Report of Subcommittee IV

Steering Committee for the development of

The Mathematical Sciences in Australia
A Vision for 2025

The Decadal Plan for the Mathematical Sciences 2016-25

Mathematics and statistics
in government instrumentalities,
both state and federal

Decadal Plan Government Instrumentalities sub-committee Full Report to the Steering Committee, 3rd March 2014

Committee chair : Geoffrey Lee

Committee members : Peter Crossman, Melissa Gare, Bronwyn Harch, Tom Karmel, Nicholas McConnell, Blair Trewin

Overview

Perspective

Government Instrumentalities view the mathematical sciences from the perspective of employers of professional staff, who apply the skills and knowledge embodied in their formal qualifications to the goals of each individual agency. They employ about 15% of the qualified Mathematical Science workforce.

There is a strong interest from specialist agencies and bureaus in maintaining an on-going supply of staff, educated and up to date in the latest developments in the mathematical sciences, capable of adapting and applying that technical knowledge to specialised and difficult real world problems.

As well, general agencies require staff capable of adapting and applying quantitative skills founded on a mathematical sciences education to the business of the agency. There are untapped opportunities for wider employment of quantitative skills generally at all levels of government. Rigorous logic and sound and innovative analysis of data are indispensable to policy and decision making, and knowledge and use of the mathematical sciences is indispensable to the seizing of opportunities now possible with new technologies and ideas.

Finally, Government Instrumentalities are also interested in broader and better population numeracy. We include interpretation of numerical evidence, and basic understanding of chance, risk and uncertainty in ‘numeracy’.

Vision

An on-going potential supply of knowledgeable staff members to Government Instrumentalities requires that the education (primary, secondary and tertiary) and research segments of the mathematical sciences discipline are in good shape. With that in mind, we have the following vision for where the discipline should be in 2025:

A vibrant and active Mathematical Science discipline will be:

- taking advantage of advances in computational power, availability of data and information systems;
- engaged with and respected by other disciplines which have a strong quantitative element, such as engineering and economics;
- delivering mutually beneficial links between the academic, government and private sectors;
- enjoying strong connections between the different branches of the discipline;
- bringing overseas developments to bear on Australia's challenges, and in return sharing advances made in Australia; and
- acknowledged for its contribution to innovation and good policy throughout Australia.

Objectives

We propose five high level objectives to pursue that vision:

1. A thriving and vigorous mathematical sciences education sector in Australia (primary, secondary and tertiary levels)
    a. attracting and educating people capable of applying their quantitative skills to the major challenges facing Australia, and also
    b. educating a generally more numerate population capable of applying basic quantitative skills in their work and lives.
2. A strong and innovative mathematical sciences research culture in Australia, connected within and across disciplines in Australia and internationally, with a keen interest in applying their knowledge and skills to the private and government sectors.
3. Mathematical sciences taking a productive role in harvesting knowledge and analytics from new technologies and data, and in managing those operations
4. A valued and influential mathematical sciences culture (e.g. in policy and decision making), whose contributions are appreciated by senior executives, elected representatives and Ministers.
5. An appreciative population that understands the role of the mathematical sciences in supporting science and technology, the social sciences and commerce.

Stakeholders

There are two primary groups of stakeholders to influence.

Firstly, people who will invest their time and energy in mathematical sciences during their education and subsequent working lives.

Secondly, key policy and decision makers who will invest in the mathematical sciences when they appreciate the contribution that can be made to the economy, society and the environment. This group includes leaders and administrators in central and line agencies and importantly, community and political leaders, who ideally will reflect a broad consensus of the high worth of the mathematical sciences.

Recommendations

Our sub-committee believes that the most strategic of the direct recommendations about the discipline will fall within the purview of other sub-committees, notably the importance of the education and research sectors in supporting the mathematical sciences. We have assumed that issues relating to the delivery of mathematics and statistics education and research will be substantively addressed by recommendations from other sub-committees.

Our recommendations are over-arching proposals about creating the culture or environment where the above objectives can be met.

We have four specific recommendations aimed at the two sets of stakeholders and all objectives above. All recommendations apply throughout the decade. All are the responsibility of the Academy of Science to initiate.

Recommendation 1 – Dialogue with potential mathematical sciences students

There should be an on-going campaign to inform and excite potential students, and those who influence their education and career choices, about:

- *the variety, range and rewards of careers and occupations which are accessible as a consequence of a solid mathematical sciences base in their education; and*
- *the many different ways that the mathematical sciences contribute to sustaining and advancing the well-being of people.*

The campaign should not be limited to "pure" or "specialist" Mathematical Science occupations; rather it should encompass the breadth of job options and career pathways that stem from an education with a base of solid quantitative skills. We have come across numerous examples which demonstrate wide, interesting and rewarding career opportunities. The recommendation is about on-going efforts to ensure this information is accessible and visible to students before they make decisions about the subjects they will study.

Recommendation 2 – Dialogue amongst specialist Government Instrumentalities

There should be periodic meetings of relevant executive level staff from such agencies to share experiences and coordinate approaches to improving the quantity and quality of mathematical sciences knowledge in their staff, including in the pool of potential recruits. The objective of the dialogue is to enable good ideas and activities which already exist within individual agencies to be mobilised on a wider scale.

Initiatives that we know about include:

- recruitment strategies (cadetships, internships, fellowships);
- pay scales (specific recognition of specialist skills);
- career structures (technical specialist versus managerial streams), joint appointments (Public Service and academic);
- organisational structures (e.g. CSIRO's recent restructure to merge CMIS and IT);
- approaches to retaining female staff with professional qualifications whose careers are interrupted by family commitments;
- support for mid-career refreshment for technical specialist staff;

- links with specific university departments (e.g. ABS's links with the University of Wollongong; ABS's recent engagement with the Australian Technology Network; and
- outreach to schools (e.g. CSIRO runs a number of valuable programs; ABS supports Census@Schools)

The specialist government instrumentalities (CSIRO, ABS and DSTO especially) have been concerned about future supply of mathematical scientists for quite some time now, and are implementing a number of strategies to address their concerns. Other (smaller) specialist agencies face similar challenges, but lack the critical mass and resources to act. The proceedings of the dialogue should be publicised to enable all Government Instrumentalities to benefit. The list of interested agencies could be expanded further by including those who employ other quantitative professionals – e.g. engineers, economists, geo-scientists, actuaries, meteorologists, etc. which are dependent upon strong secondary and tertiary mathematical sciences education.

It would also be worth broadening these discussions to include representatives from the private sector, and from the education sector. The professional societies and the Academy of Science could play a role here, for example by sponsoring and convening roundtable meetings.

Recommendation 3 – Dialogue between mathematical sciences and key policy and decision makers

There should be an on-going high level dialogue to impress key policy and decision makers – at least for major Government Instrumentalities – of the ways that the mathematical sciences generate benefits for Australia's economy, society and environment and to brief them on emerging useful applications.

While there is much the Mathematical Science community can and should do for itself, some key factors are not within the community's power to control. Therefore, for the Plan to be implemented successfully, we must convince those who have influence and authority.

Although the material for this promotion might draw on examples and material also used in Recommendation 1, this would be a much more specific exercise in engagement and dialogue, targeted at a well-educated and hard-nosed audience. The campaign would require on-going engagement from the most senior and well respected members of the community's disciplines, with the highest levels of executives in governments, private enterprise, and the education sector. Ideally this would be an enduring dialogue which over the next decade would create a feedback loop which could be used to adapt and refresh the Decadal Plan itself.

The initial draft of the Decadal Plan could be used as a trigger for commencing dialogue at this level, and building opportunities and forums for further engagement.

Recommendation 4 – Promoting the mathematical sciences in the context of 'big data'

There should be an on-going effort to provide leadership and central participation by the mathematical sciences in the emerging opportunities for what has become known as "big data", i.e. the combination of computational power, burgeoning data generation and new analytics, to be applied to policy and decision making in Government Instrumentalities.

Information technology and advances in instrumentation are changing the cost equations for data acquisition and analysis. The current challenge is to manage and interpret data correctly, and then to analyse and model effectively and rigorously. The potential pay-off for policy and program administration is huge.

However, there are a number of specific necessary conditions to ensure the success of the “big data” “revolution”. For example:

- support for “data management” and “open data” initiatives. These initiatives increase the value that can be extracted from government information assets, and can facilitate innovation in the private sector as well. Redesigns of IT systems are obvious times when data management practices can be improved, and data can be “opened” up for use. Advice from, say, professional statisticians or quantitatively skilled policy analysts should be mandatory at this point; and
- making sure that people have the right skills to analyse and interpret the data when it is available. This implies very high level quantitative skills. Technology may have made calculation cheap, but it has increased the risk of poor analysis leading to costly incorrect conclusions. Executive leaders should be alerted to this so they can ensure their agencies have people with the requisite quantitative skills. They should be encouraged to create a culture where rigour is applied and quantitative skills are recognised and valued.

Conclusion

The future of mathematical sciences is important to the government sector - both in specialist agencies and in general government. An insufficient supply of people with quantitative skills will impact on the quality and efficiency of government services, and the level of innovation. Much of the efforts required to sustain the supply will fall in the education sector, at school and tertiary level, outside the remit of most government instrumentalities. However some instrumentalities at Australian and State level administer government policies and funding mechanisms which strongly affect the education and research sectors. Senior decision makers must be kept aware of the benefits generated by the mathematical sciences, and engaged in the efforts to ensure their health and vitality.

Full Report

1. Introduction

This report considers the future of the mathematical sciences from the perspective of government instrumentalities. The mathematical sciences (in Australia and world- wide) constitute a complex interlinked system. The Australian Public Services are consumers of the outputs from other parts of the system. This sub-committee view is that the most crucial of the strategic actions that are required appear early in the sequence of events which will lead to the next generations of mathematical scientists.

Themes

The sub-committee identified 4 themes to be addressed in the course of our work.

1. Establishing and describing the value of the mathematical sciences for Australia's government instrumentalities
   - (where necessary countering perceptions of the lack of importance of the mathematical sciences)
2. Qualifying and quantifying the demand for mathematical scientists (in the public sector) including considering :
   - the range of careers available and magnitude of the demand,
   - the variety of skill sets required to complement core mathematical science expertise in order to be successful, and
   - the attractiveness of careers in a government instrumentality for mathematical scientists
3. Creating an environment where the mathematical sciences can best contribute to Australia
   - in government / through government policies
4. Improving linkage and engagement between mathematical scientists in government agencies and :
   - Other disciplines in government agencies
   - Groups of mathematical scientists across government agencies
   - Maths Scientists elsewhere :
     - in academia
     - in industry
     - across all the sub-disciplines and specialities of the broad field we call mathematical sciences

Process

The group met 6 times (5 via phone conference, once in person at the December 2013 workshop).

To seek and encourage submissions from government instrumentalities, extra presentations about the Decadal Plan, tailored to the interests of government instrumentalities, were arranged early in 2013 in Sydney and Melbourne. In Brisbane an exhibition booth (courtesy of SSAI) at the NatStats conference, which was attended by upwards of 300 public servants from state and federal levels of government, was used to advertise the Decadal Plan process.

Submissions relevant to our sub-committee were received from DSTO, CSIRO, AMSI, ABS, and several individuals from other agencies. Particular note should be taken of the detailed submission from DSTO, which articulates well the extensive range of topic areas where mathematics and statistics contribute to Australia's security and defence forces, and the broad demand for quantitatively skilled staff, not only those with mathematical science qualifications, but more broadly with qualifications from a range of quantitative disciplines such as engineering, physics, and information technology.

We sought to quantify the demand for Mathematical Science skills, by examining the current workforce. Data from the 2006 and 2011 Population Censuses were analysed, to provide information about the number, age distribution, employment (occupations, industry and sector) and incomes of the current population of people with Mathematical Science qualifications in Australia. The detailed data explorations will be recorded in a supplementary "Stats Pack"; this report will refer to the broad conclusions. The Office of the Chief Scientist is preparing a report on the broader STEM workforce, which will provide a useful "control" group for the mathematical sciences workforce.

A number of examples have been gathered, to form the basis for case studies illustrating the career options in government instrumentalities available to people with Mathematical Science qualifications, and the types of contributions the mathematical sciences can make to fulfilling government agencies' goals. They could form a starting point for recommendation 1.

2. The mathematical sciences in Australia's Government Instrumentalities

Specialist agencies contrasted with General government agencies

Many agencies are part of general government and are directly responsible to a Minister for implementing a particular area of government policy. Other agencies have more specialised purposes, and are often established in legislation as statutory authorities, or research agencies, though sometime they are embedded in a related line department. Examples of specialist agencies at the federal level include the

- Australian Bureau of Statistics,
- CSIRO
- Defence Science Technology Organisation
- Bureau of Meteorology
- Reserve Bank of Australia
- Australian Institute of Health and Welfare
- Bureau of Rural Science
- Australian Bureau of Agricultural and Resource Economics

In terms of appreciation of the mathematical sciences we observe quite a strong distinctionbetween the general government and the specialised agencies. The specialised agencies often employ sustainably large numbers of professional staff with qualifications pertinent to their function, including people with mathematical sciences qualifications. Such agencies often provide an environment which recognises the contributions that professional mathematical sciences staff can make, and which is relatively supportive of the mathematical sciences profession, both at operational and strategic levels. However in general government there seems to be far less of a strategic perspective about the mathematical sciences.

The mathematical sciences "profession" in the Public Service, as distinct from mathematical sciences as a "discipline"

Mathematical sciences work in the Public Service is invariably focussed on resolving a problem or completing a task relevant to the purpose and goals of the agency. People undertaking such work might be termed "mathematical sciences professionals" - people who employ their mathematical sciences skills in the course of their employment - as distinct from people with mathematical sciences skills and education working in some other environments - such as mathematical sciences scholars or mathematical sciences educators. Frequently the mathematical sciences professionals work with a larger group of people, with different qualifications and education backgrounds, who bring different insights, viewpoints and contextual information to the tasks and problems being tackled. The underlying task is the key objective; mathematical sciences skills often make significant contributions but are not of themselves the purpose of the efforts.

The requirement to solve problems in concert with other people and disciplines adds to the competencies required from mathematical sciences professionals working in the Public Service, over and above core mathematical sciences knowledge and aptitude. However it is not as simple as a requirement for a broad mathematical sciences education plus 'communication and teamwork' skills. In some cases, applying Mathematical Science techniques to complex real world problems requires a deeper appreciation of the underlying concepts than might be the case in a purely scholarly setting; rarely is there an exact match between the real world problem and the underlying mathematical sciences approach, and skill and experience is needed to recognise and then explain the limitations, as well as the strengths, of results obtained from mathematical sciences based work.

Levels of mathematical sciences work in Public Service agencies

Mathematical sciences work in the Public Service occurs at a number of levels. CMIS[1] (the mathematical sciences group in CSIRO) talked about 'transformation, translation and deployment'.

- Transformation refers to research and development, in concert with other disciplines, where the mathematical sciences contribution is to fundamentally recast the way in which the problem is tackled. Such work may well require or generate advances in the core of the mathematical sciences discipline itself.
- Translation refers to development and research work, again in concert with other disciplines, where adaptations and applications of possibly pre-existing mathematical sciences approaches can make a significant contribution to solving the underlying problem. Translation might be described as development work, or applied research.
- Deployment, as its name suggests, involves the use of routine mathematical sciences skills in the ongoing implementation of a solution.

The transformational and translational mathematical sciences work in the Public Service is concentrated in the specialist agencies, which employ larger groups of dedicated mathematical sciences trained staff. If general government agencies do perceive a need for 'translational' or

---

[1] CMIS was recently renamed as part of a strategic re-organisation at CSIRO

‘transformational’ style mathematical sciences work, they would typically seek assistance from specialised agencies, or consultants. Mathematical sciences work in the general government agencies more often involves what has been termed deployment of mathematical sciences skills and competencies. Staff with formal mathematical sciences qualifications in the general government agencies are usually dispersed across the agency, and many are in roles where their mathematical sciences skills are a valuable adjunct to their main role, rather than a core competency. There are also instances where deployment level mathematical sciences work is undertaken by staff without post school mathematical sciences qualification.

The demand for mathematical sciences qualified people in the Public Service

We could usefully divide the demand for mathematical sciences in the Public Service into:

3. specialist mathematical sciences skills (e.g. in ABS, BoM, CSIRO, Defence etc) which are used directly in the construction and supply of services (including information and advice) and
4. a general mathematical sciences culture to enable the Public Service to advise ministers and deliver services more and more efficiently and effectively.

We had hoped to quantify this demand, at least broadly, but the information we would have liked is not available.

- At the Australian Government level, the Public Service Commission runs an annual ‘State of the Service’ survey which does collect some information about educational qualifications and field of study, but at far too broad a level to be useful. We have had some discussions about improving the data items collected, but that did not happen in the 2013 round. We are unaware of any consolidated information sources which might provide equivalent data at the State governments’ level. The attraction of the “State of the Service” collection is that it would have provided insight not only into the demand for more highly trained mathematical sciences professionals in specialist agencies, but also into the current number, job levels and job titles of people with mathematical sciences qualifications in general government.
- An overview of the current mathematical sciences trained workforce is available from Population Census data (see below for a summary). While it provides interesting insights into demographic characteristics the mathematical sciences workforce, at Public / Private sector level, it is unable to delve below the sectoral level to look at individual agencies, nor groupings of agency types.

Specialist agencies (eg ABS, CSIRO and DSTO) have expressed their concerns about the future supply of suitably skilled mathematical sciences staff for some time now, and all have active programs in place to attract capable students to tertiary mathematical sciences study, and subsequent employment in their agency. The DSTO submission to the review (DSTO, 2013) pointed to increasing demand for mathematics skills, not just among trained mathematicians but also quantitative specialists such as engineers. The submission included a detailed list of "notable problem domains," i.e. important areas of mathematics and related fields where they felt that a skills shortage might arise in the future.

In general government agencies where the mathematical sciences workforce is more dispersed even qualitative assessments of the size and nature of the demand are not straightforward. Moreover, the appreciation of the need for quantitative expertise seems not to be so obviously compelling to senior management as is the case in the specialist agencies.

3. A Summary of the Stats Pack[2]

Numbers of people with post school Mathematical Science qualifications in Australia

The following information has been extracted from the 2011 Census of Population and Housing conducted by the Australian Bureau of Statistics. More detail and a graphical presentation of the information can be found in Appendix 1 (Lee, 2013)

In 2011 approximately 27,000 people reported having their highest post school qualification in the mathematical sciences. Around

- 22,000 are mathematicians, and
- 4,600 statisticians.

This excludes quite a number of other disciplines which require quantitative skills, and which depend upon a solid foundation (to at least advanced secondary level) in the mathematical sciences.

A substantial majority work in the private sector (around 13,500), followed by national government (around 3,500) and state government (2,400).

Around 4,500 work in the Education and Training industry (approximately 1,800 for National government, 1,300 for State/Territory governments, and 1,450 in the private sector). Excluding the Education and Training industry, there are around 12,000 employed in the private sector, 1,700 employed in National government, and 1,250 employed in Stats/Territory governments.

> Government instrumentalities (excluding education) employ around 2,950 people with Mathematical Science qualifications, which is roughly 15% of the employed Mathematical Science workforce.

Those in government instrumentalities are predominantly in the Public Administration and Safety industry (which includes Defence) and Professional, Scientific and Technical industry (which includes CSIRO and ABS), although at State/Territory level there are reasonable numbers in Health Care and Social Assistance (~230), Electricity, Gas, Water and Waste Services (~90) and Transport, Postal and Warehousing (~85) industries.

Of the total mathematical sciences qualified population around :

- 18,000 have Bachelor degrees

[2] A more complete report of the analysis of Census (and some other) data – a Stats Pack – will be produced as a separate document

- 3,800 Master degrees, and
- 2,800 PhDs

Government instrumentalities appear to employ people with graduate or post graduate qualifications in proportion to the available supply. There is a significant concentration of the people with PhD's in the Education and Training industry (~1200, or over 54% of the mathematical sciences PhD's in the workforce) but it appears to be at the "expense" of PhDs in the private sector, not in government instrumentalities.

In the Census 7,600 people with mathematical sciences qualifications reported their occupation as "Not applicable"; of these:

- 6,600 are Not in the Labour Force, comprising three main groups
    - Males and females 25-35 undertaking further study
    - Females aged 25-40 not in the labour force , and
    - People aged 55 and older, presumably retired

A government website (DEEWR, 2013), which bases its information on job-titles, reports only around 6,200 jobs for mathematicians, statisticians and actuaries in Australia, illustrating the fact the people with mathematical and statistical qualifications work in a wide variety of roles, not just jobs formally labelled as mathematician or statistician. The DEEWR good jobs guide (DEEWR, 2013) DEEWR Year 10 jobs guide - mathematician has much more comprehensive information for students about the range and types of jobs open to people with qualifications in the mathematical sciences.

There is a substantial gender imbalance, primarily amongst those with mathematics qualifications.

The age distribution has been a cause of concern for some time, showing a peak now aged around 45, and an apparently inadequate supply of younger (aged 20-40) qualified people to sustain and replace the workforce as the peak ages over the decade ahead.

Coupled with data showing declining trends in the proportion of students at high school studying advanced levels of mathematics this is suggestive of an emerging workforce supply problem.

Simplistic cohort ageing analysis supports this. A slightly more complex comparison between the 2006 and 2011 Census data suggests that over this particular 5 year period, there was an increase in people with mathematical sciences qualifications aged between 25 and 45 which may mitigate the future supply deficit. This is primarily net inward migration to Australia. Further investigation is needed to ascertain whether this is permanent migration or temporary – e.g. overseas students studying for further qualifications - and also whether it is likely to be sustained into the future.

4. Interests of Public Service agencies in the future of the mathematical sciences

Direct self-interests of government instrumentalities

This section explores the direct interests that agencies themselves have in the future of the mathematical sciences. These can be summarised as interests in:

- meeting the future demand for well qualified and highly capable mathematical sciences staff in specialist roles / agencies
- developing a more mathematical sciences adept populace; and
- filling the demand for adequately mathematical sciences capable staff in other professions and roles in the Public Service

Sustainable workforce

The most immediate self-interest from of government instrumentalities is the sustainability of the workforce they need in order to achieve their objectives. There is a growing demand for mathematical sciences skills across a diverse range of jobs in the specialist agencies, hence a keen interest in the number and qualities (depth and breadth of capabilities) of the supply.

Population numerical literacy / numeracy

In addition, some government agencies have an interest in the mathematical/statistical literacy of the population at large; for example, effective communication of information to the public is part of the mission of agencies such as the ABS and the Bureau of Meteorology, and an improved level of mathematical/statistical literacy amongst the population would assist this. There are also societal goals towards which government agencies are working where improved population mathematical sciences literacy would be beneficial e.g. financial literacy (through understanding of compound interest) or reducing problem gambling (through understanding of probability).

CSIRO puts considerable effort (substantially funded by government grants) via several programs into raising the statistical and mathematical literacy of the general population, and into support for school teachers. ABS also devotes some effort to towards this goal (e.g. via the Census@School program).

Emerging opportunities – mathematical sciences culture in General Government

Finally, even though no submissions were received from general government and state agencies, only from individuals employed within them, our group believes that there is a substantial but unrecognised demand for more people with general mathematical sciences competency.

The main generic outputs of the Public Service (policy, planning, decision making, evaluation and operations) all need both evidence and logic. These are inherently quantitative in nature. Advances in data collection, data management and computational power are creating the potential for significant advances in the evidence base, and hence the quality and effectiveness of all Public Service agencies. To get a material and persistent improvement, we need to devise a way for the Public Service to enhance technical knowledge and skills in a number of topic areas which deal with evidence and logic. Failure to do this will not be immediately apparent, since it will be a lost opportunity, rather than a visible deterioration. (Some would argue that such opportunities are being lost already, rather than yet to emerge)

Some of the topic areas are:

- Understanding statistics – official, other surveys (easily fudged or misunderstood), policy issues (e.g. open data)
- Understanding data – emerging “big data”, information management (not to be confused with IT), spatial dimensions
- Understanding analytics – e.g. cost benefit analyses, e.g. regulatory impact statements, e.g. financial, accounting, demographic analyses
- Understanding presentation – “how to (avoid the) lie with statistics”, data visualisation

5. Recommendations

Context - Specific Interventions and Influencing the Environment

To achieve success, there needs to be:

- A set of well-designed interventions, aimed at specified objectives;
- An environment where those with the power to implement the interventions agree to do so; and
- An ongoing mechanism for monitoring and guiding the implementation

Our group believes the most crucial interventions lie outside the realm of (most) government instrumentalities. We expect other sub-committees to develop the plans for the specific interventions required. Our recommendations are primarily about influencing the environment so that those interventions will be accepted and implemented.

R1 – Dialogue with students about career opportunities

Future students and their parents and advisors are a key stakeholder group. Enhancements (and repairs) within the school education systems are specific changes which are the province of other sub-committees.

In addition to those changes, we believe it is essential that potential students are aware of the opportunities and benefits of including a solid quantitative base in their school studies.

To that end we have begun to assemble material which could be incorporated in campaigns to show the contributions that the mathematical sciences make to society, and the linked career opportunities. Our list to date includes:

- “50 solutions that count” (ATN, 2013) - a glossy pamphlet produced by the ATN group of universities with an attractive style and format. While it focuses on the contributions that (ATN) research achievements broadly make to the wellbeing of Australians, and although it fails to mention mathematical sciences amongst the contributing disciplines, an informed reader would note that many rely in essential ways on the mathematical sciences. With adaptation this (and probably similar documents already

> Recommendation 1 is about an on-going campaign to inform and excite potential students, and those who influence their career choices, about including quantitative studies and a solid mathematical sciences base in their education

produced by other universities) could form a rich source of examples.

- "Science and Impact Highlights" (CMIS, CSIRO, 2013) --- a document which records some highpoints from CSIRO
- Examples from DSTO, see the accompanying "ConnectionsArticles.pdf" which is a extracted selection of articles from the DSTO Connections magazine (DSTO, 2013 and preceding)
- Examples from the Bureau of Meteorology (yet to be assembled)
- "Suggestions for possible case studies " (Karmel, 2013)
- Impacts (good or bad) from inside the Public Service general government sector (yet to be assembled)
- "Fuelling Innovation and Discovery : The mathematical sciences in the 21st century" (National Research Council, 2012) is a 64 page glossy paperback from the USA which explains how the mathematical sciences have contributed in essential ways to a wide range of advances which are very well known to the general public. It is accessible and hopefully even engaging to anyone with an enquiring mind, not just those trained in the mathematical sciences.

R2 – Coordinate and extend support from Government Instrumentalities

Government instrumentalities should offer views, guidance and support, and in some particular aspects should contribute to other specific interventions. Indeed in some noteworthy cases, they have been doing so for some time already. Some actions already being taken by instrumentalities themselves include:

- supporting school level teaching of statistics and mathematics (CSIRO, ABS)
- offering cadetships and student traineeships for university students and post-graduates (CSIRO, BoM and DSTO)
- partnering with university departments of statistics and mathematics (ABS has a well-established link with the University of Wollongong, and is expanding that to include the ATN group. CSIRO also has well established and strong links with universities).

> Recommendation 2 is about government instrumentalities collaborating to express their needs from and support for the Mathematical Sciences discipline.

R3 – Ongoing dialogue with decision makers

The plan must be accepted by and influence key decision makers for it to be successful.

Arguments in the plan must be benefits driven. Our experience of the Public Service (and the same is undoubtedly true more broadly) is that until the benefits are understood and accepted as desirable, most senior decision makers will not even assess proposals, never mind commit to adopting them.

While some decision makers will appreciate the way that the mathematical sciences contribute to much wider developments, many may not, and this must be drawn to their attention.

This means articulating the value chain linking the mathematical sciences discipline with the benefits for Australia.

- Statistics and mathematics have a foundational role in research in other disciplines, such as the physical sciences, technology and engineering, many of the social sciences, industry, commerce, finance, etc. The indirect contributions from the mathematical sciences are an important part of the chain.
- Research is part of a larger innovation process. Benefits are realised after the research stage via developments and applications which occur in the government and private sectors.
- Innovation requires a mix of people with the right education, experience and expertise. Hence a skilled labour force is a necessary component of the value chain.
- Institutional arrangements and incentives for knowledge to flow between different groups are also needed.

The need to demonstrate the benefits is not new; others have already recognised it, as shown in examples like :

- reports from the Office of the Chief Scientist (Office of the Chief Scientist, 2013),
- reports from the USA (National Research Council, 2013), (National Research Council, 2012).

Articulating this value chain is only the first step. While necessary to convince decision makers it alone is insufficient. The arguments must be drawn to the attention of senior decision makers on an <u>ongoing</u> basis, and there must be a way to understand and address the queries, objections and additional insights they will surely have.

Two way interaction will be essential. Ideally this would be an enduring dialogue which over the next decade would create a feedback loop which could be used to adapt and refresh the Decadal Plan itself.

The initial draft of the Decadal Plan could be used as a trigger for commencing dialogue at this level, and building opportunities and forums for further engagement.

> Recommendation 3 is about an on-going high level dialogue to impress on key policy and decision makers the ways that the Mathematical Sciences generate benefits for Australia's economy, society and environment and to brief them on emerging useful applications.

R4 – Promoting opportunities to take advantage of emerging trends

"Big data" is a popular catchcry these days. Truly "big data" is generated in some fields, such as astronomy and meteorology, brought on by technological advances in the resolution and lower cost availability of automated observational tools. Sources of "moderately large data", such as records of transactions between citizens and government, or individual transactions at retails stores, are burgeoning. One submission noted that for the very traditional field of 'official statistics' this posed an opportunity for a major upheaval in operational methods, requiring quite different techniques and approaches to be developed and deployed.

Short courses in "Data Science" and "Analytics" are beginning to emerge, and jobs are beginning to be advertised in the Public Service for "Data Analysts", where the selection criteria include both traditional mathematical sciences qualifications, and specific abilities (data mining, text mining, machine learning) more usually associated with other disciplines such as computer science.

A number of submissions to the Decadal Plan raised the issue of ensuring that the next generation of statisticians and mathematicians are capable of using relevant software, not just as out of the box toolsets, but as platforms on which to develop new methods. Indeed many of the advances in the mathematical sciences were made possible because of advances in the speed and complexity of computation that has become available.

Similar trends are explored in detail in Chapter 4 of (National Research Council, 2013).

Taken together, these signal that the nature of what is meant by "mathematical sciences" is evolving, and as that occurs, an opportunity for a considerable expansion in how the mathematical sciences can contribute to Australian government agencies (and elsewhere) is emerging.

With more change on the horizon, if Australia government instrumentalities (and others) are to take advantage of these opportunities then action is needed now to create the environment where they can be recognised and grasped. For example policies on access to data, and about the use of analysts with high level quantitative skills appropriate to the work they are doing will be required. Technology may have made calculation cheap, but it has increased the risk of poor analysis leading to costly incorrect conclusions. Executive leaders should be alerted to this risk.

> Recommendation 4 is about an on-going effort by the Mathematical Sciences to provide leadership in emerging opportunities such as "big data", i.e. the combination of computational power, burgeoning data generation and new analytics (in the context of policy and decision making in Government Instrumentalities.)

6. Other ideas raised in submissions

There were several other proposals raised in submissions, but after consideration, we decided against recommending them. The objectives had some merit, but we felt they would be more effectively pursued in other ways.

Government optimisation service

Our group is doubtful that proposals to create a new government body would receive much support. Nor would it necessarily be a good idea - an alternative view is that expertise is enhanced by embedding mathematical scientists in organisations.

Cadre of professionals

Identifying and creating a cadre of professionals spread throughout existing agencies (e.g. a professional stream analogous to the UK's General Statistical Service) might have more merit --- but based on experience from ABS even that would be unlikely to garner much support across the bureaucracy, or wield much influence if even if it were to be established:

Fostering an appreciation of professionalism

In plain words, this proposal was about professional accreditation.

We considered proposing that (Public Service) employers require (or at least give weight to) professional accreditation in selection criteria for relevant mathematical sciences jobs. In some ways this is a broader alternative to the 'cadre of professionals in the service' approach.

- The advantage is that for agencies which lack a critical mass of professional mathematical sciences staff already, the challenge of forming a judgement about professional skills would be made easier.
- The drawback is that agencies that already have a core group of mathematical sciences professionals will almost certainly continue to look more deeply into the professional background and experience of applicants, and weight domain specific mathematical sciences skills ahead of a general professional accreditation

Moreover, not all sub-fields where the mathematical sciences are used (in the Public Service and/or the private sector) have an existing professional accreditation scheme available to them. Even where professional accreditation schemes exist (such as the SSAI's Accredited Statistician scheme, modelled on the RSS scheme from the UK, and that of the Canadian Statistical Society, and more recently followed by the ASA scheme) it would be fair to say that the visibility of and take-up by employers is minimal. Other disciplines where accreditation has been successful usually have a legal mandate, and a public health, public safety or financial risk driver.

Our group supports professional accreditation but feels the environment is not yet ripe for it. It should be strong sub-theme of future efforts to increase the visibility to the general public of the societal benefits of mathematical sciences.

7. Conclusion

The future of mathematical sciences is important to the government sector - both in specialist agencies and in general government. An insufficient supply of people with quantitative skills will impact on the quality and efficiency of government services, and the level of innovation. Much of the efforts required to sustain the supply will fall in the education sector, at school and tertiary level, outside the remit of most government instrumentalities. However some instrumentalities at Australian and State level administer government policies and funding mechanisms which strongly affect the education and research sectors. Senior decision makers must be kept aware of the benefits generated by the mathematical sciences, and engaged in the efforts to ensure their health and vitality.

A List of References

ATN. (2013, June 27). *50 solutions that count*. Retrieved September 20, 2013, from Australian Technology Network: http://www.atn.edu.au/newsroom/Docs/ATN-web-LR.pdf

CMIS, CSIRO. (2013). *Science and Impacts Highlights.* CSIRO.

DEEWR. (2013). *Job Guide - The Good Guide - Occupation Mathematician*. Retrieved September 23, 2013, from DEEWR: http://www.jobguide.thegoodguides.com.au/occupation/Mathematician

DEEWR. (2013). *Jobs Occupation Matrix - 2013*. Retrieved September 23, 2013, from DEEWR website: http://www.foi.deewr.gov.au/documents/australian-jobs-2013-occupation-matrix

DSTO. (2013 and preceding). *DSTO Connections magazine*. Retrieved September 23, 2013, from DSTO website iPad app: http://filedir.com/ios/news/dsto-app-for-ipad-6891485.html

DSTO. (2013). *DSTO Submission to the Decadal Plan for Mathematical Sciences.pdf.* Defence Science Technology Organisation.

Karmel, T. (2013). *Suggestions for possible case studies (from NCVER).* Adelaide: Personal Communication.

Lee, G. (2013). *Summary graphs extracted from ABS Census data.* Canberra: Personal Communication.

National Research Council. (2012). *Fuelling Innovation and Discovery : The Mathematical Sciences in the 21st century.* Washington, DC: National Academies of Sciences.

National Research Council. (2013). *The Mathematical Sciences in 2025.* Washington, DC: National Academies of Sciences.

Office of the Chief Scientist. (2013). *Science, Technology, Engineering and Mathematics in the National Interest: A Strategic Approach.* Canberra: Australian Government.

B Cross reference between 'Formal' references, and copies of pdfs available from Geoff

Reference	Pdf available from Geoff
(Lee, 2013)	App0.SSAI_Submission_Decadal_Plan_Figs_ABS2011+2006_census.pdf
(DSTO, 2013)	App1.DSTO Submission to the Decadal Plan for Mathematical Sciences.pdf
(Office of the Chief Scientist, 2013)	App1.5.OCS_STEM in the National Interest_July 2013 with Geoff annotations.pdf
(National Research Council, 2012)	App2.Fuelling Innovation and Discovery.USA Plan.13373.pdf
(National Research Council, 2013)	App3.USA MathSci2025 final.Geoff highlights added.pdf
(ATN, 2013)	App4.ATN-web-LR.pdf
(CMIS, CSIRO, 2013)	App5.CSIRO Case study examples.pdf
(DSTO, 2013 and preceding)	App6.DSTO.ConnectionsArticles.pdf
(Karmel, 2013)	App7.NCVER.Suggestions for possible case studies.pdf