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Submission from the Australian Mathematical Society

Summary.
In this submission, the Australian Mathematical Society will argue that:

- A better funding model for the Mathematical Sciences is urgently needed.
- Mathematics should form a greater part of more university degrees than now.
- High school students must be encouraged to take advanced mathematics.
- The impending research quality framework must be closely monitored.

The State of the Mathematical Sciences in Australia.
There is much to be proud of in the Mathematical Sciences in Australia. Mathematics (in the broad sense of the Mathematical Sciences) has been often identified as "punching above its weight", in that it makes substantially more impact on the world scene than the numbers of people involved here might seem to justify[1]. While there may be historical or geographical explanations of the relative successes of some disciplines in Australia, the most plausible explanations of the success of the mathematical sciences here are quality and a healthy mix of pure and applied approaches to the discipline.

However, Australia's position in research in the mathematical sciences is under threat. The research community needs, if not to expand (as is happening in some other countries), at least to replace retirees, and to attract high quality mathematical scientists to the available positions. This is not occurring at the moment: many universities in Australia are shrinking their mathematics and statistics departments, by natural attrition in many cases and by retrenchments in a few. It is very difficult to attract the research leaders of tomorrow to Australia in the present climate.

The reasons for the shrinking of mathematical sciences departments include:

- the unfunded increase in the cost of teaching mathematical sciences,
- the tendency for university faculties such as commerce, education and engineering to take over and teach themselves topics that were taught by mathematicians and statisticians in the past,
- the reduction in enrolments in university mathematics programs,
- the reduction in enrolments in advanced mathematics subjects in high school, and
- the dropping of prerequisites and reduction of mathematical content in many university courses.

[1] See, for instance, paragraph 116 of Higher Education at the Crossroads, produced by the Ministry for Education, Science and Training in 2002. Web address of the relevant section: http://www.backingaustraliasfuture.gov.au/publications/crossroads/4.htm.

These factors are all contributing to a diminished mathematical capability in Australian business, industry, government, schools, universities, and the wider community. Australia is already experiencing a shortage of skilled tradesmen and professionals in many areas, and has had to increase overseas recruitment and government spending on technical colleges. The Australian Mathematical Society predicts a worsening shortage of Australian trained professionals in disciplines requiring a strong understanding of the mathematical sciences.

What is at risk?

A recent mathematical research project will exemplify one of the intellectual and economic contributions of the mathematical sciences to Australia. Dr Gary Froyland, a Senior Lecturer in Applied Mathematics, has been working with Patrick Corporation on the design of a new container terminal at Botany Bay. When containers are brought into the terminal, they are stacked, and when they are taken away, it is often necessary to move containers from the top of the stack to release containers at the bottom of the stack. Dr Froyland's project aims to minimise the number of times a container needs to be moved. With good design and software, at a one-off cost measured in tens of thousands of dollars, it is possible to reduce to zero the number of movements to free up the lower containers, and thereby make ongoing savings measured in hundreds of thousands of dollars every year.

There are many more scientific and technological areas, ranging from biomedical sciences through electrical engineering to financial risk modelling, in which Australia excels at using mathematical ideas to solve problems of national and human importance. The Australian Mathematical Society is worried that it is becoming harder for mathematical scientists in universities to contribute to the nation in this way, and that it may become impossible if the present trends are maintained.

Apart from harming the Australian research base, the changes that are occurring in the education of teachers, engineers, and others are damaging in other ways. The number of mathematically well-qualified teachers in high schools is decreasing. Education faculties argue that pedagogical studies are more important than discipline knowledge, and so teachers with limited discipline knowledge are replacing teachers with a solid background in mathematics[2]. The Australian Mathematical Society expresses particular concern about the lack of discipline training of primary and secondary teachers of mathematics and the lack of incentives for mathematical sciences graduates to pursue a career in teaching. Indeed, there are disincentives: a mathematics teacher with solid foundations in the discipline starts teaching on the same salary as a graduate of courses with little discipline knowledge but with considerably more debt relating to fee repayments.

A high level mathematical education adds value to the economy-in the UK, those who take A Level mathematics earn, on average, ten thousand pounds per year more than those who do not[3], and the Sydney Morning Herald's economics writer Ross Gittins says that Mathematics is the most useful subject for all students to take at school. Unless there are knowledgeable teachers in our schools, the Australian economy will suffer from an ever-greater lack of high school graduate with these essential skills.

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[2] The Deans of Science have recently documented the general lack of discipline knowledge of science, particularly physics, teachers. A similar report on mathematics teachers is expected soon.

[3] See A. Gray, *Does Teaching Matter*, Penguin; pages 30–34.

In the case of engineering and some other disciplines, the tendency is to argue for the "contextual teaching" of mathematical techniques rather that the teaching of mathematics per se. Weaker students, particularly, may find it easier to apply a recipe than to master a theory. But contextually trained students do not discover the "unreasonable effectiveness of mathematics"—to use an expression of the Nobel Prize winning physicist Eugene Wigner. For instance, a student who has learnt a recipe for relating inputs and outputs in a chemical plant but has not seen linear algebra and a wide range of its applications is not equipped to understand how the same mathematical ideas may be applied to fraud detection.

We are often told that young people will have a range of careers; if so, it is surely important to provide them with knowledge that can be used in all of these careers rather than in one only. A real mathematical understanding underpins much innovation, especially applications of new technologies. Short-term thinking in universities is not producing people with the flexibility to understand new technologies and incorporate them into their working lives.

What can be done to stem the tide?

The Review of the Teaching of Statistics in Universities has already clearly outlined the effect of the current funding model on the mathematical science in universities[4]. The funding model dates to the late 1980s and predates the need for mathematical sciences departments to maintain large computing laboratories. For instance, employers nowadays want statistics graduates to be experienced users of standard statistics software packages. There are similar expectations of graduates in other areas of the mathematical sciences. The expansion of the tertiary education sector since the 1980s also means that departments of mathematical sciences have to meet the needs of a more diverse student body and offer more courses to do so. In short, the current funding model does not reflect the real cost of teaching mathematical sciences relative to other disciplines.

The mathematical sciences are better funded in many other countries. For instance, the University of Edinburgh receives £4,835 per "unit of teaching resource" in Mathematics, Statistics and Operations Research, and £7,145 per "unit of teaching resource" in experimental sciences, and a mathematical science student therefore "earns" the university about 68% of the amount "earnt" by an experimental science student. At the National University of Singapore, the corresponding ratio is about 65%. In Australia the ratio was 2.2 to 1.3, that is, about 59%, and is still close to this level[5]. On the other hand, computer science is comparable to mathematics in terms of the resources for teaching and research, and a computer science student "earns" 73% of the amount that an experimental science student "earns".

The funding mechanisms (internal and external) affect behaviours in ways that are detrimental to departments of mathematical sciences. For example, more generous funding to teach engineering than mathematics encourages universities to convert mathematics subjects into engineering subjects. The resulting loss of service teaching

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[4] See http://www.statsoc.org.au/Review0405/ReviewofStatsFinalReport.pdf.

[5] In 2005, the government (DEST) contribution for a mathematics student (Cluster 4) was $4718 and the student contribution was $6837, a total of $11555. The corresponding amounts for a science student (Cluster 8) were $11757, $6837 and $18594. Thus, a mathematics student "is worth" about 62% of a science student. Students who have been at university longer have their contributions capped at a lower rate, and for these students the ratio is lower.

and the reduction of mathematical content in many degrees have seriously weakened mathematical sciences in the universities and is eroding the skills base in Australia.

The decrease in enrolments in mathematics programs also seems to be due to a lack of understanding, on the part of students and their parents, of the careers to which advanced training in the mathematical sciences leads. It is also possible that fewer schools are offering the advanced subjects because they cannot get the teachers they need and universities have dropped mathematics prerequisites for aspiring engineers and scientists.

Urgent action is needed to support the mathematical sciences.
The timeline for educating specialists in the many disciplines based on the mathematical sciences is longer than for tradesman. Further, it is increasingly difficult to attract students into the mathematically based disciplines through a combination of changes in the school curriculum and attitudes to teaching core skills, the range of courses and support for the disciplines in universities, the cost to students of courses in these disciplines, and the under-emphasis on high-level technical skills as a basis for informed decision making by our future leaders. Thus urgent action is needed to ensure the future supply of mathematically trained workers in business, industry, government and education.

The Society believes that short term and long term solutions are needed.

- A better funding model for the discipline is needed to reflect the increased costs of teaching and research. This would help the mathematical sciences immediately.
- Universities need to pay more attention to encouraging cross faculty courses to ensure that university study maintains the spirit of wide-ranging enquiry and intellectual rigour that has been one of its defining characteristics. In particular, Mathematics needs to be a greater part of many more degrees than it is now. This would improve the health of university mathematical sciences departments over a period of three to five years.
- More must be done to encourage students to take advanced mathematics at high school and to consider careers in the mathematical sciences, in order to increase student numbers in quantitative areas in general, and in the mathematical sciences in particular. The Society, in conjunction with others, has been involved in this, and is currently involved in a national workshop on promotion of mathematics and careers.
- Finally, the impending research quality framework must be closely monitored so that further damage is not inflicted on the mathematical sciences in Australia.

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