2030 STRATEGIC PLAN:

SUBMISSION BY THE NATIONAL COMMITTEE FOR PHYSICS

OF THE AUSTRALIAN ACADEMY OF SCIENCE

1. INTRODUCTION

The National Committee for Physics (NCP) of the Australian Academy of Science welcomes the opportunity to comment on the "2030 Strategic Plan" issues paper released in March 2017 by Innovation and Science Australia (ISA), following on from the review of the current performance of the innovation, science and research system in Australia released in February 2017. We note that ISA recognizes there are many relevant reviews to be considered in developing the 2030 Strategic Plan, and we wish to draw attention to the Decadal Plan for Physics 2012-2021 [1]. As highlighted below, we consider this is very relevant to the Challenges identified in the issues paper (including part 2 [2] of the Decadal Plan, which contains a wealth of evidence and data that underlies the recommendations in part 1).

The context of the issues paper is that whilst Australia is a prosperous country, there have been, and will continue to be, waves of major change that effect our economy and society. Australia needs to be in a position to "ride these waves to our national advantage." History tells us that a significant number of these new waves are likely to be technology driven, and that many of these technologies have their origins in fundamental Physics. An early example is found in the experiments by Oersted and Ampere in the 1820's that showed that motion of wires in magnetic fields produce electric currents – still the basis of most of our electricity generation in the 21st century. Imaging technologies that underlie modern medicine, such as MRI, ultrasound, PET scans and Doppler imaging of blood flow all have their origins in fundamental Physics. Revolutionary impacts on society and the economy have arisen from the development of electronics and telecommunications technologies that allow modern computing and the internet. Research performed within Australia and in international collaborations is playing a crucial role in growing the Australian economy [3].

Australia needs a strong base in Physics training and research to be able to understand and most effectively deploy new waves of technology as they arise. Currently, Australia only undertakes 3% of the world's research, and thus it is crucial that we are globally linked and create appropriately trained personnel to access and capitalize on the remaining 97%. It follows that one worthy goal for 2030 would be for Australia to become a much greater international contributor to discovering and developing new technologies. The response from the NCP to the issues paper on the 2030 Strategic Plan is framed in these terms, as summarized in the title of the 2012-2021 Decadal Plan, "Building on Excellence."

2. STRUCTURE OF THIS RESPONSE

The Physics Decadal Plan 2012-2021 [1] identified four critical issues relating to future directions and opportunities with broad benefit to Australia:

- **Achieving a Physics-literate workforce and community;**
- **Realising human capital in Physics;**
- **Building on Physics research and investment;**
- **Engaging in the international enterprise of Physics.**

There are significant overlaps between these issues and all six challenges identified in the 2030 Strategic Plan issues paper. For the purposes of brevity, this document will not make a comprehensive mapping. Rather, it highlights some key points, noting that the Physics Decadal Plan [1] contains a wealth of further information relevant to the 2030 Strategic Plan.

We also wish to emphasize that the timescale on which some waves of change will occur is much shorter than the 13 years remaining until 2030. We therefore urge that agility and flexibility need to be built into the 2030 vision of the innovation, science and research system to allow rapid adaptation to new developments and opportunities that cannot be predicted in this planning process.

3. CHALLENGES 1, 2 AND 4

Challenges 1, 2 and 4 identified in the issues paper are:

1. Moving more firms, in more sectors, closer to the innovation frontier;
2. Moving, and keeping, Government closer to the innovation frontier;
4. Maximising the engagement of our world class research system with end users.

The NCP strongly agrees with these objectives as priorities for the 2030 Strategy. Australia currently has the luxury of a very high standard of living based to a large extent on the export of unprocessed natural resources, and to a lesser extent these days, on agricultural products. Whilst innovation in these sectors and other sectors of our economy has been important, innovation more generally has not been the principal driver of Australia's prosperity – unlike countries such as Germany, France and Japan, which have very few natural resources.

Physics, along with other Physical and Mathematical Sciences, is already making a major contribution to the Australian economy. In a 2015 report commissioned by the Australian Chief Scientist [3] (based on an initiative from the NCP), it was estimated that 11% of economic activity in Australia relies directly on advanced physical and mathematical sciences, contributing $145 billion to the Australian economy annually. Indirect flow-on benefits result in another 11%, bringing the total contribution to 22%, or around $292 billion per year.

There is an opportunity to realize innovation as a more significant contributor to the Australian economy by 2030, reducing reliance on export of natural resources, and Physics has a key role to play through the interaction of researchers with end users including industry and government in development and implementation of new technologies. This is encompassed in the Physics Decadal priorities **"Building on Physics research and investment",** and also overlaps with the priority "**Realising human capital in Physics"**, in the form of professionals trained in Physics and in the skills (including entrepreneurial skills) needed to build the bridges with end users. Increased incentives for industry to fund and engage in research and development, and a means to ameliorate the risks involved, would also encourage industry to move closer to the innovation frontier.

The Physics Decadal Plan also has recommendations on improving mobility between academic and government research positions and industry employment, in both directions. This will help break down barriers between researchers and end-users, and also bring understanding of the needs of end users to researchers. Models might include industry internships for academics and PhD students, and greater recognition of industry experience by universities in making appointments.

Another emerging theme that should be addressed in the 2030 plan is the need to encourage and support interdisciplinary research, bringing skills and tools from many disciplines to bear on major challenges such as climate change, green energy, food and water security, and health and medical technology. Solutions to many of these challenges are likely to lie at the innovation frontier, and Physics has much to contribute.

4. CHALLENGE 3

Challenge 3 identified in the issues paper is:

> *3. Delivering high-quality and relevant education and skills development for Australians throughout their lives.*

This Challenge overlaps completely with the Physics Decadal priority **"Achieving a Physics-literate workforce and community"**.

The 2014 report by the Chief Scientist "Science, Technology, Engineering and Mathematics: Australia's Future" [4] notes that "Our competitiveness cannot be underpinned by our natural resources alone … We need a reliable pipeline of specialist STEM skills; but we also need informed workers, users and consumers who have the curiosity and imagination to be part of the broader

STEM economy. This must be underpinned by lifetime engagement for all Australians with STEM, beginning in childhood and constantly renewed as knowledge and technologies expand."

These messages are fully reflected in the Physics Decadal Plan. Amongst a number of issues identified in the Decadal Plan are a "worrying decline in the uptake of physics by students at secondary level", and a need to "improve physics literacy in the general community." The Plan also provides specific recommendations for achieving these outcomes.

The report by the Chief Scientist also identifies the need for the development of an "entrepreneurship culture". The NCP has also identified this as a key objective for the 2030 Strategic Plan, with a focus on equipping Physics graduates (both undergraduate and postgraduate) with the skills to enable them to convert ideas into practical and commercial outcomes.

A major issue highlighted in the Physics Decadal Plan is under-representation of females at all levels in Physics education and training, with a subsequent flow on to careers. Falling under the priority "**Realising human capital in Physics",** this failure to engage fully with half of the Australian population means that there is a major lost opportunity in terms of potential contribution to research and innovation in Physics in Australia. We strongly recommend that mechanisms to address this imbalance be a key priority in the 2030 Strategic Plan.

5. CHALLENGE 5

Challenge 5 identified in the issues paper is:

> *5. Maximizing advantage from international knowledge, talent and capital.*

Again, this challenge finds resonance with a Physics Decadal priority **"Engaging in the international enterprise of Physics".**

International collaboration lies at the heart of all research. This is particularly true for Physics in Australia, where the size of investment in individual universities and government organizations is small compared to that in countries such as Germany, the US and France, with much larger populations and therefore larger research and education budgets. Achieving critical mass for Australian researchers is often reliant on national collaborations (greatly aided by the ARC Centre of Excellence scheme) and international collaborations. It is therefore critical that the 2030 Strategic Plan recognize the need to invest in the costs associated with building and maintaining collaborations between high quality research groups in Australia and their national and international partners. In particular, the high cost of travel for Australian participants in international collaborations and meetings or conferences compared to that of their colleagues in the USA/Canada and Europe can be a major impediment, particularly for early career researchers.

Australia would benefit strongly from researchers in all STEM fields having access to EU Framework funding programs. This could be achieved by establishing a matching fund for allocation to successful programs. With the exit of British research institutions from the EU funding programs, this is a particular opportunity for Australian research to become more visible and impactful internationally.

Australian researchers also need the opportunity to access major international infrastructure, such as the Large Hadron Collider at CERN and the Square Kilometer Array (SKA) radio telescope, that are beyond the means of any single nation to fund. The 2030 Strategic Plan must provide a mechanism for Australia to “buy into” international research programs in order to provide Australian researchers with access to the best possible research facilities. The opportunity to make a contribution to the development and operation of these facilities will be important in marking Australia as a leading technological nation. The 2030 Strategic Plan should also encompass the aspiration that Australia should host a major piece of research infrastructure funded by the international community – for example, following the recent discovery of gravity waves, there is a strong case to base an advanced interferometric gravitational wave detector in Australia that would augment the northern hemisphere detectors by offering a massive increase in baseline to allow better determination of the location of sources of gravitational wave events. Australia’s geographical location also offers a unique opportunity for a contribution to the search for Dark Matter at the new Stawell Underground Physics Laboratory (SUPL). Dark matter is one of the most important and intriguing scientific questions of the 21st century.

Another aspect of maximizing advantage from international talent and capital is the flow of students and early career researchers between Australia and overseas countries. In particular, the domestic supply of PhD students in Physics does not fully meet the need for quality students able to carry out advanced research projects. Currently, there are very limited opportunities to provide funding for international PhD students to make up the shortfall. Australia would also benefit from greater opportunities to support long-term exchanges of postdoctoral researchers between Australia and overseas in order to build international research collaborations and broaden the experiences of our researchers.

There is much to be gained from a larger number of Australians building their knowledge and skill level in science at the postdoctoral level before transitioning into other roles in society. Dr Angela Merkel, a physics PhD graduate, had a twelve-year career in research as a physical chemist before her election to the Bundestag in Germany. This type of career path is more common in nations that have more industrial and government activity closer to the innovation frontier. We recommend the strategy for 2030 should build human capital and facilitate industry and government in moving closer to the innovation frontier in parallel. Success of the strategy can be measured through the increase of the number of people in the nation with the Australian

Qualification "10^{+}", and assessing whether these people have jobs befitting their education and training.

6. CHALLENGE 6

Challenge 6 identified in the issues paper is:

6. Bold, high-impact initiatives.

This Challenge is not specifically identified in the four priorities in the Physics Decadal Plan as it is an inherent element of nearly all research in Physics; this type of research is "blue sky", and therefore bold by definition. Research into the fundamentals of Physics is a venture into the unknown, and the outcome is a contribution to knowledge about the way the Universe in which we live operates. Additionally, history has shown that a significant proportion of the high-impact technologies that define society and economies have been unexpected outcomes from research in fundamental Physics. For example, whilst quantum mechanics was an obscure theory understood by only a few of the world's top physicists in the 1920's, it is now estimated that quantum physics underlies one third of the GDP of the US via the electronics industry. Other examples include the development of the world wide web at CERN for the dissemination of large scientific data sets around the world, and similarly the invention of WiFi by the CSIRO for local transmission of large data sets.

The key message is that although it is never possible to predict the outcomes of fundamental research, it is clear that many world-changing technologies (which by definition have major impact) have been unanticipated outcomes of fundamental research. For this reason, it is necessary for Australia to deliver sufficient financial support for such fundamental endeavours if we wish to achieve world-changing impact. In order that Australia reap all of the benefits of this research it is also essential that we have effective funding of applied physics and engineering research. Without adequate funding for both fundamental and applied streams of research, society cannot gain access to revolutionary technologies.

The major source of funding for fundamental Physics research is the Australian Research Council (ARC), and therefore Physics in Australia is keenly dependent on the health of the ARC. The 2030 Strategic Plan should address the crucial role played by ARC and NHMRC funding in Australian research and innovation, and consider setting targets for funding levels benchmarked to comparator countries. The NCP has recently made a submission to the new CEO of the ARC with suggestions for streamlining application and assessment processes, which currently take an inordinate amount of time by researchers for a low success rate. Also, how to reduce the opportunity loss associated with very well planned research proposals going unfunded should be given serious consideration in plans to improve the innovation system. The NCP's submission to the ARC was based on feedback from Physics researchers in universities and in government organizations, and we are happy to make it available to ISA. Another major issue, highlighted in the Decadal Plan, is that it is difficult to obtain funding for the ongoing costs of operation and maintenance of research infrastructure beyond the lifetime of a research grant.

A welcome development in recent times has been additional large investments into defence innovation through the Next Generation Technology fund. In the USA, long-term investment in similar programs (DARPA, iARPA) has led to some highly innovative technologies. Defence is frequently a first-adopter of innovative technologies and one would hope that this type of investment is extended out to 2030 to bring similar benefits to Australia.

7. IN SUMMARY

On the 1-5 year horizon, improvements to physics and science education at all levels should be planned, resourced and implemented, along with similar developments in related disciplines, as a key part of up-skilling and preparing the population for lives of making a changing contribution to meet changing societal needs. High quality teaching can only be achieved with adequate resourcing, particularly staff time. Monitoring the number and employment categories of physics and similar graduates and postgraduates will be a useful measure of the uptake and usage of their high-end skills and capability levels in growing activity at the innovation frontier, across all relevant sectors. Investment will be required to achieve improved outcomes. Planning and implementation should be ramped up to create a more continuous and connected science and innovation system. This should include serious effort being put into considering disruptive visions for education, science and innovation, for the benefit of Australia, to be carried forward to the 5-10 years horizon. Immediate attention should be given to growing and targeting investment in the innovation system across all of fundamental, applied and strategic research and facilitating transfer of knowledge.

On the 5-10 years horizon and beyond, Australia should have in place robust planning and implementation processes across the broad range of contributing stakeholders to support migration to an internationally competitive science and innovation system.

References

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