Submission to Te Ara Paerangi about regional shared capabilities with a focus on specialist research infrastructure

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Theme/question addressed and the problem we face

This submission addresses the question posed by MBIE, "how do we support sustainable, efficient and enabling investment in research infrastructure?", but in doing so touches on themes about: coordination of large property and capital investments; the funding model and its effects on stability and resilience for research organisations; enabling and protect mātauranga Māori in the research system.

The theme Te Hanganga Rangahau/Research Infrastructure is described in understandably top-down language. My perspective, as a scientist (bottom-up view), is that of a research infrastructure user, an organiser of use by other dedicated technical and science staff, and where the rubber hits the road on helping stakeholders apply the benefits of instrumentation into their research and development projects (the middle view).

For members of the science engine who have the technical acumen for any given instrument type (e.g., transmission electron microscopes) the main issue they face is hassle-free access to local critical instrumentation and occasionally to world-class instrumentation. Expensive instruments are typically embedded within individual CRI teams with a specific research focus. Although many instruments can be applied to a greater range of science areas, currently they are not. This leads to missed opportunities for wider NZ science, unnecessary replication in some cases, and also limits inter-discipline innovation because of a lack of collegial interactions between experts who use the same technology platform but applied to different application fields (e.g., wool, trees, plankton, fungi, viruses, food etc.). Another issue is that NZ is gradually falling behind Australia and other countries due to deferred acquisition and maintenance of regional critical instrumentation infrastructure. Critical instrumentation is of a sort that a research project working at a globally accepted standard would access on a day-to-day or week-to-week basis. Increasingly use of these critical instrumentation involves planned travel and complex contractual negotiations, and thus begin to resemble the situation expected for world-class capabilities which are accessed on a monthly or yearly-basis (e.g., synchrotrons, research ships etc.).

The purpose of this submission is to discuss possible solutions to improve this shared need of the collective science engine and of the institutions for, respectively, access and management.

Approaches to research infrastructure cluster access

Common approaches

The problem is not new, and shared access to specialised, unique, and typically, expensive science instrumentation happens across Aotearoa-New Zealand through a variety of arrangements. We just do it in a piecemeal way. The common issue for shared access across various approaches is that of ownership.

Below is a non-exhaustive list of types of approaches to enable access within or across organisations.

- **Core facilities** are a common model globally and in New Zealand. They tend to be local clusters of instrumentation requiring similar technical skills (e.g., an engineering workshop) or are accessed by many users who want to do a similar task (e.g., gene sequencing). In my area of microscopy, an example is the Manawatu Microscopy and Imaging Centre (MMIC) at Massey University. The advantages of such an approach are throughput and tidy finances. The disadvantage is a loss of innovation and science advancement brought about by the difficulty of fitting the flexibility needed for scientific exploration/new ways/result-driven timelines and collaborations (including Māori approaches) within the core facility model. This disadvantage is due to institutional pressure that drive core facilities to act as strictly service-based businesses (rather than on strategic or science merit/impact).
- There are many **loose networks** around the universities and research institutes of Aotearoa that act as an instrumentation access clubs and lobbying group within universities to coordinate capex investment. An example of one of these is the Biomolecular Interaction Centre which is run out of the University of Canterbury but includes members from a range of NZ institutions (myself included). Such a network allows for a distributed ownership of equipment, but the focus is largely on collaboration and there are rarely standard approaches to access (other than an expectation that members will assist one another to navigate the institutional barrier/mechanisms to access).
- **Government level investment** occurs for some high value instrumentation, typically through negotiated access with special conditions. Normally this is for instrumentation that is not used day to day, but typically as part of a planned study (e.g., Scott base, or the NZ Synchrotron Inc access to ANSTO infrastructure in Australia).
- There are some **hybrid approaches**. Another example from microscopy is the Otago Micro and Nano Imaging (OMNI) facility at the University of Otago. Since 2005, when I first visited the unit, there has been a turbulent and cyclic history of the unit being treated as a critical research asset, or a core unit, or somewhere in between. OMNI has been

threatened with closure on a few occasions when treated as core unit but pulled though because of the essential need for the capability within medical research. Currently (2022) the unit is a good example of a hybrid approach in which there is both an academic and technical lead and exploratory research is supported by a "club" model in which departments invest a set amount to cover the base running of the unit in exchange for full access to instruments and OMNI staff expertise. The flexibility inherent in this arrangement allows for less-certain higher-risk science to be undertaken than would occur at a core facility. The disadvantage of the unit remains that with all staff, instruments and overheads being owned by one institution, inter-organisational collaboration and sharing is practically non-existent.

Critical local infrastructure and unique attractors

Critical infrastructure is that which supports the day-to-day needs of research for which science quality is at a globally accepted standard (e.g., publication in high-ranking journals or entry into international collaborations as equals). Most scientists would be expected to use critical instruments themselves following training.

*An **example** of a critical instrument is a confocal microscope (generates high-resolution optical slices through specimens on microscope slides). Fifteen years ago, this instrument was considered unusual and there were only about six scattered across NZ, almost all at universities. In 2022, the situation is about the same, and often these are the same instrument bought 15 to 20 years ago and now in a fragile state, making access more difficult. Internationally, confocal microscopes are now a routine part of biological and biotechnology research. We would expect that each CRI should have an accessible instrument of this sort in the local areas of each major campus. Currently this is not the case for any CRI except Scion.*

Unique attractors are capabilities (instrument + knowledge) that are unique in New Zealand, unique in Oceania, or globally unique. Typically, such capabilities would be something worth travelling to access and there is an expectation that most scientists would not be hands-on but would work with local technical experts.

*An **example** of a unique attractor is the recently installed serial-blockface scanning electron microscope at the University of Otago which is supported by another unique instrument called a high-pressure freezer. Together these instruments allow the generation of three-dimensional microscopic structure data from biological cell and tissue samples which were cryogenically frozen to exactly preserve their in-life microstructure. This enables unique analysis of biological samples amenable to new artificial intelligence powered data analysis. In another decade this type of instrument will likely transfer to critical instrument status. Currently access to the instrument is not routine for CRI scientists.*

Success from the researcher view

What might an organisation that enables successful access and collaboration experience look like? As a senior scientist (25 years in the NZ science system), and 10 years on the executive team of Microscopy NZ Inc, I have observed situations that have held back or enabled world class science in NZ relating to access to infrastructure. I've been a user and experimental modifier of instruments, and more recently organiser of access for others to enable innovative science projects. I've considered what a shared facility might look like from a user and science impact perspective for microscopy and microanalysis of bio-based materials.

The main capability would be:

- a suite of laboratories in one building or between nearby buildings;
- the capability organisation is owned by multiple stakeholders (CRIs and other R&D organisations) with respective responsibilities and access rights;
- instruments (critical, essential support, and one unique attractor) of which all are owned by or under lease (from their owning CRI) to the regional capability organisation;
- technical staff, who's day-to-day or time-to-time role in the capability is to maintain the instruments, manage laboratories and enable science, are employed by stakeholder CRIs;
- scientist staff with knowledge capabilities in subjects (e.g., food, wool, fungi, plankton, biopolymers, etc.) are regular users and associates of the capability and are from the different stakeholders CRIs;
- collectively technical staff and scientists look after the instruments and provide training on use and maintenance;
- user access to the instruments and laboratories by non-associated scientists, postgraduate students, postdocs etc. should be through associate scientists and may include the payment of an "access"/club fee that helps support the running of the capability if the person accessing is not from or sponsored by a stakeholder organisation;
- a common code will exist for conduct for access, scheduling, data handling etc.;
- a culture of collaboration within the capability that allows transfer of assistance and expertise between associate members irrespective of their parent CRI (e.g., it should be possible for a user with shifting needs often based in responding to data (e.g., food expert → insect physiology expert) to access knowledge capability from initial engagement with, for example, an AgResearch food scientist to, for example, a Landcare insect scientist without the usual inter-CRI barriers.

Through the capability organisation it should be possible for associate scientists and technical staff to gain hands-on access to instruments in other organisations via reciprocal access agreements (e.g., access, including training, to defined instruments at a non-local university would be reciprocal against some number/usage of the local capabilities instruments). The unique attractor instrument(s) will play an important drawcard for inter-organisational access agreements.

This successful approach would look similar for a wide range of appropriately scoped capability need areas where cutting-edge instrumentation is used across science and application disciplines.

***Example**. Fictional context – an AgResearch scientist working on new biobased materials for encapsulating anti-viral compounds, six months into a study confirms from preliminary data the potential value of extracts from native fungi as part of a planned collaboration with Māori researchers facilitated by AgResearch's Mātai Ahuwhenua team. Results indicate that a fungal cell biology expert is required (but not available at AgResearch) and that the direction of the developing relationship with the Māori collaborators will depend on some preliminary imaging of some physical samples by the fungal cell biologist, with no guarantees of ongoing work.*

***The way it happens now.** For AgResearch to bring in a local fungal cell biologist from the nearby Landcare campus involves subcontracting, time for budgeting and legal review of the subcontract. Extra time and cost arise from the lack of collegial day-to-day contact between the scientists at AgResearch and Landcare who, despite working on the same kind of instrumentation on a day-to-day basis (one to study encapsulation the other fungal biology), do so in different locations under different CRIs. Internally, the cost of the subcontract for an uncertain outcome is questioned and the Landcare business manager involved tries to make sure that enough revenue is generated to make the effort of subcontracting worth it. Internally AgResearch delivery managers question the scientist on where the funding is coming from, while the early stage of the relationship with the Māori collaborator means that passing the bill to them would be inappropriate. The attempt eventually gets approved, but sample preparation is slow because sample preparation is carried out in the AgResearch laboratory (to save money) under advice of the Landcare scientist (who is unfamiliar with AgResearch's preparation laboratory). The result is examined using a microscope at Landcare that is not the most suitable for getting the results, but neither AgResearch nor Landcare have been able to afford the optimal instrument.*

***Shared capability.** The AgResearch and Landcare scientists know each other well; they work from time to time in the same laboratory at the shared facility. The cost of instrumentation and preparatory laboratory access is already covered. Both are aware that a large project will require their respective CRIs to generate a subcontract, but for the purposes of a few hours to try some samples and work out if more is needed is no problem. The Landcare scientist advises how to prepare the samples by talking directly to the AgResearch technician working in a laboratory they are both familiar with. There is flexibility to charge or not charge the Māori collaborators and to get a direct conversation going between them and the Landcare scientist. The results outcome is improved because the best* *possible instrumentation is used (a microscope contributed to the shared facility by a nearby university who is a stakeholder) and the sample preparation is done efficiently because both AgResearch and Landcare scientists are familiar with the shared facility's laboratory.*

The long-term outcome of the work is not different because it is guided by new findings from scientific investigation. Possibly a new anti-viral product emerges or not, but the route to finding this will be quicker, more efficient and based on higher quality data.

Recommendation 1

Investigate current types and numbers of organisations, groups, and service units across all NZ research organisations (CRIs, Universities, Govt depts (e.g., DOC) and Industry/private science organisations). NOTE that this recommendation is about groups and how they operate to understand what enables science outcomes, not what instrumentation they support (i.e., different from the current Kitmap Survey MBIE is undertaking).

Recommendation 2

MBIE should include universities and other institutes (e.g., LAZRA, DOC, MPI etc.) in the Kitmap survey and should interview CRI scientists at all regional research campuses to establish what they see as critical instrumentation for which they see a day-to-day or week-to-week hands-on need (see definition above).

Key issues

Ownership and shared investment

A significant barrier to collaborative use of expensive specialised instrumentation is the current legal ownership restrictions. Unique attractor instruments (NZ-unique, Oceania-unique, or world-unique application) are typically too expensive for single CRIs to consider due to initial costs, infrastructure integration (e.g., buildings) and long-term maintenance. Unique often means that instrumentation with cutting edge and experimental components have an expected higher level of downtime than standard instruments.

***Example** of prospective costs associated with a world-unique instrument capability in bio-based material analysis. An electron-imaging instrument for collecting high-resolution volume data of samples up to 10 mm diameter at a resolution down to 4 nm with correlated chemical maps of atomic elements and of bond-chemistry. The base unit would be a scanning electron microscope specialised for biological samples. Within this there would be an experimental three-dimensional slicing system using a femtosecond laser and an oxygen-plasma focused ion beam to respectively ablate and polish the sample surface to allow the electron beam to record high-resolution sub volumes of samples. An x-ray dispersive spectroscopy unit, and a correlative Raman spectroscopic microscope will allow the addition of chemical information for each slice of the sample. Unique workflow processes and instrument control software, along with data handling and analysis* *will provide a world-unique capability to powerfully analyse new bio-based materials. Cost of instrument ~$3.5M, suitable room ~$0.5M, support instrumentation and ongoing costs ~$0.2M PA. (total ~$5M over 5 years of expected unique-attractor status).*

If such an instrument was bought by part investment by AgResearch, Plant and Food, Landcare, NIWA, Scion and included contributions from three universities in exchange for access, and some ongoing costs (such as support for an electrical engineer to look after the capability, and hands-on technical staff to run samples and train users) could be covered by a staff-time rather than cash contribution. Such an arrangement would give NZ an edge globally, but in the current legal framework of single-CRI ownership and inter-CRI competition it does not work.

Shared ownership may require that the capability organisation is a legal entity that can facilitate the joint contributions and legally own the instrument. Appropriate control/access based on organisational contributions would be facilitated by the capability organisation.

Something similar, but on a national scale occurs in Australia. The origin of this approach was a government-led drive to develop Australia's microscopy capabilities in general and the organisation to facilitate this is now called Microscopy Australia (https://micro.org.au/about/microscopy-australia/).

The concept of investing in instrumentation that will be owned by another organisation is not new. When I began working at Wool Research Organisation of New Zealand (WRONZ) back in the early 2000s, cash contributions were made toward several high-value items of infrastructure at the University of Canterbury in exchange for a time-limited access guarantee (contributions toward a scanning electron microscope and an atomic force microscope guaranteed that WRONZ staff could be trained as hands-on users of the instruments and time was set aside (e.g., 0.5 days a week) for exclusive use by WRONZ scientists). I have not observed this approach used between CRIs.

Recommendation 3

Investigate the legal feasibility of a collaborative shared ownership model via contributions that may include direct funding, standardly valued staff time, and capital and operating contributions.

Access and collaboration

Ultimately the only thing that matters for generating scientific impact from both critical and unique-attractor instrumentation is appropriate access by scientist users. The primary role of the type of capability organisation described here is to facilitate access. Access to locally situated critical instruments and to instruments in collaborator organisations. Agreements on the rules of access, the expectations (training etc.), rights and responsibilities of users can be standardised so that collaboration between different CRIs (and other stakeholders) is enhanced. A standard framework for implementing and monitoring such an organisation could be a role for MBIE, the Royal Society, or some other similar organisation.

Scale of the capability organisation

To enable co-ownership and provide a standard access approach (agreements etc.) a legal entity will likely be required. The entity may or may not be the same thing as the capability organisation, but we will assume it is at this stage. The capability organisation must have its enduring number one priority to generate science outcomes (access, provision of critical and unique attractor needs, and collaboration) within its topic area, and must do this within an appropriate income and grant structure.

While grants for equipment or support may come from a variety of one-off sources, the main operational budget of the capability organisation would be from "club fees" from stakeholder organisations who see value in the capability. Such fees could be a mixture of cash and non-cash contributions valued in a standard way (e.g., staff time contribution, rental of stakeholder instrumentation). Some stakeholders may buy in at greater levels than others and therefore buy more guaranteed access. Additional access could be granted via top-up fees when a short-term need arises. Alternatively, a simple "contribute and you're in" model with a set fee may be more appropriate.

Whether this approach will work, and the details of success depend on scale. Too small (too few instruments, too few stakeholders) and the costs for each stakeholder would be too high and utilisation of critical instruments too low. Too large (e.g., nation-wide) and the organisation will likely slip toward a series of inflexible service-business-model core facilities (as has been the case in Sweden, for example).

Scale would have to be carefully examined and, at this early stage of thinking, be baseline for success is envisioned as:

- major buy-in from at least three local research organisations (this has worked for other successful collaborative focused efforts such as the Biopolymer Network, however, it may be that major stakeholder have equal share or it could be proportional, with one taking lead);
- minor buy-in from at least three additional local or non-local NZ organisations (buying lesser access);
- access to MBIE equipment grants;
- successful reciprocal inter-access agreements with at least two other national organisations with relevant critical or unique-attractor instrumentation.

While the capability organisations need to have local cohesion to allow individuals to talk face to face and walk from instrument to instrument, there is also an important enabler at a national level. MBIE's key role in enabling such capability organisations might be to provide a standardisation framework (in collaboration with CRIs) for the operation of such an entity. MBIE could provide a role to approve the formation of capability hubs and to provide a seed top-up grant for start-up or for the acquisition of unique attractor instrumentation. Then to monitor and assess the yearly performance of these regional organisations to keep their focus on science and access.

Recommendation 4

MBIE consider if the model described, or something similar, could be a useful tool to accelerate NZ science in key areas where an overlap in instrumentation needs (now poorly met) provides the basis for a kind of science and access driven entity that allows co-ownership/investment by collaborating CRIs and other research/science/technology organisations in NZ.

Example organisation

The following example is based on a provisional plan developed between 2020 and 2022 as part of long-term considerations and future proofing for

AgResearch's new science building on the Lincoln University Campus. The concept does not include financial calculations or a business plan. The example relationships are fictional and illustrative only. No negotiations have occurred with the mentioned organisations.

The fictional **centre for bio-based material microanalysis** is a capability unit specialising in advanced microscopy and microstructural analysis of bio-based materials (within a wider capability in a food and fibre space).

(Location, facilities, instrumentation)

- Located in one part of AgResearch's new building at Lincoln (the suite was designed to support high precision current and future instruments physical requirements and services).
- Two chemical laboratories and one large open plan laboratory for communal work and sample preparation.
- Rooms for specialist equipment (e.g., freeze dryers and ultramicrotomes).
- A room for two high-profile imaging instruments with windows that allow science to be on display from external meeting/lounge (e.g., for unique attractor instrument).
- Two more enclosed rooms for other critical imaging instruments.
- Some critical instruments may be located nearby (within walking distance).
- Critical instruments are a transmission electron microscope, scanning electron microscope, laser-scanning confocal microscope, fluorescence microscope, high-resolution automated light microscope, ultramicrotome, carbon coater, metal sputter coater, cryostat, critical point dryer, freeze dryer (and a range of small essential support instruments).
- A unique attractor instrument (volume imaging, laser ablation focused ion beam scanning electron microscope with correlative Raman spectroscopic imaging platform) is a world-unique capability for imaging of new high-tech bio-based materials.

(Stakeholders)

- Major stakeholder AgResearch – provides facility space, services, transmission electron microscope, various other infrastructure, 0.2 FTE each for 2 scientists, 0.4 FTE for two technical staff, small cash contribution to operating costs, contribution to unique-attractor 25%.
- Major stakeholder Plant and Food Research – confocal microscope part contribution 33%, technical staff 0.75 FTE, scientists 0.2 FTE each for 3 scientists, one postdoc, contribution to unique-attractor 25%.
- Major stakeholder Landcare – confocal microscope part contribution 33%, 0.4 FTE for one scientist, contribution to unique attractor 15%.
- Major stakeholder Lincoln University – confocal microscope part contribution 34%, 0.1 FTE for 4 scientists, 0.2 FTE for one technical staff, one postdoc, contributor to unique attractor 10%.
- MBIE – contribution to unique attractor instrument 25% through a start-up grant.
- University of Canterbury School of Engineering, the Biomolecular Interaction Centre, University of Otago, University of Auckland are partner stakeholders that have reciprocal access arrangements for use of specific instrumentation of interest to the bio-based material microanalysis centre (with proportional access depending on instruments and need).
- Scion, Cawthron Institute, LASRA, and Lincoln Agritech Ltd. are minor stakeholders who have agreed to pay-per use fees (typically pre-paid as guaranteed sessions per year).

(Operational)

- Agreements between major stakeholders define how total value contribution is determined year-by-year which helps define the amount each will pay in operating top-up contribution (which covers sundry items, repair and preventative maintenance contracts, consumables).
- Standard access agreements (locally adapted from a common standard set by MBIE) define how individuals are trained, rules of conduct on instruments and what happens should there be a health-and-safety or instrument damage incident.
- Standard agreements guarantee hands-on access for a list of members for a quanta of hours/sessions per year for named instruments (or specific instruments) at remote partner organisations (e.g., the cryo-transmission electron microscopy capability at University of Otago).
- An operational committee consisting of the laboratory managers and representing the major stakeholders meets regularly to deal with on-the-ground operations.
- A wider committee including representatives from major, partner and minor stakeholders will meet occasionally to maintain the smooth running of the facility year on year and gauge emerging needs.

(Measurement of success/impact/outcomes)

- Records are kept of instrument utilisation, user base, scientific publications, high-profile expositions (press and international science conferences), commercial contracts, attraction of external researchers and students.
- Financial balances.
- Survey results of the perceived value of the capability organisation by users and stakeholder organisations.

Author and acknowledgements

Duane Harland (Ph.D. BSc Hons) is a Senior Scientist in the Smart Food and Bioproducts Innovation Centre of Excellence at AgResearch where he leads the electron microscopy capability in the Proteins & Metabolites Team at AgResearch's Lincoln campus. He is currently vice president, and former multi-term president of Microscopy NZ Inc. Over the past couple of decades Duane has worked in multi-disciplinary research on natural and human-made bio-based products.

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