# Submission
# 2016 National Research Infrastructure Roadmap
# Capability Issues Paper

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The National Measurement Institute (NMI) is a division of the Department of Industry, Innovation and Science (DIIS). NMI is Australia's peak measurement body responsible for biological, chemical, legal, physical and trade measurement. NMI's specialist in-house capabilities and external linkages deliver the measurements needed by Australian researchers across a wide range of fields, and support the growth and productivity of Australian businesses.

## SECTION 3.4: SKILLS AND TRAINING

**Question 5: Should research workforce skills be considered a research infrastructure issue?**

**Question 6: How can national research infrastructure assist in training and skills development?**

As outlined in the submission from the Department of Industry, Innovation and Science, appropriately trained and skilled technicians and researchers are essential to take full advantage of specialised facilities. Without a skilled workforce, national research infrastructure facilities cannot be maintained, operated or used effectively. This holds true for research infrastructure in the field of measurement, including customised facilities.

A number of mechanisms for national research infrastructure facilities to provide training and skills development are outlined in the DIIS submission. As an additional example, NMI takes undergraduate 'year in industry' students through a formal university programme and offers them a one year post during which they perform projects and gain on the job training. Some of these students return to NMI later in their careers, but all take away a greater understanding of metrology and its role supporting a wide range of applications in research.

## SECTION 3.4: STANDARDS AND ACCREDITATION

**Question 11: When should capabilities be expected to address standard and accreditation requirements?**

The value of data is dramatically increased when it is validated and its accuracy can be quantified (e.g. climate records). As reliance on data increases, and unknown future uses of data expand, the importance of data quality increases over time, and a quality infrastructure that incorporates standards and accreditation can make an important contribution to ensure the quality, integrity and comparability of data. This is particularly true for datasets that will be in use over long periods.

For example, Australia's ocean temperature monitoring programmes through CSIRO and the Bureau of Meteorology are intended to gather detailed, long term data sets. The importance of decadal data comparability and reliability has been recognised by ensuring that instruments are regularly calibrated and validated. NMI provides CSIRO with temperature calibrations to one thousandth of a degree, using measurement infrastructure (physical reference standards) that is in turn linked to the international system of units (*Système International d'Unités*, or SI).

Standards and conformance infrastructure also plays an important role in research translation[1]. However, SMEs in particular may lack the resources to anticipate and accommodate future requirements, such as regulatory constraints, that could be addressed by adoption of relevant standards relatively early in the research translation process. Support for businesses to access relevant expertise could help in successful commercialisation, particularly in demystifying requirements for export to overseas jurisdictions.

## SECTION 4: CAPABILITY FOCUS AREAS

### Question 12: Are there international or global models that represent best practice for national research infrastructure that could be considered?

Specialised measurement facilities operated by national institutes in other countries support their researchers and industries through a variety of access models which may be valuable to consider. For example, in the United States, several major facilities are operated either by or with the National Institute of Standards and Technology (NIST), who also maintain US national measurement standards:

- NIST Center for Neutron Research: "The Center supports important NIST measurement needs, but is also operated as a major national user facility with merit-based access made available to the entire U.S. technological community. Each year, more than 2000 research participants from government, industry, and academia from all areas of the country are served by the facility. Beam time for research to be published in the open literature is without cost to the user, but full operating costs are recovered for proprietary research. Access is gained mainly through a web-based, peer-reviewed proposal system with user time allotted by a beamtime allocation committee twice a year"[2].
- NIST Center for Nanoscale Science and Technology (CNST): "NanoFab provides researchers with rapid access to state-of-the-art, commercial nanoscale measurement and fabrication tools and methods, along with associated technical expertise, at economical hourly rates… If a non-proprietary project advances the CNST mission, rates may be reduced by up to 50%". "NanoLab offers opportunities for researchers to collaborate on creating and using the next generation of nanoscale measurement instruments and fabrication methods… with significant contributions from a rotating cadre of postdoctoral researchers and collaborative projects both with NIST scientists and with others from across the U.S. and

[1] See for example *Infratechnologies: The Building Blocks of Innovation-Based Industrial Competitiveness*, NESTA UK, available at http://www.nesta.org.uk/publications/infratechnologies (accessed 7 September 2016).
[2] *Annual Report 2015*, NIST Center for Neutron Research, available at https://www.ncnr.nist.gov/AnnualReport/FY2015/NCNR_AR_2015.pdf (accessed 7 September 2016).

abroad. Researchers are invited to gain expertise by working directly with the NanoLab's multidisciplinary scientists and engineers"[3].

- U.S. National Cancer Institute Nanotechnology Characterization Laboratory[4]: "Working in concert with the (NIST) and the U.S. Food and Drug Administration (FDA), the National Cancer Institute (NCI) established the Nanotechnology Characterization Laboratory to perform preclinical efficacy and toxicity testing of nanoparticles. The NCL serves as a national resource and knowledge base for all cancer researchers to facilitate the regulatory review of nanotechnologies intended for cancer therapies and diagnostics. By providing the critical infrastructure and characterization services to nanomaterial providers, the NCL accelerates the transition of basic nanoscale particles and devices into clinical applications, thereby reducing suffering and death from cancer." The NCL is government-owned and contractor-operated.

## SECTION 4: HEALTH AND MEDICAL SCIENCES

### Question 15: Are the identified emerging directions and research infrastructure capabilities for Health and Medical Sciences right? Are there any missing or additional needed?

Measurement is a fundamental underpinning capability for medical research and health care. Patients are monitored in terms of physical, chemical and biological parameters, from body temperature, mass, pressure and flow, to blood and hormonal chemistry and increasingly, genetics and genomics. The instrumentation used for R&D and clinical healthcare brings together electronics, optics, mechanical and chemical technologies, plus materials and precision manufacturing.

The cross disciplinary expertise and scientific instrumentation present in a metrology institute like NMI is well suited to support health research by assisting with measurement issues, including understanding, applying and optimising techniques, making sense of measurement data, and treating measurement uncertainty.

Many genetic measurement technologies are in the process of translation from research to clinical use. Quality assurance processes and controls are still being established for use of these technologies in a routine setting, but will be critical to enable comparable results between laboratories. Currently, there are very few nucleic acid reference materials available for genetic tests across many fields including, for example, pathogen detection, disease (including cancer) diagnosis and prognosis of treatment. Many standards are prepared 'in-house' and are not adequately characterised to serve as points of reference for interlaboratory comparisons.

### Question 16: Are there any international research infrastructure collaborations or emerging projects that Australia should engage in over the next ten years and beyond?

Several international activities aim to standardise and improve the quality of measurements in the health sector, including programmes within the International Federation of Clinical Chemistry and Laboratory Medicine (IFCC). NMI contributes to these within its resourcing constraints.

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[3] NIST Center for Nanoscale Science and Technology brochure, available at https://www.nist.gov/sites/default/files/cnst_brochure.pdf (accessed 7 September 2016).
[4] http://ncl.cancer.gov/ (accessed 7 September 2016).

For example, there are opportunities to improve the cost effectiveness, efficiency, reliability and clinical effectiveness of chemical pathology testing by increasing the linkage of local test methods to international programmes which are aimed at standardisation and assessment of comparability. NMI's activities in this area include provision of a suite of highest level calibrator materials, e.g. pure testosterone; developing high accuracy reference measurement procedures for priority clinical analytes in human serum; and assisting laboratories with the adoption and validation of mass spectrometry based assays for sample analysis.

## SECTION 7: ADVANCED PHYSICS, CHEMISTRY, MATHEMATICS AND MATERIALS

**Question 21: Are the identified emerging directions and research infrastructure capabilities for Advanced Physics, Chemistry, Mathematics and Materials right? Are there any missing or additional needed?**

*Redefinition of the Système International d'Unités (SI)*

The Issues Paper (section 7.3.1) mentions the need to maintain and extend the capabilities that exist, for example in the National Measurement Institute, to reference new precision measurement techniques to international standards. A key example is the redefinition of the SI system of measurement units, which is expected to be formally introduced from 2018 and to require new dissemination methods.

Out of seven base SI units, four (kilogram, ampere, kelvin and mole) will be substantially redefined in a way that will have no adverse effects on the accuracy of measurements currently required, but which will allow future technological advancement. The last artefact-based definition will be removed from the SI: the kilogram will transition from the most outdated SI unit definition to one of the most elegant, advanced and future-ready.

Since 2007 national metrology institutes in different countries have been working to determine fundamental constants with sufficient precision to allow a smooth transition through the proposed redefinition. Metrologists have also been developing methods to realise 'new units' in practice, for example through 'Watt-balance' experiments and the Avogadro $^{28}$Si crystal project to replace the International Prototype Kilogram.

The NMI maintains primary standards of physical measurement at a level appropriate for Australia's current and projected future needs. At present, this does not include some leading-edge infrastructure maintained by international counterparts, such as a Watt balance for mass or an optical frequency standard for time and frequency.

*Future directions for measurement science*

While we don't know where science, innovation and technology may lead us in decades to come, we do know that many of the rapid technological changes of the past century have been supported by an ever-improving measurement system: we can only have effective GPS systems, for example, because we can build atomic clocks and measure time very accurately.

Overviews of future metrology needs which could usefully inform consideration of Australia's required infrastructure have been prepared by the UK's National Physical Laboratory[5],by a collaboration of all European national metrology institutes[6], and by the US[7].

To give two specific examples:

- Maturation and widespread availability of currently emerging sensors based on quantum, bio- and nanotechnologies will require new supporting infrastructure to take full advantage of these emerging technologies.
- New space-based instrumentation will require space-qualified, accurate and reliable measurement technologies, such new methods for interferometry developed for the GRACE mission developed in a collaboration led by the ANU and supported by NMI.

## SECTION 7: NATIONAL SECURITY

### Question 27: Are the identified emerging directions and research infrastructure capabilities for National Security right? Are there any missing or additional needed?

The measurement infrastructure and expertise maintained by the NMI helps ensure that:

- defence and security agencies have access to specialised measurement support where required to achieve their objectives, e.g. instrument calibrations for defence and its major suppliers and contractors to support hardware supply, maintenance and repair; combat ration food safety and nutritional value; and workplace drug testing of personnel;
- law enforcement agencies have scientific and intelligence support in their fight against illicit drugs, as well as access to accurate and reliable measurement infrastructure;
- Australia's digital economy and communications networks can rely on accurate time standards to support time stamping, authentication and cybersecurity;
- rapid and flexible chemical and biological analysis capabilities are available to respond to and avert critical events, such as food and environmental contamination, and for testing of imported products to support Australia's biosecurity.

In each of these cases the supporting infrastructure must evolve to meet evolving national security needs.

[5] http://www.npl.co.uk/upload/pdf/metrology-2020vision.pdf
[6] http://ec.europa.eu/research/consultations/pdf/empir-survey-final-report.pdf
[7] *An Assessment of the United States Measurement System: Addressing Measurement Barriers to Accelerate Innovation*, NIST February 2007

## SECTION 7: DATA FOR RESEARCH AND DISCOVERABILITY

**Question 33 Are the identified emerging directions and research infrastructure capabilities for Data for Research and Discoverability right? Are there any missing or additional needed?**

As the infrastructure for collecting, distributing, storing, managing and interpreting ever increasing amounts of data develops, it also becomes increasingly important to maximise the value inherent in the data by ensuring its quality and integrity. More and more ubiquitous sensing (the 'Internet of Things'), data collection and real-time monitoring lead to an increasing reliance on data for process control and decision-making using complex algorithms and models – characteristics that are considered part of revolutionary changes in business ('Industry 4.0'). This transition presents numerous challenges for metrology, e.g. in sensor and data validation, sampling strategies, or automated and remote calibration, which –when addressed– can add significant value to the data and to the decision making processes that they inform.

Maintaining the infrastructure that collects the data in field is crucial for data quality. The return on investment from calibration and verification is sometimes overlooked, yet is fundamental to ensure that instruments are performing correctly, and hence that data is useful.

To give a specific example, gene sequencers produce large amounts of data that needs to be of a high quality, as samples may be rare and unable to be obtained again (e.g. a patient's tumour biopsy) and critical diagnosis and treatment decisions are made based on these data. Quality control and validation for complex bio-chemical instruments like sequencers generally relies on reference materials, rather than instrument calibrations. Metrology institutes like NMI research, develop and produce reference materials for a wide range of tests, including for gene-based analyses; however the range of target molecules is vast, and available RMs are still few.