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Networking strategies of the microscopy community for improved utilisation of advanced instruments: (1) The Australian Microscopy and Microanalysis Research Facility (AMMRF)

Stratégies de mise en réseau élaborées par les communautés de la microscopie électronique pour optimiser l'utilisation des nouvelles plateformes instrumentales : (1) Le réseau australien de recherche en microscopie et microanalyse (AMMRF)

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ABSTRACT

This paper describes the strategy underpinning the formation and operation of the Australian Microscopy & Microanalysis Research Facility (AMMRF). The governance and funding of the organisation are described and the advantages and achievements of a nationally coordinated facility for microscopy and microanalysis are set out. Selected data are presented that benchmark the performance of the facility, describe the economic impact and demonstrate the impact on the quality of research outcomes as a result of operating national collaborative research infrastructure for microscopy and microanalysis.

RÉSUMÉ

Cet article décrit la stratégie sous-jacente à la création et au fonctionnement du réseau australien de recherche en microscopie et microanalyse (AMMRF). La gouvernance et le financement de l'organisation sont expliqués, et les avantages qu'il y a à mener et à développer des projets coordonnés à un niveau national autour de et avec la microscopie électronique et la microanalyse sont présentés, ainsi que les réalisations. Une sélection de résultats permet d'évaluer les performances de cette infrastructure collaborative entre des centres répartis sur toute la surface d'un pays et d'en démontrer l'impact au niveau de la qualité de la recherche qui en résulte.

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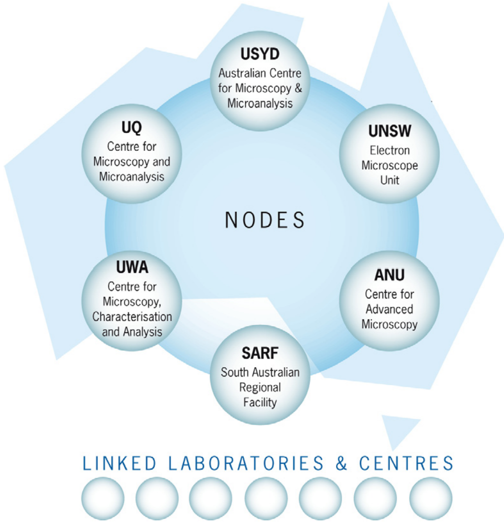

Fig. 1. The six nodes of the AMMRF collaborating to form the national grid of microscopy and microanalysis research infrastructure.

1. Introduction

The Australian Microscopy and Microanalysis Research Facility (AMMRF) is a formal collaboration that links eight Australian Universities together to create a user-focused national capability in microscopy and microanalysis. In addition to the foundation nodes, Fig. 1, the facility also sponsors a number of "Linked Laboratories" which offer niche expertise in particular techniques and so extend the capability significantly. The facility was established in 2007 under the National Collaborative Research Infrastructure Strategy (NCRIS), an initiative of the Commonwealth Government of Australia [1]. Although the current structure was formalized at that time, the basis of the collaborative partnership and the formulation of the user-focused, open access operating model was established in 2002 with the formation of a smaller network of laboratories called the NANO Major National Research Facility. The AMMRF therefore has more than 10 years of the partner laboratories working cooperatively to devise and design best practice in the operation of a research facility. The AMMRF prides itself on the quality of the user-experience and features of this include a common access policy, similar booking and charging protocols, similar user training protocols which enable mobility amongst the users, and access to the AMMRF's extensive online tools.

2. Why a national facility for microscopy and microanalysis?

Fig. 2 maps the spatial and chemical resolution limits for a selection of techniques that are familiar to researchers undertaking advanced characterization as a part of their scientific research. Whether related to the environment, clean energy, health and disease or information and communications, the major scientific and technological challenges of tomorrow involve physical and chemical processes that occur over a wide range of length and time scales. Clearly, a range of techniques is required to explore the processes and phenomena that occur across these various scales. Now, whilst one could debate the precise limits of certain fields of the chart in Fig. 2, it is most unlikely that all of these techniques could be supported in a single research centre. The diversity of expertise required, combined with the capital outlay to support such a facility would seem to be beyond most individual institutions.

To overcome these pragmatic limits and yet provide our community of researchers with a comprehensive capability that spans this chart and beyond, our strategy has been to form a strategic collaboration that connects laboratories in separate institutions. Besides achieving the primary objective of providing capability across the wide range of physical and chemical processes such as occur within the limits of Fig. 2, this strategy achieves several key advantages.

Firstly, this coordinated approach allows the facility to devise and manage an equipment and expertise plan of significant scale that maps into national strategic research priorities. Coordination replaces competition between facilities, and allows a balance between common workhorse type instrumentation and highly specialised "flagship" facilities that have exceptional requirements in terms of operating costs, and expertise.

AMMRF flagship capabilities include:

Cameca IMS 1280 & NanoSIMS 50 ion microprobes	University of Western Australia
High-throughput, high-resolution cryoTEM	University of Queensland
Atom Probe Microscopy	University of Sydney
High-resolution Focussed Ion-Beam and SEM	Universities of Adelaide & NSW

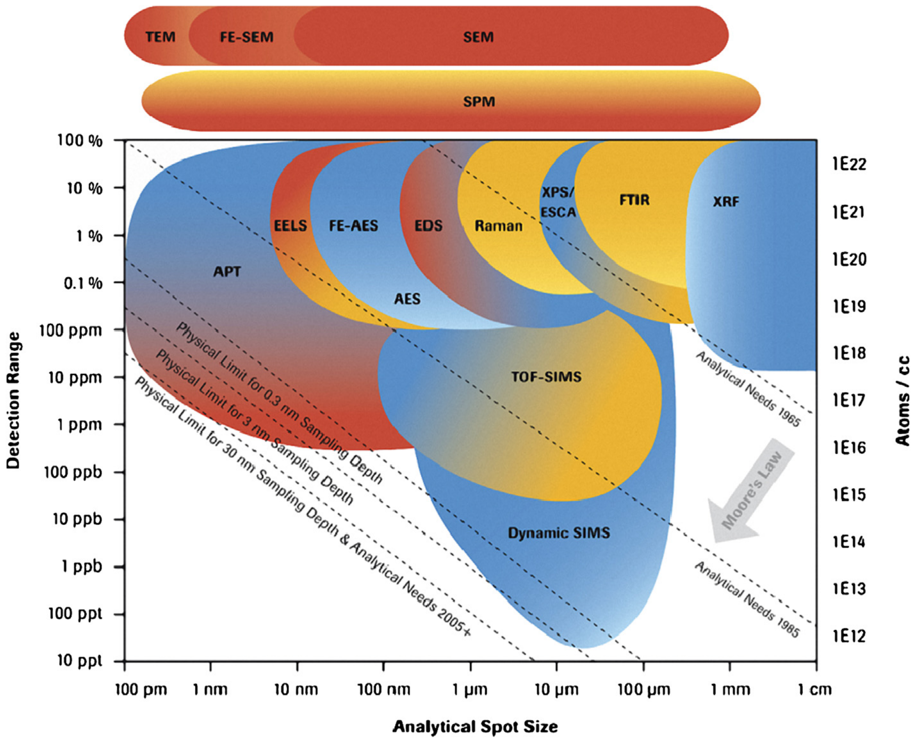

Fig. 2. (Colour online.) The concentration limits and detection range required of modern microscopy and microanalysis capability to meet the needs of researchers (after Evans Analytical Group LLC).

High-resolution SEM microanalysis facility	University of New South Wales
PHI TRIFT V nanoToF ToF-SIMS	University of South Australia

Secondly, a network of peer support and expert training has been established amongst facility professional support staff. Through this network, capability and expertise can efficiently be transferred amongst the nodes, helping to improve the delivery of a particular technique or capability at a node so that the level of expertise is similar across all nodes. The AMMRF has been able to recruit and retain highly specialized technical support personnel, known as Flagship Engineers. These staff members are crucial to the effective utilisation of flagship instrument investments within the nodes. The role of these engineers in enabling world-class outcomes cannot be overstated. They are responsible for the up-keep of state-of-the-art instrumentation, user engagement, support experimental design, planning and execution and also provide support in data analysis and interpretation—the important step in transforming data into knowledge.

The third advantage of forming the collaborative infrastructure is the development of best practice around laboratory management and operations, including, occupational safety standards and procedures as well as procurement and maintenance of equipment. By working co-operatively, laboratory managers at each node are able to share know-how and experiences, which enables the facilities to provide a common level of user experience to 3000 users across all facilities. The annual satisfaction survey conducted since 2008 regularly shows that more than 90% of users are highly satisfied with the research staff and the facilities that are available. The co-operation also extends to strategically working together on the procurement of instruments, consumables and spare parts yielding pricing discounts as a result of larger order quantities.

A final benefit of the network to be discussed is the ability to collaborate to develop online tools that are then accessible by all the laboratories in the network. In addition to web-based instrument booking systems, and other resource management tools, that are widely used by many core facilities, the AMMRF has developed specialist tools for microscopy and microanalysis research facilities. These tools assist researchers to identify the techniques they need to use, facilitate training and enable data analysis and management. Further details regarding these tools are outlined in the following sections.

3. Facility performance data

A range of metrics has been used to measure the performance and more importantly to describe the impact that the AMMRF has had on Australian research outcomes. In terms of measuring the scale of the operation the number of registered users, the amount of instrument beam time utilised and the diversity of research fields are recorded. The data show that on average 3000 users per year are registered to use facilities, typically utilising 200 000 hours of instrument beam time

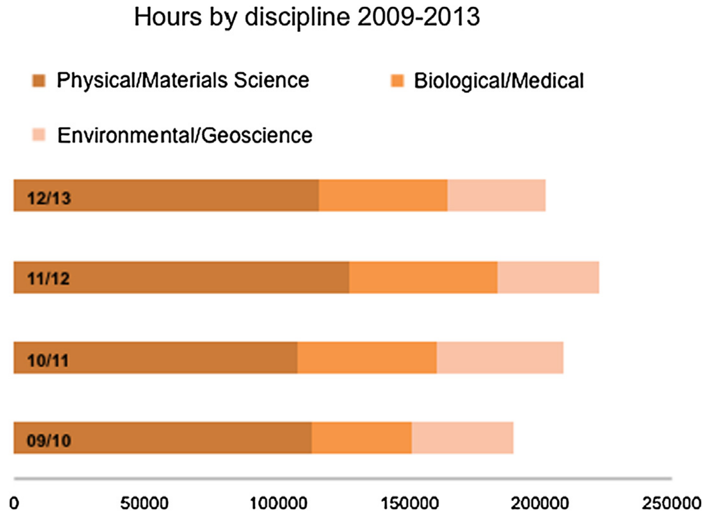

Fig. 3. (Colour online.) The amount of instrument beam time consumed by AMMRF users in various research fields since 2009.

(Fig. 3). Typically one-third of the users are new to the facility each year and require training on at least one instrument platform as well as support in specimen preparation and image or data analysis.

Providing evidence, especially quantitative evidence, of increasing science impact or collaborative behaviour in the user community is very difficult. The best approach is to seek metrics or proxies that can be considered to provide quantitative evidence of increasing science impact or collaboration. As far as increasing science impact, a promising and relatively simple approach would be to look at the quality of the journals in which the members of the user-community publishes their work. A trend to publishing in higher-quality journals over time would suggest an increasing science impact of the users' work. Such an analysis would be relatively straightforward to do given that the AMMRF collects details of users' publications each year.

Another important measure AMMRF impact has been an investigation into the economic impact and benefit of the facility. Economic modelling to determine the potential contribution of the AMMRF to the Australian economy was performed in 2011 [2]. The value of the investment in the AMMRF was evaluated using a widely accepted model of the Australian economy as well as through case studies, qualitatively describing the broader impact and benefit of the facility.

The key results of the modelling revealed that investment in the AMMRF is resulting in significant benefits for the Australian economy, and the community at large. Importantly, these benefits go beyond direct economic impacts, with the AMMRF helping to find solutions and pursue opportunities in areas as diverse as health, climate change, and innovative manufacturing. The analysis revealed that standard economic indicators such as Gross Domestic Product (national output), Consumption (community well being) and Investment (expansion of productive capacity) will increase as a result of the investment in the AMMRF.

4. Recent achievements

We conclude this article with a summary of certain recent achievements that would not have been possible without the strategy and operational approach of the AMMRF.

Outstanding publications. Perhaps the most enduring legacy of any national research facility is the science that is enabled that would otherwise not be possible. The experience in the AMMRF is that the notion of 'world-class' is tied very closely to the ability of the facility to support expert technical staff that are motivated and capable to ensure that the instruments can be tuned to solve the particular research questions of the users. Of the many patents, theses, books and publications that include work conducted at the AMMRF, there have been certain particularly important research papers spanning both methodological innovation, particularly in the flagship microscopy science, as well as in the advanced applications of these and related techniques (Fig. 4) [3–21].

International relationships. The AMMRF has numerous international relationships arising from the instrumental capability and the specialised expertise of its staff. The AMMRF user community now extends to every continent, and many individual international relationships, particularly surrounding the flagship capabilities, exist as a result of these interactions. The International Atomic Energy Agency (IAEA) maintains a network of analytical labs that monitor samples from areas suspected of undisclosed use of nuclear materials from the nuclear fuel cycle. After stringent testing and certification the flagship 1280 ion probe capability at the AMMRF node at the University of Western Australia has recently become a part of this network and will begin to play its part in monitoring global nuclear safeguards.

Strategic international connections ensure that the AMMRF maintains a leading position in world microscopy. Developing technical trends and how they can be best used to address emerging global issues in research can be understood.

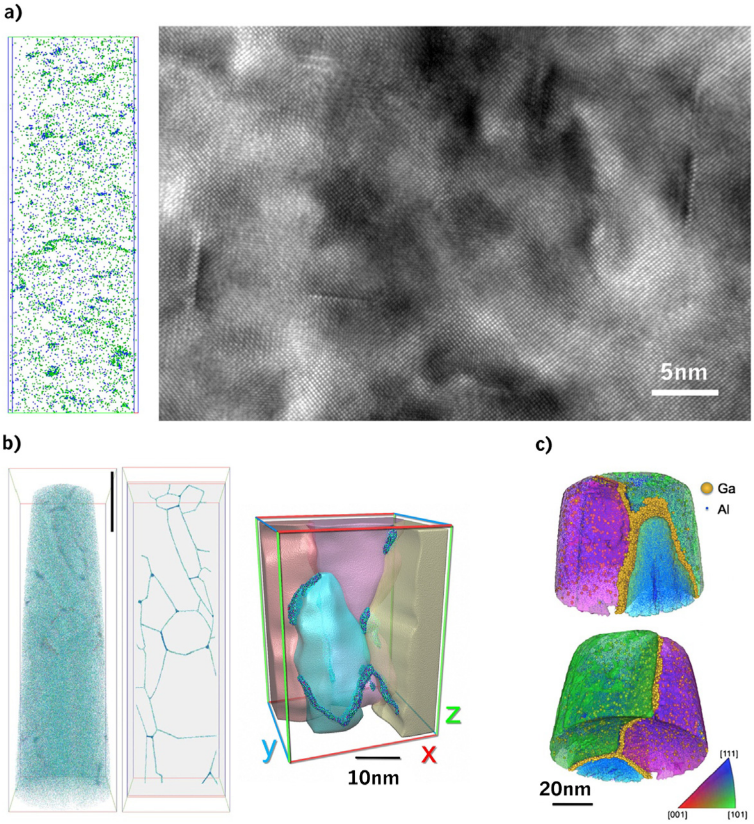

Fig. 4. (Colour online.) Some of the high-profile outcomes enabled by AMMRF capability. (a) APT dataset and TEM image showing cluster hardening of niobium-microalloyed steel [6]. (b) Three views of APT data showing nano-structural hierarchies in a 7075 aluminium alloy after severe plastic deformation [5]. (c) A reconstructed volume of a nanocrystalline aluminium sample in which the colours of the grains represent the orientation according to the pole figure. This atomic-scale orientation mapping by APT was developed in the AMMRF and is a powerful new tool in materials science [7].

A practical way to keep up to date in these areas is through the AMMRF International Technical and User Advisory Group (ITUAG), a panel of the world's leading microscopists and formal links to similar networks in other countries and regions. Such networks include Euro-BioImaging a large, pan-European network of advanced light microscopy and imaging facilities, ESTEEM2 (European network for electron microscopy) and INSTRUCT.

Industrial engagement. Recognising that high-quality research is not the exclusive domain of universities and national laboratories, the AMMRF has an active engagement strategy with industry. Our user engagement spans from research contracts with major global multinational corporations through to support of smaller start-ups and can follow a number of paths, according to the needs of the individual business concerned. The major forms of industry interaction or access include: *Contract R&D projects*; *Leveraged R&D projects*; *Access by industry users to instruments and capability*; *Testing and consultancy services*; and *Training*.

On line tools. The most popular on line tool developed by the AMMRF has been MyScope: Training for Advanced Research. MyScope is an online suite of education tools for teaching and learning in the area of microscopy and microanalysis. A range of modules has been developed to sit within the suite: scanning electron microscopy; transmission electron microscopy; scanning probe and atomic force microscopy; confocal microscopy; and X-ray diffraction techniques. The modules in MyScope contain a number of components including: an interactive questionnaire to allow the user to assess their knowledge, guide choices and tailor the learning environment for flexible learning; self guided tutorials with videos, animations and glossary to prepare students with knowledge and specialist language; virtual instrument platforms to practice use of instrumentation; and online competency testing to demonstrate readiness for hands-on experience (Fig. 5).

MyScope is openly accessible to all researchers and is not limited to the AMMRF laboratories. From 2012 to 2013 almost 60 000 people visited the tools for a variety of reasons including undergraduate and postgraduate teaching and training, research facility management and scientists from industry based microscopy facilities and research laboratories. The flexibility of MyScope is further enhanced by the ability for trainers to customize a module and present only the content and key points that they need to deliver effectively hiding from the student content which is advanced or not in the scope of learning objectives. As a user progresses in their training and competency increases these hidden areas can be made available to aid advanced training.

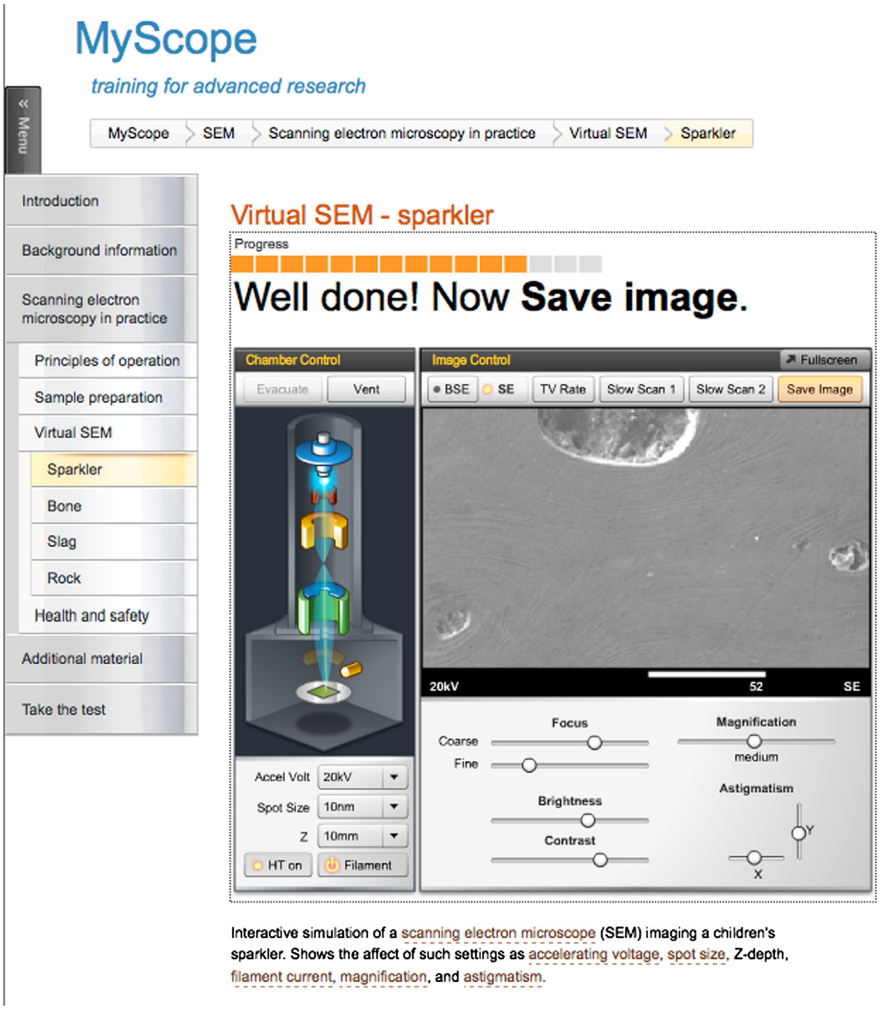

Fig. 5. (Colour online.) The virtual SEM in MyScope enables realistic instrument training and prepares researchers for effective and efficient training on actual instruments.

The Technique Finder (TF) is a web application that enables prospective facility users to identify the techniques most suited to their research, based on a researcher-centric approach and terminology as opposed to instrument-oriented jargon. Specifically, it offers two areas, one for biological scientists and another for researchers in physical sciences, which allow them to identify techniques based on research dimensions in corresponding fields.

A Data Management System (DMS) addresses the needs of an increasing number of AMMRF users who are using high-end instruments to produce large datasets. The DMS offers a uniform user interface to access remote or local data and metadata resources, effectively leveraging the web as Software as a Service platform for data management. It provides basic protocol interfaces, allowing AMMRF users to leverage common storage infrastructure as well as the potential to connect to a range of online analysis tools or platforms.

A specific data analysis platform being developed is the Atom Probe Workbench. This tool is a component of a larger national eResearch project in Australia, that is integrating existing tools and techniques with a network of specialised cloud-based computing systems and data-storage facilities. This integration will enable the atom probe research community to access and create valuable tools, accelerating the research process.

5. Conclusions

Australian Microscopy & Microanalysis Research Facility (AMMRF) is a highly successful national research infrastructure collaboration for microscopy and microanalysis. With more than ten years of operating experience, the AMMRF has demonstrated several advantages including: national strategy and co-ordination of capability comprising microscopy and microanalysis instruments and expertise as well as the development of a range of facility online tools; formation of a peer network of professional support staff; and development of best practice around laboratory management and operations, instrument and consumables procurement and performance measurement.

The impact of the facility has been significant with more than 3000 researchers annually using the network of laboratories and performing more than 200 000 hours of microscopy and microanalysis. It has been demonstrated that the AMMRF has an impact on raising the overall quality or research outcomes as measured by the publication record of it users. External modelling of the economic impact of the AMMRF has revealed that it will benefit the national economy by increasing Gross Domestic Product (national output), Consumption (community well being) and Investment (expansion of productive capacity).

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