulage paths - which may be many kilometres long - can correspond to a $100,000 saving, taking into account construction, ventilation, maintenance and haulage costs through the life of a mine. Companies such as Newmont Australia Limited, BHP-Billiton and MPI Mines have been significant supporters of this work.

The profitability of bulk mining enterprises such as those in Australia's Pilbara iron ore province depend on efficient transport and logistics operations. Major mining companies have used software developed at the University of South Australia in collaboration with rail transport consulting group TMG International to optimise train movements and plan for future expansion of their rail system. This software has the potential to provide major benefits for the operations of coal, wheat and general freight long haul train networks through Australia.

FreightMiser and ScheduleMiser

Contributed by Professor Phil Howlett, University of South Australia

FreightMiser is an on-board computer that provides advice to drivers of freight trains about energy efficient driving strategies. The technology was developed by TMG International and the Centre for Industrial and Applied Mathematics (CIAM) at the University of South Australia with recent support from the Rail CRC. FreightMiser won the Australasian Railway Association technology award in 2004 and is currently on trial with Pacific National. The FreightMiser technology has been supported by several different Federal Government grants. Previous trials in-service have shown that FreightMiser can save up to 15% of fuel costs and improve time-keeping by allowing drivers to drive more efficiently. The annual savings of this technology when it is adopted by Pacific national are expected to be of the order of $10 million dollars per annum. FreightMiser uses optimal control to calculate the speed profile that minimises fuel consumption subject to on-time arrival.

ScheduleMiser is a computer package that constructs train timetables on busy rail networks using a probabilistic algorithm called Problem Space Search. ScheduleMiser can draw many hundreds of low cost train graphs in a matter of seconds. Train graphs are currently constructed over many weeks and with great difficulty by a team of train controllers. ScheduleMiser is currently being used by BHP-Billiton on its Pilbara iron ore railways to plan daily and weekly operations and by ARTC to investigate potential network infrastructure investments as part of the Federal Government AusLink program. ScheduleMiser was developed by TMG International and UniSA with recent support from the Rail CRC. The potential benefits of this technology for organisations like BHP-Billiton and ARTC could be many millions of dollars per annum.

More information can be obtained from the TMG International website

www.tmg-international.com

Maximizing Value of Open Pit Mining Projects:

The strategic planning of open pit mining projects spanning several decades is critical to achieving maximum project value. Dr Gary Froyland (UNSW) and Associate Professor Natashia Boland (UniMelb), along with postgraduate students and postdoctoral fellows have created new mathematical models and optimisation techniques to guide BHP-Billiton on how to maximise the value of their mining projects. These new mathematical algorithms reduce costs, increase productivity, stabilise regional employment, and minimise environmental impact. The improvements are achieved not by spending more money, but by using mathematics (optimisation) to operate existing infrastructure more smoothly and efficiently. The mathematics has been encoded into software and is used at mine sites around the world.

Increasing Container Handling Efficiency at Port Botany

Container terminals are complex systems; containers have to be moved on time with limited space and equipment. Dr Gary Froyland (UNSW), Dr Thorsten Koch (Matheon/ZIB), Ms Nicole Megow (Matheon/TU Berlin), Dr Andre Costa (UniMelb), and Ms Emily Duane (UniMelb) undertook a study of Patrick Corporation's Port Botany container exchange area. Patrick is constructing an innovative gantry crane system to exchange containers between trucks/trains and ships. This team of mathematicians used optimisation techniques to create a movement schedule for the gantry cranes to maximise throughput and balance crane load. This was a joint research project with Patrick Corporation, the ARC Centre of Excellence *MASCOS*, and the German Research Centre *Matheon*.

Optimisation in the oil industry

Contributed by Associate Professor J.Yearwood, Director of Centre for Informatics and Applied Optimization (CIAO)
Professor A. Rubinov, University of Ballarat, Founding Director of CIAO

New powerful numerical methods for solving complicated optimisation problems have recently been developed in the Centre for Informatics and Applied Optimisation at University of Ballarat. These methods are based on some new results in two fields of mathematics. One of them is the so-called "Monotonic analysis", the theory of special classes of monotonic functions and corresponding sets based on ideas of abstract convex analysis. The other is a theory of discrete gradients, a new branch of non-smooth analysis. Both monotonic analysis and discrete gradient theory were studied extensively in CIAO for the last eight years. This research was supported by ARC discovery grants.

New numerical methods were applied for solving some complicated optimisation problems in various fields of Data Analysis and engineering. In particular, optimisation of oil production was examined in the framework of a joint project between CIAO and Woodside Petroleum Limited. The results obtained, lead to a significant profit increase in the oil industry.

2. Healthcare and bioinformatics

Contributed by Andrew Conway

History of Silicon Genetics

In the past fifteen years biochemistry as a science has significantly changed through the introduction of new measurement technologies such as robotics and miniaturization. These have allowed biochemists to make enormous numbers of measurements and produce enormous quantities of data. The Human Genome Project is the most well known manifestation of this, but there have been several other similar massive quantities of data generated. This has lead to a significant increase in the proportion of a biochemists time spend *data mining* – searching for useful information in a sea of mostly irrelevant data. This has caused a massive influx of mathematicians, statisticians and computer scientists into biochemistry and the naming of a new sub-discipline, *bioinformatics*.

Andrew Conway, a mathematics Ph.D. graduate from the University of Melbourne amongst other qualifications, was working at Stanford University in the biochemistry department when some scientists came to him with the results of a new kind of experiment, gene expression, which measured how active each gene was in a cell in a whole lot of different conditions. Having generated this data, the scientists did not know what to do with it, and so went to a mathematician for advice. After helping them statistically, and bemoaning the lack of appropriate labour saving tools, Andrew decided to start a company, *Silicon Genetics*, to make specialized tools for interpreting this kind of data.

In 1998 Silicon Genetics started out as a one-man show for a few months. With a useful prototype, Andrew hired two more people. After a few sales of the first product, *GeneSpring*, hiring continued, and Silicon Genetics grew to over fifty employees. Most of the sales, marketing and technical support staff had degrees (frequently Ph.D.s) in biochemistry or a related field; most of the developers had degrees (frequently Ph.D.s) in mathematics, physics, statistics, or engineering.

GeneSpring was used by thousands of researchers in universities, hospitals, research institutes, and pharmaceutical companies. As the first product of its type, GeneSpring had a variety of advantages that let it beat its fifty or so competitors who sprung up when it became clear that Silicon Genetics was profitable. In 2004 Andrew sold Silicon Genetics to *Agilent Technologies*, and returned to Australia. See http://www.silicongenetics.com for more details.

Andrew considers the mathematical experience he had to be an essential part of the success of Silicon Genetics, and found little difficulty adapting the general quantitative skills of the mathematical sciences to the specific framework of data mining in biochemistry.

Spin-off companies in bioinformatics and drug discovery

Professor Peter Adams and QEII Research Fellow Dr Darryn Bryant are University of Queensland mathematics researchers and council members of the Combinatorial Mathematics Society of Australasia. Both were trained at the University of Queensland, obtaining PhD degrees in 1995 and 1993 respectively, and have published extensively in theoretical combinatorics. Like many Australian mathematical scientists, they also have significant collaborations with colleagues in other disciplines.

Professor Adams is active in researching and developing new technologies in drug discovery and DNA sequencing, which are being commercialised through two University of Queensland spin-off companies, Protagonist Pty Ltd and Combinomics Pty Ltd.
Dr Bryant is the co-inventor of the colloidal barcoding approach to combinatorial chemistry that has led to the spin-off nanotechnology company Nanomics Biosystems. Colloidal barcoding allows rapid, high-throughput screening in drug testing and medical diagnostics. Between them Professor Bryant and Dr Adams are named on four patents arising from the application of combinatorial mathematics in chemistry and biotechnology, illustrating the significance of the mathematical sciences in new areas in biology

Healthcare delivery

Contributed by Professor Terry Mills, La Trobe University, Hon Visiting Professor, Bendigo Health

This is a report on my activity as a mathematician working with Bendigo Health. In this report, as always, when I use the term “mathematics”, I include pure mathematics, applied mathematics, statistics, and operations research, and some branches of computer science.

Bendigo Health (BH) is the major health care provider in north central Victoria. BH offers acute, sub-acute, residential, and mental health care services. Since 1998, I have been using my mathematical skills to assist BH with various projects in health care. Here is a summary of those projects.

Patient satisfaction is a key quality measure in health care. For several years, I have been involved in determining those factors that distinguish between inpatients who are satisfied with their stay in hospital and those who are not so satisfied. Using ideas from multivariate statistical analysis and machine learning, we found that the way in which patients are treated when they first arrive at the hospital is very important in their overall level of satisfaction. This means that the role of those at the reception desk is vital. In short, first impressions count. Bendigo Health can use this work to improve the overall level of patient satisfaction.

In the 2004/2005 budget, the Federal Government initiated a program of transition care in hospitals in co-operation with State Governments. This program is aimed at elderly patients who have completed a stay in hospital and, although their hospital treatment is complete, they need some transition care before returning to their home or other suitable accommodation. Bendigo Health has made a submission to the Department of Human Services, Victoria for a certain number of places in the transition care program. If we bid for too few places, then we will not satisfy local demand; if we bid for too many places then we will waste resources. We used queuing theory to assist Bendigo Health to estimate the number of places needed.

Waiting time and congestion in the emergency departments (EDs) of hospitals are well known issues of public concern. I am a member of a team of clinicians and researchers that is investigating activity in the ED at Bendigo Health. Although individual emergencies are not predictable, the overall patterns of presentations at ED are predictable. We are developing methods for forecasting the demand for emergency services in Bendigo; this will lead to evidence-based staffing rosters. We are investigating fascinating questions such as the following. What can we say about patients who leave ED without being seen? How accurate is the data from ED where there is so much activity? Are there better ways of organising patient flow in the ED? To solve these problems our team of clinicians and mathematicians use advanced models from time series analysis and other mathematical ideas with which clinicians are not familiar.

There are many other problems in which I have been involved recently. How do we monitor the spread of hospital acquired infection? What can we do to reduce the rate at which hospitals postpone elective surgery? How should a hospital position itself to meet its funded patient load? Can we model how patients flow through a hospital? In addressing these questions I use my research training as a mathematician ... and I use whatever mathematics I need to solve the problem.

Working at Bendigo Health has provided me with a lifetime of fascinating, important and useful projects.

All this work was done through mutual co-operation between Bendigo Health and the Department of Mathematics and Statistics at La Trobe University. La Trobe University approves of me using my research time in research that solves problems that benefit Bendigo Health. I devote about 20% of my university time working on these problems, I have taken study leave twice at Bendigo Health, and I write papers on these topics.

Key features of this co-operation are as follows.

Firstly, the work has been done by teams of people from Bendigo Health and La Trobe University. Hence, academics are involved in research problems of importance to real, local issues in health care, and clinicians gain research experience. It's win-win for both organisations.

Secondly, some research assistance has been funded by La Trobe University and Bendigo Health. This is indicative of the institutional cooperation.

Thirdly, these projects could not have been undertaken by the normal resources at Bendigo Health. The input from a mathematician was essential for these projects to be conducted at these levels. For me to make the contribution required the co-operation between Bendigo Health and La Trobe University.

Fourth, the collaboration between clinicians, health care professionals and mathematicians is essential for rigorous, practical applied research.

Fifth, this experience has convinced me of the importance of partnerships to academic research. The way forward for mathematics will be created, at least in part, by partnerships between universities and other organisations like Bendigo Health.

Finally, I come to the classroom filled with real applications of mathematics in my community. Once, I came from a meeting at BH in the morning to the classroom in the afternoon to lecture to first year students on ideas that our team used that very morning. I can show my students "equations in action" in our town.

An example of a meeting that addresses the contributions that mathematics and statistics make to the health sciences is given in Appendix 3.

3. Manufacturing and financial services

Faster to Market

Contributed by CSIRO Division of Mathematical and Information Sciences

Lens design software developed by CSIRO has enabled SOLA to improve their progressive lenses so that they now give clearer and more comfortable vision to millions of people.

Moving into new markets and rapidly creating unique new products is a key part of growing any business. But product designer are often constrained by the design tools at their disposal.

For SOLA International, a leading manufacturer of spectacle lenses, creating innovative new products and refining existing product designs came hand in hand with new design tools developed by CSIRO.

The new tools mean that SOLA can constantly work towards optimising lens design and performance, reducing the product design cycle time. They have also allowed SOLA to create more complex and sophisticated products for their discerning market.

"CSIRO's design tools allow us to quickly manipulate and optimise the surface of the lens to create a product that performs the way we, and our customers, want."
Dugald Rose, Research Manager, Lens Design, SOLA International.

CSIRO and SOLA have collaborated for over 14 years to develop the tools, As a result, SOLA has been able to market a stream of innovative new lens products. SOLA has used the tools to develop and refine progressive lens designs as well as create unique new products such as wrap around prescription sunglasses. At the same time, SOLA's market share has grown to nearly a quarter of the world lens market.

The design tools rely on mathematical models of the lens surface. CSIRO's mathematicians used a novel mathematical approach describing and analysing the lens surface. The software provides a systematic approach to finding the best possible lens surface to meet the product specifications.

Advanced mathematical modelling of this type is a useful tool for speeding up product design and reducing development costs. Modelling can point the way towards optimising a products performance. It also minimises costly and time consuming experimentation, removing the "trial and error" aspect of the design process.

Designers may have a concept of what they want a product to do, but not know exactly how to create it. For SOLA, CSIRO's mathematical tools have meant they can find the best lens surface to make their design ideas a reality.

"The ability of SOLA to remain at the forefront of this highly competitive industry is dependent on delivering innovative new products to the marketplace. This relies on our strong tradition in lens design and development. A crucial part of growing this strength has been CSIRO's work in collaboration with SOLA."
Dugald Rose, Research Manager, Lens Design, SOLA International.

Mathematics in Financial Markets

Contributed by Dr Jack Gray, GMO, www.gmo.com

(Jack Gray has spent 17 years as an investment manager, after a career as an academic mathematician at UNSW.

From the website - GMO is a private partnership that employs approximately 300 people worldwide. Investment management is our only business. We manage more than $102 billion in client assets, $29 billion of which is in asset allocation strategies.
Our global offices include the firm's headquarters in Boston and offices in San Francisco, London, Zurich, Singapore and Sydney.)

"In my world of finance/investing mathematics plays a dual role. First, it provides deep tools for modelling and understanding the behaviour of financial markets that (rarely of course) leads to new investment strategies. The Black-Scholes formula for valuing of options is the most famous example, one that has spawned entire industries, both commercial and academic. Second, and more prosaically, it provides the language and basic tools of much of finance. Galileo's claim that "nature is written in the language of mathematics" doesn't fully extend to finance, but it does come close. Often the language and tools are relatively unsophisticated, but to use simple tools effectively requires mastery at a far higher level.

It is notoriously problematic to measure the impact of either role on national productivity, as expected in an economy dominated by "knowledge workers". The US Department of Commerce is still revising its productivity figures from seven years ago."

Jack Gray, GMO

Dr Gray brought attention to the article in Appendix 4 about the funds manager James Simons, who is considered as possibly the leading funds trader in the U.S. A. Professor Simons had a brilliant career as an academic mathematician and has been a pioneer in bringing together a team of mathematicians, statisticians, physicists and other scientists to model financial markets. He is also a major contributor to mathematical sciences in the U.S and is active in Government panels on science and innovation.

Missed opportunity

Contributed by Professor Nick Wormald, Canadian Research Chair, University of Waterloo

Michael Luby is founder of "Digital Fountain" *http://www.digitalfountain.com/company/management.cfm*, whose products are based on "LT codes". He recently gave a talk at the SIAM (Society for Industrial and Applied Mathematics) conference that I attended.

These codes use a deletion algorithm on random bipartite graphs with given degree sequences for encoding/decoding. When analysing his codes to show they have low probability of errors, he/they used my technique for analysing algorithms by differential equations. They tweaked the proof in my 1995 paper to get a stronger error bound (independently in 2000 I had improved it past what they got). Stronger error bounds imply lower probability of not being able to decode after bits have been deleted. By the way, since it's a graph, there is no distinction between burst errors and others. The total number of missing bits is what is important.

In his talk, he said that these LT codes are being adopted as a standard for some forms of wireless communication. They are the first asymptotically optimal codes for reconstructing missing bits, in a certain practical sense, so potentially all mobile communication can find them useful.

This story made me think of my Australian Research Council (ARC) grant proposal for 1995 in which I applied to work more with the differential equation method. I dug out my rejoinder; there had been only one negative comment, as follows: in the referee's opinion " a lot of the ingenious research in this area will prove in the long run be of distinctly limited relevance for the rest of science"

I recall mentioning the referee comments to you at the time and you said something like "how can anybody tell". I guess you were right. The ARC application was unsuccessful. This points out some weakness in an evaluation system, which is prone to one bad comment from someone outside the area.

In the same rejoinder, I pointed out that two of the three referees made no comment in the "potential applications to technology" column even though the grant application mentioned the application to minimal perfect hash functions that had arisen just prior, in a joint paper I had with others, using random hypergraphs. The reason these erasure codes of Luby’s work, is almost exactly the same reason that the random hypergraphs are useful for hashing: it's a matter of being able to determine one variable because all the "adjacent" ones are known, and deleting it. Luby specifically said there is no known method of avoiding the probabilistic step of random bipartite graphs for constructing his codes.

(Note; Professor Wormald left University of Melbourne for a Canadian Research Chair several years ago.)

Comparisons with Canada

Canada has a network of research institutes in which the mathematical sciences find a focus. This has the advantage of efficient use of resources, providing excellent facilities for workshops and conferences and overcoming the problems of large separation of population centres. The three major institutes are the Centre Recherches de Mathematiques, which is run by a consortium of universities in the Montreal area, the Fields Institute based in Toronto and the Pacific Institute for Mathematical Sciences in the Western States, which has facilities at the University of British Columbia in Vancouver. All these institutes are partnerships between Universities, Provincial Governments and the Federal Government.

Recently Canada opened the Banff International Research Station, which is a facility for running advanced workshops in mathematical sciences. This is a cooperative venture between Canada and the U.S with some funding coming from the National Science Foundation. Finally MITACS is the major focus for industry/university collaboration in Canada and more details are given in Appendix 2.

Appendix 1

Australian research centres in the mathematical sciences

In Australia, we are trying to build up the Australian Mathematical Sciences Institute AMSI. This was begun with a strategic technology grant of $1 million dollars from the

Victorian Government with matching funds given by a consortium of university Departments of Mathematics and Statistics. The founding partners were Melbourne University, Monash University, La Trobe University, RMIT University, UNSW, ANU, University of Queensland. Many other departments have since joined, often as associate members at a lower subscription rate. The Victorian Government funding has now run out, so AMSI mainly exists on university departmental funds. AMSI would like to play a similar role to the three major Canadian research institutes, but clearly is limited by funding possibilities. It supports workshops around Australia in advanced topics in the mathematical sciences.

ICE-EM is the international centre of excellence in education in mathematics. It is funded by the Federal Government for four years and is running workshops for school mathematics teachers, producing new textbooks for schools and also runs summer and winter advanced workshops for undergraduate and postgraduate students in topical areas of mathematical sciences.

MASCOS is an ARC funded special research centre in complex systems and has a number of Chief investigators who are senior mathematicians and statisticians at MU, La Trobe University, ANU, UNSW, UQ. The main areas of research are in stochastic processes, dynamical systems, control theory, numerical methods, optimization, statistics and statistical mechanics.

Both AMSI and MASCOS undertake industrial work. In particular, one of the ways in which AMSI and MASCOS are coordinated is through sharing an Industry Manager.

Appendix 2

We give some information taken from the website of MITACS to give an idea of the scope of their activities in industrial collaboration.

Mathematics of Information Technology and complex systems. MITACS

Creation of MITACS - Phase I

MITACS began as a vision of the three Canadian Mathematical Sciences Institutes: The Pacific Institute for the Mathematical Sciences (PIMS) , The Fields Institute for Research in Mathematical Sciences (FI) , and the Centre de Recherches Mathématiques (CRM) . They envisioned a pan-Canadian network of projects each focused on using sophisticated mathematical tools for modelling industrial problems in key sectors of the Canadian economy.

The Institutes chose to realize this vision through the Networks of Centres of

Excellence Program (NCE). They submitted a letter of intent to form the MITACS NCE. In January 1998, the NCE program invited 11 of the 72 applicants to proceed to the full proposal stage. As one of the finalists, the institutes made a national call for possible projects for inclusion in their submission. More than 400 scientists responded with 85 project proposals. A peer-reviewed process resulted in 21 projects being selected to be a part of the final proposal.

MITACS was officially launched on February 19, 1999. By March 1999, all 21 initial research projects were underway.

Renewal - Phase II

MITACS has been successful in obtaining a 2nd round of funding in the 2005 national NCE competition. The Government of Canada will invest $21.6 million in MITACS.

“With this important funding, MITACS can forge ahead in building on our past successes, and develop and apply mathematical technologies to deal with problems that are strategically fundamental to Canada,” said Dr. Arvind Gupta, MITACS Scientific Director,

The funding will be provided to MITACS over four years and will be applied to bringing together university researchers with corporate and government partners in a collaborative effort to solve large-scale problems in the biomedical & health, environment & natural resources, information processing, risk & finance and communication, networks & security sectors.

“MITACS is driving the recruiting, training and placement of a new generation of highly mathematically-skilled personnel, which is vital to Canada’s future social and economic well being,” Dr. Gupta added. “Since our inception five years ago, well over a hundred private and public sector partners have seen first-hand the advancements that mathematical tools can deliver to their organizations, products and services. It’s clear that, although mathematics is perceived by many to be limited to the classroom or lab, it is actually playing an important role in society at large as the basis of the knowledge economy.”

Our vision

To harness the power of the mathematical sciences to address the inherent complexity of modern industrial and societal problems for the benefit of all

Canadians.

Our mission

MITACS leads Canada's effort in the generation, application and commercialization of new mathematical tools and methodologies within a world-class research program. The network initiates and fosters linkages with industrial, governmental, and not-for-profit organizations that require mathematical technologies to deal with problems of strategic importance to Canada. MITACS is driving the recruiting, training, and placement of a new generation of highly mathematically skilled personnel that is vital to Canada's future social and economic well being.

What we do

MITACS networks academia, industry and the public sector to develop cutting edge mathematical tools vital to a knowledge-based economy.

The only Network of Centres of Excellence (NCE) for the mathematical sciences, we currently have 305 scientists, 611 students and 169 partner organizations working on 32 ongoing projects, involving 48 Canadian universities.

To improve Canada's international competitiveness, our research focuses on five key sectors of the economy: Biomedical & Health, Environment & Natural Resources, Information Processing, Risk & Finance and Communication, Networks & Security.

MITACS Inc. is a federally incorporated not-for-profit society formed to administer the MITACS Network of Centres of Excellence.

Why MITACS?

MITACS was conceived and developed as a direct response to a recognized need for the mathematical sciences to contribute to the technological revolution. MITACS is vital to our national interests because Canada's short and long term strategic interests required:

A coherent and sustainable national vision, for strategically targeted mathematical research and training in emerging applied and computational sciences, efficient transfer of mathematical technology, and for the successful commercialization of mathematically based technologies.

Highly-skilled workers, to carry Canada forward into the 21st century: namely, a core of mathematical scientists armed with powerful computational and analytical tools, and with experience in applying mathematics in an interdisciplinary context. A looming shortage of personnel will develop into a critical handicap if not addressed. It takes at least a decade to train a cohort of future scientists, and the ranks of those currently in place is dwindling due to demographics and retirement.

An effective national organization, to implement this vision in close partnership with universities, the private sector, and key government agencies. An organization that will enlist Canada's top researchers, that will co-opt the support of Canada's private sector and that would lead the drive of recruiting and training the required HQP to enact the vision.

For Canada to achieve its goal (stated in the government's Innovation Agenda(1)) of becoming one of the top five R&D performers in the world by the year 2010, this country must have a strong applied mathematical sciences foundation to support its technological base.

(1)Canada's Innovation Strategy, February, 2002. http://www.innovation.ca/

Current Projects

A major re-organization of the MITACS research program was initiated by the RMC in 2003-04. This change focused the research where MITACS teams had developed distinctive strengths in emerging sectors of the economy.

The Biomedical & Health Sector: The biomedical sector is small but rapidly growing with 1999 revenues of $1.9B and about 8000 employees(1). The health sector is one of Canada's largest, expending more than $121B in 2003(2), and will soon represent 10% of the Canadian GDP. MITACS focuses on projects that model cells, pharmaceutical development, and spread of disease, as well as major health problems such as heart arrhythmias. These projects feature a combined effort of mathematicians and clinicians.

Theme Leader: Dr. Michael Mackey, McGill University

The Communication, Networks & Security Sector: Canada is viewed as a world leader in telecommunications with Ottawa being the home of many leading telecommunication firms. This sector accounts for 2.6% of Canada's GDP with annual growth rates of over 13% (compared to the 3.5% growth rate of the economy as a whole)3. Security of information and networks is increasingly becoming a central issue in this sector. Projects focus on network security, developing new cryptographic protocols, and quantum computing (a technology

that has the potential to revolutionize all aspects of communication).
Theme Leader: Dr. Evangelos Kranakis**, Carleton University**

The Environment & Natural Resources Sector: Clean energy technologies and pollution prevention are the fastest growing environmental segments, while natural resources account for 12% of Canadian GDP. With the increasing concern about global warming and our dependence on fossil fuels, problems in this sector focus on developing clean technologies such as fuel cells, and ensuring optimal oil extraction through new techniques in seismic imaging. Other projects involve bioinvasions of pests. Both the public and private sectors are well represented amongst the partners in this theme.
Theme Leader: Dr. John Stockie, Simon Fraser University

The Information Processing Sector: Since 1997, the Information Processing Sector has seen 14.1% annual growth and now represents 6.2% of the Canadian economy(3). Employment gains have resulted in twice as many IT workers in 2000 as in 1995. While the sector showed a slow-down in 2001 with only 0.9% growth, by the end of 2003 it was once again expanding briskly with a 15.2% increase in Information Processing equipment purchases by Canadian business(4). MITACS' emphasis is on the design and application of information technology to other sectors of the economy. Projects deal with issues such as handling of massive data sets, developing new tools for Maple, and tracking of interacting particles. Other projects deal with modelling shape for the animation industry and the optimal deployment of resources whether for courier companies or for VLSI chips. Many of Canada’s largest IT firms are partners on these projects.
Theme Leader: Dr. Frank Tompa , University of Waterloo

The Risk & Finance Sector: The Financial sector is fundamental to the market economy. In 2002, the Canadian financial services sector represented 5% of Canadian GDP and employed over 500,000 Canadians(5). The projects in this sector will consider new methods of evaluating risk, pricing commodities and financial instruments, and managing revenue.
Theme Leader: Dr. John Walsh, University of British Columbia

(1)Government of Canada report: Canada’s Innovation strategy, 2001.
(2)Canadian Institute for Health Information Report: National Health Expenditure Trends 1975-2003.
(3)Statistics Canada Publication 56-506-XIE: Information and Communication Technologies in Canada, 2002.
(4)Bank of Montreal Economic Research Analysis, January 30, 2004.
(5)Department of Finance: Canada, Fact Sheet, June 2002.

Appendix 3

International Conference on Health and Social Care Modelling and Applications (HSCM2006)

About the Conference

HSCM2006 was held in Adelaide during April 2006 at the University of Adelaide where approximately 50 presentations and keynote speeches were given. The papers highlighted the work that has been occurring in Australia and overseas, most of which involved some kind of mathematics or statistics.

HSCM2006 emanated from discussions at the Institute Of Mathematics And Its Applications conference on health care held in Manchester (UK) during 2004. The group consisted of clinicians, mathematicians, statisticians and analysts, including Mark Mackay from Australia. This group, has been responsible for Nosokinetic News (a free email newsletter on health care modelling) and collaborating on health care modelling research.

HSCM2006 provided a unique opportunity for practitioners and researchers to meet, exchange ideas, examine the current modelling trends and issues, and develop new solutions and research directions to ultimately, improve patient and client care by:

- Widening international understanding of the potential benefits of modelling health and social care systems
- Highlighting instances where theory meets practice and practice meets theory
- Encouraging close working relationships between practitioners, decision-makers and modellers, and
- Increasing understanding of the different modelling, computational and data analytical methods used to measure and model health and social care services.

The work highlighted the following:

- The health sector is one that benefits from multi-disciplinary work – including contributions from mathematicians, statisticians and those analysts with a maths-stats background
- The problems facing the health sector are not restricted to anyone Australian state, but rather are consistent around Australia and are similar in most developed countries
- There is a lack of engagement of mathematicians and statisticians in what could be loosely described as “health services and systems research”
- Health services and systems research is poorly funded in Australia – it is difficult to develop a base of researchers and analysts when funding is not large or secure
- The opportunities are significant – provided that there is collaboration

- Education of key stakeholder groups is required (hard to get engagement when people want the outcomes now, there is constant staff turnover, people have not received sufficient education to help them engage with other professions, etc).

Economic benefit:
- Short term – the conference
- Longer term – the work being used to improve the health care sector

Moving Forward

As a consequence of the conference the following activities are now occurring:

- Papers are being sought for publication in two journals (Omega and the Australian Health Review).
- Within Australia there is now greater enthusiasm for moving this work forward. Most of the people who have been involved in this work (health focus) work in small units that are spread across Australia. People are now keen to push this forward on the National agenda and thought is being given as to how this might occur.
- Internationally, the international convenors are taking away information from Australia as to how this might be progressed (Australia would appear to be developing and overtaking in this work, despite the work having being instigated in the UK). It is likely that there will be an international and at least an Australian (or Australasian) group with the aim to move towards some kind of formal structure in the near future (i.e. association).
- A new book on this work is being discussed.

Appendix 4

Long Island's richest man
A nose for numbers made James Simons rich, and now he wants others to get the same chance

Newsday Staff Writer; July 5, 2006
(This story has been edited to focus on issues of innovation and education).

He's been called the richest Long Islander, and not a lot of people know who he is. At an estimated $2.6 billion, James Simons' net worth is greater than Cablevision's Charles Dolan.

In May, the 68-year-old former math chairman at Stony Brook University gave the college $25 million to improve studies in math and physics, one of the largest gifts in its history. He also was named by the Bush administration to the National Mathematics

Advisory Panel to suggest ways to improve the teaching of math. In January he raised $13 million to keep a major nuclear physics experiment running at Brookhaven National Laboratory after it lost some of its government funding. And last year, Math for America, a foundation overseen by Simons, provided $25 million to recruit and train 180 math teachers over the next four years in the New York City public schools.

He even landed on television with CNN's Lou Dobbs to express concern about the nation's educational system and admitted that he finds it hard to hire anyone born in the United States for his hedge fund business -- which earned him, according to one estimate, a whopping $1.5 billion last year alone. "I can't find Americans," said Simons in that rare public appearance in February 2005. "That is, the majority of the people that I've hired in the last seven or eight years, high-quality research people, are not U.S. people. They're not born in America, and they weren't educated in America." Simons' public call to improve America's math and science training seems a distinct departure for him after three decades of quietly building up a fortune in the mostly unregulated world of hedge fund investing.

Simons declined to be interviewed for this story. But his genius for making money is well known among the financial cogniscenti. Salomon Konig, a Miami investor and a board member of the Hedge Fund Association, an industry trade group, says Simons is recognized as a top performer, comparable to other investment gurus like George Soros and Mario Gabelli. "He has some of the best people in the world working for him," Konig said. "They're the best quant house in the business, without a doubt," a reference to the firm's quantitative analysis methods. "They've made a lot of money with that approach." Simons' financial empire is based primarily on using math skills and computerized statistical models to select investments. By employing math and science experts -- rather than traditional Wall Street traders -- Simons' firm, Renaissance Technologies Corp., and its flagship Medallion fund have created remarkable returns for its roughly 500 investors, with an average 34 percent annual return since 1988, according to Forbes magazine.

High success rate

That's a success rate about double that of the standard hedge fund, which is a fund whose investors are usually wealthy individuals and institutions. Unlike mutual funds, a hedge fund is allowed to use aggressive investment strategies. The returns can be greater than that of mutual funds, but so are the risks. Simons' firm stopped taking new investors for Medallion by 1993; today, it has $10 billion in assets. Last year, Simons also launched a new hedge fund aimed at large institutional investors, hoping eventually to handle $100 billion. Simons' recent selection as the world's top hedge fund manager -- earning $1.5 billion in fees on a gross return of nearly 60 percent on his investments for 2005 -- underlined the success of his firm's math-driven methods.

"When it comes to pure wealth creation -- arguably the biggest motivation for the majority of hedge fund managers -- times have never been better," according to Institutional Investor's Alpha magazine, which conducted the survey and put Simons' face on its cover. "Thanks to the power of hedge fund math, driven by management fees and performance incentives, more managers are making more money today than ever before

... James Simons' legend grows apace with his portfolio and his philanthropy." "There's a lot of mathematics in what he does," said Irwin Kra, a longtime Simons friend and retired math chairman at Stony Brook who is now Math for America's executive director. "What is more surprising is his having mathematical talent combined with business acumen."

Simons earned a bachelor of science in mathematics from the Massachusetts Institute of Technology and a doctorate in mathematics from the University of California at Berkeley. For a time in the 1960s, he was a cryptanalyst at the Institute for Defense Analyses in Princeton, N.J. (until he was fired for opposing the Vietnam War), and later taught math at Harvard.

Geometry wunderkind

By the 1970s, he was a wunderkind department chairman at Stony Brook and eventually won the American Mathematical Society's Veblen Prize in Geometry for his work in differential geometry, co-authoring a theorem about spheres and other curved surfaces.

At first, Simons, the son of a shoe factory owner in Massachusetts, invested relatively modestly. Then, in the 1960s, he began trading commodities with Charles Freifeld, a fellow Harvard math whiz, whose strategy in playing the commodities market more than tripled their money. The experience opened Simons' eyes to the possibilities for market returns based on mathematical analysis. "His desire all along was to have a mathematical model so you don't spend your whole day trading," explains Freifeld, 64, now a private investor in Brookline, Mass. Freifeld says their most successful year as partners was 1974, when their investments in sugar commodities caught an inflationary wave and they rode it to great results. Over time, Simons used quantitative research methods to come up with math-based models for commodities, stocks and other investments that could be incorporated into a strategy for Renaissance, the firm that moved into its own headquarters in 1982. Simons and his firm kept their stake in these investments for a precise amount of time, shifting investments with lightning precision, and remained consistently reliant on their computer models to make money.
"Jim is doing something that you can show statistically works and isn't just luck," said Freifeld, who remains a friend though no longer involved with the Simons business ventures.

Historically, privately run hedge funds such as Simons' take advantage of market opportunities by placing large bets on investments that they consider undervalued or ripe for a sudden plunge, and cashing in when the time is right. Experts say the use of quantitative analysis in statistical arbitrage -- often called "black box research" because of its secretiveness -- can yield large payouts for investors willing to stomach the risk, considered greater than mutual funds or other more conservative investment strategies.

Computerized approach

Renaissance has invested more than $600 million in developing Simons' elaborate computerized system, an approach that has become somewhat the rage on Wall Street. As Institutional Investor recently noted, "At a time when big Wall Street firms are paring back budgets and covering fewer stocks with smaller rosters of less-experienced analysts, research firms that analyze shares using algorithms and computers rather than armies of humans are rapidly pushing to the fore."

After beginning in a small office on the Stony Brook campus, Renaissance eventually bought a 16-acre parcel along Route 25A in East Setauket for its headquarters -- complete with a gym, lighted tennis courts and library with a fireplace -- where approximately 100 staffers are employed. Its only effort at self-promotion seems a discreet sign outside the entrance. "When you go inside, it's like a little university," said Leo Guthart of Roslyn Heights, a longtime Simons friend, who attributes Simons' success to possessing a keen analytical mind with the plainspoken simplicity of a masterful teacher. Of Simons, he said, "He's not driven to make money as much as he's driven to analyze and solve puzzles." Rather than relying on a golden touch like other money managers who bet big in the market, Simons' methodical approach makes its profits through "the aggregate of a lot of small hits," Guthart explains.

Simons is known for giving high salaries and other perks to his hedge fund managers, about 60 of whom have PhDs in math, physics or other scientific disciplines. But despite his ties to Stony Brook's academic community, much of Simons' recent braintrust comes from foreign nations. Last year, he acknowledged his firm's trouble in seeking home-grown talent during his CNN interview and before a congressional subcommittee. "At my own company, for example, fewer than half of our more than 60 PhDs were born in America, and the vast majority of technologically based companies are in the same boat," he testified. "The leading edge of our economy is increasingly based on importing scientifically trained people and exporting scientifically based projects. It is absurd, and ultimately contradictory, that a country which aspires to maintain world economic leadership be so grossly deficient in producing the very workers who can make this possible. "

Stony Brook president Shirley Strum Kenny said "a number of Stony Brook PhDs work at Renaissance but a number of our PhDs are not native-born" -- indicative of a trend. Kenny underlines that Simons' efforts to improve math education, both locally and nationally, are part of his attempt to address that perception.

Education challenges

Simons is hoping his nonprofit group, Math for America, will become the model for a national campaign to improve the nation's math and science capabilities, with an urgency he likens to the Cold War threat this nation once faced. "In 1961 I was the first person in the United States to receive his PhD under the auspices of the National Defense Education Act," Simons told a Congressional panel last year. "Shaken by the Soviet Union's launch of Sputnik, and concerned by a shortage of scientists and mathematicians teaching at our universities, Congress responded by enacting this program. It was an outstanding success. I may have been the first, but a great many followed, and in less than a decade, whatever shortage may have existed was surely eliminated ... The challenge we face today is just as real and perhaps even more urgent -- to see that our nation is properly equipped to economically compete in the 21st century."