June 2017

Innovation and Science Australia
Department of Industry, Innovation and Science
GPO Box 2013
Canberra ACT 2601

Dear Mr Ferris,

The Australian Mathematical Sciences Institute (AMSI) welcomes this opportunity to respond the Innovation and Science Australia's Strategic Issues Paper.

As the national advocate for the mathematical sciences, AMSI has a significant body of policy recommendations and submissions concerning the innovation system, which we invite you to review. These documents can be found on our website at http://amsi.org.au/publications_category/publications/submissions/

Australia's mathematical sciences pipeline is critical to strategic planning of the national innovation system, underpinning as it does our STEM capacity. But it does far more than support science, it is a direct and crucial contributor to a world so dependent on data acquisition, data analysis, data security, and simulation.

While our discipline has a strong record in individual research and in research training, the pipeline has some major challenges. Mathematics is in dire shape in our schooling system with declining number of students studying intermediate and advanced maths at Year 12, the almost complete absence of university mathematics prerequisites for STEM degrees, significant gender imbalance and the worst out of field teaching problem in the OECD.

At the other end of the pipeline Australia is notable in the OECD for the absence of a well-funded national research framework, provided elsewhere by outstanding national research centres and institutes. Such frameworks are highly valued as drivers of knowledge transfer and innovation and for attracting international talent.

It is the firm view of the discipline, represented by AMSI and expressed in the Academy of Sciences recent decadal plan, that we must strategically invest now in the mathematical sciences at a whole-of-system level to achieve ISA's vision for a "top tier" innovation system in 2030.

Yours sincerely,

Professor Geoff Prince

AMSI Director

Innovation and Science Australia 2030 Strategic Plan Issues Paper

AMSI Submission
June 2017

Challenge 1 – Moving more firms, in more sectors, closer to the innovation frontier

- *What is your reaction to this challenge? What's missing, such as other opportunities? Can you nominate your three highest-priority responses to address this challenge?*

  1. Migrate research trained staff into the established private sector workforce to grow the rate of product innovation (as opposed to process innovation).
  2. Make transformative technologies, especially in data acquisition and analysis, readily available so that there is competitive and disruptive pressure on non-innovation-active businesses to adopt those technologies (or exit).
  3. Universities and corporates to create joint multidisciplinary hot house environments to encourage start-ups amongst young graduates and postdocs.

- *How do we ensure our current (and future) workforce has the necessary skills to support firms in their ambition and realise Australia's vision to be a "top tier" innovation nation?*

  Wider adoption of the gold standard industry engagement structures in use by some university disciplines and professions to maintain the currency of degrees; especially in areas of increasing demand such as data and computational sciences. (Broader education issues are addressed in response to Challenge 3).

- *What regulatory reform, and in what sectors, is required to help firms move closer to the innovation frontier and enable greater adaptability?*

  The recommendations of the Research and Development Tax Incentive scheme review should be implemented. AMSI particularly applauds the recommendation on the employment of new STEM PhDs.

Challenge 2 – Moving, and keeping, Government closer to the innovation frontier

- *What is your reaction to this challenge? What's missing such as other opportunities? Can you nominate your three highest-priority responses to address this challenge?*

  1. Mandate "Optimisation by Design" for all major public infrastructure projects. Here "optimisation" has its mathematical meaning. All too often hospitals, public transport systems (road, rail and air), ports and telecommunication systems are partially optimised after construction – a less than optimal outcome. There are a number of important examples where it has delivered both economic and social benefit, for example, the NBN and various projects undertaken by DST Group. Australia is far behind the USA and Germany in this regard. See https://www.informs.org/Recognizing-Excellence/INFORMS-Prizes/Franz-Edelman-Award and http://www.matheon.de/transfer/industry
  2. Australian governments should adopt an intern system to draw PhD students and postdocs into projects in the Public Service. This is effective in the USA and Canada in making government more innovative.

3. Break down the siloing which artificially separates scientists in government agencies and universities from each other. For example, ABS, BoM, CSIRO, DST Group, Geoscience Australia and the universities employ many mathematical scientists; many agency scientists being Australian university graduates so that the ties are close. However, it is extraordinarily difficult for a university mathematician to undertake joint work with one from an agency even though there are significant benefits in the knowledge creation and transfer, for example in the computational and data sciences. Inter-agency projects are at least as difficult. There are some positive counter examples but examining the ARC's funding rules is a good place to start.

- *How could government seek to leverage greater social benefit and public value from major program expenditure?*

  See "optimisation by design" discussion above.

- *Where can government reduce impediments to innovation within the public sector?*

  See university-agency and agency-agency co-operation points above.

Challenge 3: Delivering high-quality and relevant education and skills development for Australians throughout their lives

- *What is your reaction to this challenge? What's missing? Can you nominate your three highest-priority responses to address this challenge?*

AMSI believes that Australia's school education system is in dire straits and is structurally unable to meet ISA's vision for Australia in 2030.

It is our view that the transcendental skill sets of the arts and sciences must form the basis of our formal education system. These skills equip us to cope with, and to lead, innovation in an increasingly disrupted employment environment. Of course, we must deliver these in a contemporary context. But we should not be seduced by the latest technology or commercial trend into the wholesale displacement of core, life-long competencies.

The Australian school education system has some endemic, fundamental problems which are largely due to its fragmented nature – the Commonwealth graduates teachers from its universities and the jurisdictions employ them in their schools. Along the way we lose critical information, such as the numbers of secondary mathematics teachers who graduate and, of those, who register (as teachers) each year. Without such information, workforce planning is inadequate and the consequences unintended. This is why Australia has one of the worst out of field teaching problems in secondary mathematics in the OECD. This entrenched problem has been instrumental in lowering participation rates over 25 years in the Year 12 mathematics subjects which lead to tertiary STEM courses. In turn, this has led to the almost complete degradation of the mathematics prerequisite arrangements for tertiary STEM studies and downward pressure on Year 12 intermediate and advanced mathematics enrolments. Only 14% of Australian universities now have mathematics prerequisites in place for their science degrees. Students without the necessary background are known to suffer considerably worse tertiary outcomes across a range of disciplines than those who do. This is a deepening spiral of failure.

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AMSI has developed a significant policy base titled *"Securing Australia's Mathematical Workforce"* (http://amsi.org.au/publications/securing-australias-mathematical-workforce/) based on a broad range of evidence and published annually as the *"Discipline Profile of the Mathematical Sciences"* (http://amsi.org.au/publications/discipline-profile-mathematical-sciences-2016/). The Australian Academy of Science, in conjunction with AMSI and the discipline, last year published the *"The Mathematical Sciences in Australia: A Vision For 2025"* (https://www.science.org.au/support/analysis/decadal-plans-science/decadal-plan-mathematical-sciences-australia-2016-2025). This decadal plan makes strong recommendations, aligned with AMSI's, for the development of our discipline through to 2025.

Together with the Academy we identify three critical areas of need for mathematics education in Australia.

1. Prerequisites

Both AMSI and the Academy of Science advocate for the phased and universal introduction of mathematics prerequisites for university studies in science, engineering and commerce. This position has been publicly supported by the current and former Chief Scientists and by the current Minister for Education and Training, nonetheless Australia has no plan to deliver on this aspiration.

AMSI urges ISA to recommend university and government action on this issue.

2. Out-of-field mathematics teaching

Around 30% of Year 7 to 10 maths classes do not have a trained teacher of mathematics. This shortage is far from uniform with many low SES, regional and remote schools having no maths or stats graduates on staff and many well off metropolitan schools have a fully trained cohort of teachers of mathematics. Indeed, there are out of work mathematics teachers in some Australian cities. The result is that many children do not have access to an adequate mathematics education and many schools do not offer calculus based mathematics at Year 12.

AMSI's policy document contains a number of concrete measures designed to rectify this situation and which have been successful in the UK which this century has also experienced significant shortages.

AMSI suggests that the Commonwealth requires the States to address this issue as part of its school funding arrangements.

AMSI urges ISA to recommend government action on this issue.

3. Increase the rates of graduation of maths and stats specialists

As a percentage of all graduates, Australian mathematical sciences graduation rates less than half the OECD average. They have been falling consistently, contrary to international trends, and they are now around 40% lower than in 2003. Female participation in undergraduate courses reflects the participation in Year 12 advanced mathematics, it is half that of males. In honours courses women are outnumbered four to one. In part, this is because of the increasingly small number of our graduates going on to teaching and the concentration of graduations in the Group of Eight universities.

In a data driven economy Australian businesses, agencies, governments and universities are frustrated with the inadequacy of mathematical sciences graduate supply. While employer STEM campaigns have become common, they have yet to become coherent. There is not yet a clear and pervasive message that mathematics is integral to STEM and not simply the M on the end.

AMSI urges ISA to recommend government and public and private sector employer action to build graduation rates in the mathematical sciences.

- *How do we create a cohesive education and training system that is integrated into to the innovation and research system?*

The Australian Curriculum needs clear mechanisms for review and revision in order to maintain its currency and effectiveness. In order for this to happen, the Australian Curriculum needs to be nationally adopted! This is not currently the case with the senior curriculum (Years 11,12).

Fragmented adoption of the curriculum by the jurisdictions is the enemy of currency.

A second and important condition for the integration of the education system with the research and innovation system is a qualified teaching workforce. This is far from the case in mathematics, but the issue goes further than simply having teachers with appropriate pedagogy training: it is critical that every school have at least one genuine discipline expert in a leadership position in the mathematics and science subjects. To be concrete, the jurisdictions should return to policies to recruit honours graduates with pedagogy specialisations in their chosen disciplines. They should turn away from policies which have led to the recruiting of generalists to the exclusion of specialists and which have failed to provide discipline leadership in mathematics and the sciences.

Discipline leadership in schools is fundamental in stabilising the deteriorating staffing situation in mathematics in schools around Australia.

AMSI urges ISA to recommend government action on out of field teaching and leadership in mathematics.

- *How can we increase people and idea exchanges between industry and the education and training system?*

There are many excellent programs in place and in preparation to grow the engagement of industry with schools both at an individual and corporate level. One of the greatest challenges in mathematics, and probably also in the science disciplines, is the lack of industry exposure available to our teachers when they are/were undergraduates. Few teachers of mathematics have a clear perspective of the roles of mathematically capable professionals in the workforce. This is a serious brake on engagement and it should not be overlooked when planning industry engagement with schools.

It is to be hoped that the current expansion of Work Integrated Learning (WIL) experiences for undergraduates will resolve this problem in the long term, but by 2030 only a relatively small number of current teachers of mathematics will have exited the system and been replaced by WIL experienced graduates.

AMSI believes that teacher professional development is critical to bringing industry context to the curriculum. This professional development should be developed and delivered in conjunction with industry and government agencies.

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AUSTRALIAN MATHEMATICAL SCIENCES INSTITUTE

Challenge 4: Maximising the engagement of our world-class research system with end users

- *What is your reaction to this challenge? What's missing? Can you nominate your three highest-priority responses to address this challenge?*

Our Reaction

As a discipline which often plays the "long game" we believe that an emphasis on engagement must not focus solely on the short term and divert us from basic research, long term strategic research and, of course, long term engagement.
We are concerned that measures of engagement and impact will do exactly that and we urge ISA to give close consideration to protecting us from adverse behavioural responses.

AMSI itself has two major items on its engagement agenda:

A. PhD Industry Internships

AMSI has now accepted a contract with the Commonwealth to provide 1400 PhD Industry Internships from 2017 to 2020 across all public and private industry sectors and all disciplines, with an emphasis on women and STEM. This initiative builds on AMSI's track record of 200 placements to date and forms part of the Commonwealth's response to the recent ACOLA Review of Research Training (http://acola.org.au/wp/PDF/SAF13/SAF13%20RTS%20report.pdf) in the context of NISA.

Late stage PhD students spend 3-5 months with industry partners working on a tightly specified research project (these are NOT work placements). Their PhD supervisor acts as mentor; students are paid a stipend of $3k per month.

Each internship delivers:

1. A transformative impact on the student who gets to apply their research skill set in a commercial environment and on a short time frame, communicating with management and staff from different knowledge domains.
2. An ongoing relationship between the university and the industry partner through the involvement of the academic supervisor.
3. A solution to the industry partners problem.

These internships increase the employment of research trained graduates outside of universities and allow companies to test the viability of capacity in new areas.

They also produce intellectual property and deliver knowledge transfer.

Our target for 2020 is 700 internships heading towards 1000 in 2021. A similar program in Canada delivered 3500 HDR internships in 2016.

B. NCRIS mobilisation of mathematical sciences research

In our submission to the recent NCRIS Capabilities discussion paper (http://amsi.org.au/publications/2016-national-research-infrastructure-roadmap-capability-issues-paper-response/) we said:

> "Australia's big capability gap is the "at scale" flexible engagement of mathematical sciences researchers with our innovation system in the age of data and computation. Reliance on the mathematical and statistical capacity of end users in the Science and Research Priority areas and in Australian businesses is inadequate to the task of dealing with the major mathematical challenges of disruptive technologies."

We recommended the creation of

> "A flexible and responsive resource centre staffed by expert support personnel, servicing a diverse range of mathematical collaborations between mathematical sciences researchers and sophisticated end users from universities, agencies and the private sector.
>
> The Centre will also broker new collaborations and assist them to set up their legal and financial frameworks.
>
> The centre's expert support staff will be mathematicians, statisticians, optimisers, computational scientists and interns along with administrative and business personnel. The expert staff will be sourced from both the public and private sectors.
>
> The staff will be mobile and deliver both on site and remote services to collaborations. Secondary nodes may develop.
>
> The Centre will be co-located with a major university mathematical sciences school with a full spectrum of research interests.
>
> Projects will be of varying size but the imperative is to deliver proof of concept on time scales not otherwise achievable by the collaborating partners.
>
> The Centre will be linked to centres overseas and create a channel for the rapid adoption of international innovation.
>
> It will use other NCRIS facilities as required.
>
> The Centre will be part of AMSI and consequently hard-wired to the discipline and its networks."

We were disappointed that the published NCRIS framework does not address the mathematical sciences directly.

- *How do we create a comprehensive research training system that is connected to the needs of end users?*

  AMSI supports the finding and recommendations of the ACOLA Review of Research training.

- *How can we increase people and idea exchanges between industry and research? How can we increase the multi-disciplinary engagement and exchanges across industries?*

  See our reaction to Challenge 4 above.

- *Do we have the right incentives to encourage research translation?*

  Clearly a work in progress!

Challenge 5: Maximising advantage from international knowledge, talent and capital

- *What is your reaction to this challenge? What's missing such as other opportunities? Can you nominate your three highest-priority responses to address this challenge?*

We restrict ourselves to issues around knowledge and talent. Our response here is based on the position of mathematics as a truly international discipline.

Australia's approach to international research collaborations has some significant shortcomings. One of these is that, as a country, we constrain international collaborations by placing too much emphasis on focussed investment in specific geographic and discipline areas. Australia needs to be agile in responding to the international engagement programs of other countries. For example, if scientists in the EU wish to engage with workers here on quality projects for mutual benefit and can bring funds to the table, we need to be able to reciprocate even if the area is not officially identified by Australia for international collaboration. This agility will attract favourable international attention.

The European Union's IRSES program is an example. The failure of Australia to have a functioning International Linkages program has reduced the ability of Australian researchers to participate with European and other international partners in this scheme. Repairing this does not require more government to government linkages but simply a targeted scheme on our side.

The absence of such broad international engagement programs hampers knowledge and talent transfer between Australia and the world. It has resulted from a failure of policy makers to understand the international modus operandi of global disciplines including our own. And our international colleagues and research centres look elsewhere for large scale collaboration.

The Australian Mathematical Sciences Institute plans significant investment in a distributed, national research facility which will have a large impact on the flow of knowledge and talent to Australia. This is detailed at Challenge 6.

Challenge 6: Bold, high-impact initiatives

- *What is your reaction to this challenge? What is missing? Are there other opportunities?*

Again, we restrict ourselves to a discipline perspective.

Many OECD economies, certainly the innovative ones, have taken the initiative to establish high impact research centres on a national scale in the mathematical sciences.

The Academy of Science's *The Mathematical Sciences In Australia: A Vision For 2025* (https://www.science.org.au/support/analysis/decadal-plans-science/decadal-plan-mathematical-sciences-australia-2016-2025) recommends that (page 25) that

> "Australian universities should collaborate with the discipline to source seed funding for a new national research centre in the mathematical sciences with the objective of enhancing connectivity with industry and

> strengthening the international collaboration and visibility of Australian research in mathematics and statistics."

Mathematical sciences institutes and centres have become internationally recognised as an effective means of providing the infrastructure for both discipline-based and cross-disciplinary research essential for innovation and training across many areas. While AMSI itself delivers internationally recognised research training programs our national research programs are not as extensive as those of our OECD comparators.

The absence of such a facility is increasingly hampering our ability to attract international talent, create knowledge and to be early adopters in a discipline always at the frontier of new science.

With AMSI's considerable track record and current position, our discipline is in a sweet spot to deliver major benefits to the innovation system and to science from a timely investment in such a facility. This investment will be jointly sourced from AMSI, the universities, government and the private and philanthropic sectors. Note that this is not a project within the ARC's remit.

We urge ISA to take a system view of the mathematical sciences from schools through to research training, research and knowledge transfer. In a world so dependent on data acquisition, data analysis, data security, and simulation we must invest now for a "top tier" innovation system in 2030.