MICROSCOPY AUSTRALIA

NCRIS
National Research Infrastructure for Australia
An Australian Government Initiative

FUTURE TECHNOLOGIES INVESTMENT PLAN

CONSULTATION PAPER | AUGUST 2026

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1. PURPOSE

Microscopy Australia is seeking feedback from the Australian research community on the draft 2026 Future Technologies Investment Plan ("the Investment Plan"). This Consultation Paper outlines the proposed infrastructure, capability, workforce, and digital investments that underpin the Investment Plan, which is designed to ensure Australia remains globally competitive in microscopy-enabled science and innovation. This draft Investment Plan is the result of feedback from Microscopy Australia's 2024 Future Needs Survey, combined with feedback provided as part of the 2026 National Research Infrastructure Roadmap consultations. Input is being sought from Microscopy Australia's Scientific Advisory Committee, the Australian research community, and industry stakeholders through consultation sessions and an online submission form.

The feedback will guide strategic directions and priorities, over the next 5-10 years, as inputs into Australia's future national research infrastructure roadmaps, and future funding submissions as part of the Australian Government National Collaborative Research Infrastructure Strategy (NCRIS).

2. STRATEGIC CONTEXT

Microscopy Australia operates a national, open-access network to enable Australian discovery and acts as a core enabler that de-risks innovation for over 4,000 researchers across a broad range of scientific disciplines. The insights reveal fundamental scientific understanding, solve innovation and industry challenges and deliver evidence for start-up and spin-outs to secure capital investments. These benefits are achieved through the combination of expertise and advanced instruments aligned with key national missions.

The Investment Plan responds to the:

- increasing demand for high-resolution, multi-modal and high-throughput analysis
- rapid growth in data-intensive and AI-enabled science
- three priority impact areas of Critical Minerals; Energy Transition and Frontier Technologies; and Health and Agriculture
- critical need for coordinated reinvestment of nationally significant instrumentation (supported by expertise) due to a significant proportion approaching end-of-life by 2030

3. CROSS-CUTTING THEMES

Across the priority impact areas, three themes underpin the proposed future investments:

Enabling Infrastructure. Sustained investment in national, open-access instrumentation is required to maintain sovereign capability and support industry translation.

Digital Capability. There is a critical and unmet need for data infrastructure, automated analysis workflows, AI-enabled analysis, and integration across multi-modal datasets.

Skilled Workforce. Targeted workforce development is essential to maximise the return on infrastructure investment, ensuring Australian researchers have access to world-class expertise alongside world-class facilities. Along with industry-facing roles and positions focused on developing new techniques and applications for Australian discovery and innovation.

4. MICROSCOPY AUSTRALIA'S PROPOSED INVESTMENTS

Microscopy Australia (est. 2007) is an unincorporated joint venture between eight Australian university-based microscopy facilities. We also have partnerships with nine affiliated microscopy facilities, our 'Linked Laboratories'. Both Facilities and Linked Labs are open to all Australian researchers. We are united by common values of collaboration, accessibility, excellence, and innovation. Microscopy Australia's role is to make the expertise and equipment needed to tackle Australia's research priorities open access. We achieve this by:

- acquiring, developing and providing access to important emerging microscopy capabilities
- strategically placing advanced instruments where they align best with a critical mass of scientific expertise and relevant user groups
- providing access to world-first technology and developing new microscopy techniques
- directly supporting industry, focusing on start-ups and small businesses
- developing and sharing high-quality training resources including the world-leading training website, MyScope.

The proposed investments have been aligned with three priority impact areas, Critical Minerals, Energy Transition and Frontier Technologies, and Health and Agriculture.

4.1 CRITICAL MINERALS

Opportunity for Impact

Microscopy is a key enabler across the critical minerals value chain, from exploration to improved processing. Australia has strong resource endowment but lacks sufficient microanalysis capacity to fully capitalise on this advantage and requires coordination with industry and NCRIS partner AuScope for future investments.

National Strategic Directions

Microscopy Australia can:

- enable faster and more accurate mineral analysis and characterisation
- support development of sovereign processing capability for green steel
- unlock value from low-grade ores and mine waste
- strengthen links between mining and advanced manufacturing

Summary of Proposed Investments

Integrated Time of Flight Secondary Ion Mass Spec (TOF-SIMS) Suite

- High-resolution nanoscale analysis combined with high-throughput screening
- Enables end-to-end workflows from bulk samples to molecular profiling

Large-Core Spectral X-ray CT

- 3D, large-scale ore characterisation
- Improved detection of complex mineralogy and minority phases
- Increased throughput and decision-making speed

Dynamic Micro/Nano CT (4D Imaging)

- Real-time observation of material behaviour under operational conditions
- Applications in mineral processing, environmental performance, and energy materials

Integrated Time of Flight Secondary Ion Mass Spec (TOF-SIMS) Suite

Purpose: To improve Australia's ability to analyse critical minerals, rare earth elements, and materials used in mineral processing, along with solar cells, batteries and quantum technologies. This is crucial for safe-guarding national supply chains and achieving net-zero.

Need addressed: This integrated system addresses the lack of a powerful national pipeline that can efficiently process bulk samples from high-throughput screening to nanoscale elemental analysis and molecular depth profiling.

How it works: This is an integrated investment comprising three complementary platforms to provide:

- rapid, high-throughput elemental screening of large numbers of geological and mineral samples using laser ablation coupled with time-of-flight mass spectrometry to deliver fast, quantitative multi-element analysis at 100ppb potential with minimal sample preparation
- high-resolution, 3D elemental, molecular, and isotopic profiling with high sensitivity (10ppb) and molecular identification (up to 5000 molecular weight), ideal for surface chemistry and isotopic analysis at the nanoscale. It includes cryo-capability for beam-sensitive materials
- a multi-ion FIB/SEM column with integrated SIMS, combining nanofabrication capabilities (precision milling, implantation, patterning) with in situ analytical power. It would enhance light element (e.g., Li) imaging and profiling, and support elemental and low molecular SIMS imaging with higher depth accuracy and advanced spatial resolution

Large-Core Spectral X-ray CT

Purpose: To provide fast, accurate, and comprehensive 3D analysis of mineral ore core on a large scale. This investment addresses the constraints of traditional mineralogical and chemical analyses (XRD, SEM, automated mineralogy, XRF, ICP) that are often limited to small sample sizes, ex situ analysis, and incur long wait times. These traditional methods also struggle with fine particles, clay analysis, or samples with non-uniform distribution and complex mineralogy, and automated techniques like MLA can miss vital minority phases or lead to incorrect liberation and void analysis.

Need addressed: Similar investments already exist in Australia, however, there is a need for increased capacity across the country, so that identification of small quantities of minerals is improved and faster on-site decision making is enabled. Planned investments will require coordination with NCRIS colleagues at the National Imaging Facility.

How it works: This technology involves combining large volume micro-CT with XRF and correlative XRD, along with elemental analysis using XFM.

Dynamic Micro/Nano CT

Purpose: To deepen the understanding of mineral and material behaviour to inform environmental sustainability, mineral processing, and energy solutions. It aims to shift from simply describing material properties to understanding how materials respond and behave under different dynamic conditions.

Need addressed: While synchrotron facilities have made advances, there is a clear need for accessible, laboratory-based systems that can image samples in 4D within an open access national research infrastructure. This dynamic system fills a critical gap by enabling real-time observation and understanding of how materials respond and behave under dynamic conditions (e.g., mechanical deformation, fluid flow), which is a significant advance from existing micro-CT investments. This requires coordination with NCRIS colleagues at the National Imaging Facility.

How it works: This investment would be a laboratory-based system capable of imaging, reconstructing, and understanding samples in 4D (length, width, height, and time). It allows researchers to observe how materials change over time by rapidly acquiring images and provides in-situ observations of materials in their natural environment. It can use a Multi-Spectral Source (MSS) to generate quasi-monochromatic beams, improving contrast between similar-Z materials.

4.2 ENERGY TRANSITION AND FRONTIER TECHNOLOGIES

Opportunity for Impact

Advanced microscopy is essential for designing, optimising, and validating materials for clean energy, including batteries, hydrogen systems, and catalysts, along with new materials for quantum applications, additive manufacturing and semiconductors.

National Strategic Directions

Microscopy Australia will enable:

- atomic-scale understanding of materials in real-world conditions
- development of more efficient and durable energy systems
- faster translation from discovery to deployment

Summary of Proposed Investments

Environmental Transmission Electron Microscopy (ETEM)

- Integration of real-world condition imaging for materials under stress, temperature, or chemical environments

Atomic Bond-Resolved TEM

- Direct measurement of atomic bonding environments
- Combines spatial resolution with chemical insight
- Bridges gap between imaging and spectroscopy

Beam-Sensitive TEM / 4D-STEM

- Enables analysis of previously inaccessible materials
- Critical for polymers, perovskites, and energy materials

Atomic-Scale Analytical Tomography (ASAT)

- Reveals how atomic-scale composition affects the performance and degradation of catalysts, batteries, and fuel cells
- Quantitative analysis and identifies atomic-level defects, grain boundaries, phase boundaries, and transformations in advanced alloys and structural materials

Environmental Transmission Electron Microscopy (ETEM)

Purpose: To develop new materials and technologies for net-zero emissions by providing a deep understanding of how materials behave at the atomic scale under real-world operating conditions (e.g., gas atmospheres, elevated temperatures, and electrical or chemical stimuli). Existing tools often fail to provide real-time, atomic-scale insights into dynamic changes necessary for tracking reaction mechanisms in catalysts, understanding degradation pathways in batteries and fuel cells, and designing robust and efficient materials for net-zero.

Need addressed: Australian researchers currently rely on international collaborations to access ETEM capabilities overseas, so this would bring a new capability to Australia.

How it works: ETEM enables atomic-scale imaging and analysis in dynamic, realistic environments, allowing direct observation of changes like phase transformations, oxidation-reduction reactions, and atomic restructuring as they occur. Key advancements include ultra-fast and ultra-sensitive detectors, precise control of reaction conditions, ultra-sensitive chemical and elemental characterisation (next-generation EELS and XEDS for high-speed, low-dose analysis), and an ultrahigh energy resolution monochromated electron beam.

Atomic Bond-Resolved TEM

Purpose: To design and control advanced materials for clean energy systems (batteries, fuel cells, hydrogen technologies, catalysts) by fundamentally understanding their atomic bonding environments and how they determine functional properties.

Need addressed: The critical frontier is the lack of an existing technique that can directly resolve atomic bonding information at the atomic scale, especially for single atoms or heterogeneous sites. Existing tools like X-ray absorption spectroscopy (XAS) provide only bulk-averaged or indirect information. This proposed TEM fills this gap by providing bonding-sensitive characterisation with atomic spatial resolution, offering "synchrotron-equivalent bonding information" but at the atomic scale. It bridges the gap between synchrotron spectroscopy and atomic-resolution imaging, offering both spatial precision and chemical insight in one platform in a lab-based system.

How it works: This ground-breaking TEM capitalises on three transformative breakthroughs: an ultrahigh energy resolution electron beam (sub-10 meV energy resolution for direct detection of bond vibrations and electronic structure changes), ultrawide energy range Electron Energy Loss Spectroscopy (EELS) (spanning up to 80 keV for comprehensive probing of low and high-energy interactions), and a next-generation TEM platform with cutting-edge electronic stability for atomic resolution and ultrasensitive spectroscopy. This effectively transforms the TEM into a localised, atomic-resolution analogue of synchrotron XAS.

Beam Sensitive TEM / 4D-STEM

Purpose: To enable atomic-scale structural and chemical analysis of beam-sensitive materials that are crucial for a net-zero future, but previously inaccessible to conventional TEM due to electron beam damage. The single biggest limitation to the broad application of transmission electron microscopy to next-generation energy materials is electron beam damage, which renders whole classes of technologically important materials (e.g., polymers, batteries, perovskite solar cells, metal-organic frameworks, minerals) inaccessible for atomic-scale analysis. These materials previously could only be studied at low resolution or not at all. Beam-Sensitive TEM and 4D-STEM capabilities fill this gap by enabling atomic-scale structural and chemical analysis of these previously inaccessible materials.

Need addressed: Technology continues to evolve to improve performance for samples that are easily damaged by the electron beam. Additional capacity is required, as well as new technology to improve TEM capabilities for beam sensitive samples that use new beam blanker technology, integrated with scan and dose control for high throughput, automated processing. This could be further extended by utilising liquid helium sample holders.

How it works: This platform will allow analysis of materials that are easily damaged by electrons through incorporating advanced beam blanker technology with integrated scan control to precisely control beam position and dose. Future improvements in detector technology will enhance spatial resolution and sensitivity, enabling event-based operation for time-resolved data and low-dose applications.

Atomic-Scale Analytical Tomography (ASAT)

Purpose: The purpose of ASAT is to reconstruct the 3D atomic arrangement and chemical composition of a material with near-atomic or atomic-scale resolution. It allows researchers to identify the position and type of individual atoms within a specimen, providing detailed insight into its structure and chemistry. It is considered a state-of-the-art but still developing approach for studying dopant distribution in silicon semiconductors and analysing grain boundary chemistry in advanced alloys used in aerospace and battery materials.

Need addressed: ASAT addresses the need in Australia for atomic-level understanding of advanced materials used in mining, energy, defence, and semiconductor research where conventional imaging is insufficient. It is used, for example, to study dopant placement in silicon devices and atomic-scale defects in high-performance engineering alloys. Currently, Australia has no ASAT capabilities and relies on limited overseas access.

How it works: ASAT combines multiple advanced techniques, primarily Transmission Electron Microscopy (TEM/STEM) for high-resolution structural imaging and Atom Probe

Tomography (APT) for single-atom chemical quantification. It is a 3D imaging and analysis method designed to achieve atomic-scale spatial resolution while also providing 3D chemical sensitivity through elemental mapping. As such it helps bridge the gap between experimental observations and computational material design. ASAT is considered a state-of-the-art but still developing approach, with ongoing research focused on integrating TEM–APT techniques into a single, unified instrument.

4.3 HEALTH AND AGRICULTURE

Opportunity for Impact

There is growing demand for integrated structural and molecular analysis to support life science research, biomedical discovery, biosecurity, and agricultural innovation.

National Strategic Directions

Microscopy Australia will:

- enable spatial biology at scale
- support drug discovery and precision medicine
- aid crop-resilience and pest control

Summary of Proposed Investments

Morpho-Omics Platform

- Integration of high resolution microscopy, imaging mass spectrometry, transcriptomics, and proteomics
- Whole-sample, spatially resolved molecular analysis
- High-throughput and high-resolution capabilities

Next-Generation Cryo-EM

- Continued investment in 300 kV cryo-TEM and cryo FIB-SEM
- Expanded capacity for cryo-electron tomography
- Improved sample preparation workflows

Soft X-ray Tomography

- High-resolution 3D imaging of whole cells
- Synchrotron-like capability in a laboratory setting
- Increased accessibility and throughput

Morpho-Omics (integrated Imaging Mass Spectrometry/Multi-Omics) Platform

Purpose: To seamlessly measure both structural and molecular (omics) information in whole, biological samples in natural conformation. It aims to bridge microscopy and omics to allow spatially resolved understanding of tissue regionalisation, gene expression, and protein distribution for applications like disease pathology and drug discovery and development (e.g., screening how treatments shift gene expression and phenotypes spatially).

Need addressed: National coordination of spatial-omics is critical to improve data processing pipelines and coordinated investment in this technology with other national research infrastructure providers such as NCRIS Partner BioPlatforms Australia.

How it works: The platform comprises:

- High-Content Smart Microscopy for automated, high-throughput, high-resolution imaging of live specimens
- 3D Molecular Imaging for 3-nm resolution and rapid tracking of molecular movements, linking structure-function data (e.g., MINFLUX)
- Spatial Omics Imaging (transcriptomics and proteomics) for visualising gene expression or protein distribution within whole-tissue sections, linking gene expression to protein function spatially up to the single cell level
- Imaging Mass Spectrometry (MSI) techniques (including SIMS, MALDI, DESI, and specifically ToF SIMS) for visualising the spatial distribution of biomolecules (proteins, lipids, metabolites) within samples, combining chemical specificity with microscopic imaging. ToF SIMS offers high spatial resolution (50-100 nm) for label-free chemical/molecule mapping
- the increasing complexity of data from these integrated approaches also points to a data analysis and bioinformatics gap, necessitating more powerful AI-based tools

Next-Generation CryoEM Suites

Purpose: To increase Australian capacity and throughput for in-situ structural biology with cryo-TEM investments. Cryo-TEM enables 3D observation of subcellular and supramolecular structures in their near-native, hydrated state at high resolution, which is critical for gathering insights into drug-target interactions, early-stage drug discovery, and developing novel therapeutic compounds for emerging diseases. Cryo-FIB SEM enables high-quality sample preparation, enabling the creation of thin, vitreous cryo-lamellae necessary for cryo-ET.

Need addressed: This investment fills the need for increased capacity for cryo-electron tomography for structural determination at the subcellular and supramolecular levels, as a significant number of these advanced platforms are now approaching 10 years of operations. Continued investment specifically addresses the insufficient capacity and throughput within Australia, as well as emerging technology developments to push resolution boundaries. CryoFIBs are critical to prepare high-quality lamella for subsequent cryo-ET image data recording to increase volume imaging throughput and connectivity to high-voltage TEMs.

How it works: This investment includes two key components:

- next-generation investments in 300 kV cryo-TEM which is a dedicated cryo-ET platform allowing 3D observation of biological samples in their near-native, hydrated state at high resolution. This is particularly useful for mapping complex, large macromolecular assemblies and cellular structures. The technology aims to incorporate next-generation energy filters and phase plate technology for atomic-scale analysis.
- Cryo-FIB SEMs for sample screening and preparation. Its primary role is to produce thin, vitreous cryo-lamellae, which are necessary for subsequent high-resolution cryo-ET imaging, preserving biological matter in its near-native state.

Rapid Whole Cell Volume Imaging with Lab-Based Soft X-ray Tomography

Purpose: To enable fast, high-resolution 3D structural imaging of *whole cells* in their fully hydrated, cryogenically preserved, and native-contrast state, making this capability accessible outside of large synchrotron facilities.

Need addressed: The key gap is the limited access to high-resolution 3D structural imaging of *whole cells* in their native state (without staining or labelling) outside of large-scale synchrotron facilities. It fills the need for a compact, lab-based system that can achieve comparable spatial resolutions and a large field of view, while also allowing for the correlation of different microscopy techniques. This would enable rapid imaging of multiple cells and supporting dynamic molecular microscopy, which current methods may miss or be too slow to capture.

How it works: This compact, lab-based soft X-ray tomography (SXT) microscope achieves spatial resolutions comparable to synchrotrons (down to 25 nm) with a large field of view. It allows rapid imaging of multiple cells (approximately 50 cells in 3D over different time points within a week), and facilitates the correlation of fluorescence microscopy, electron, and X-ray microscopy. The system enables dynamic molecular microscopy (X, Y, Z, and t) to identify and locate specific molecules and their targets of interest.

5. DIGITAL RESEARCH INFRASTRUCTURE

A major theme across all impact areas is the urgent requirement for a nationally coordinated digital strategy for Microscopy Australia. Proposed initiatives include:

- national data infrastructure for imaging datasets
- coordinated use of AI models for microscopy data analysis
- partnerships with national and international organisations
- standardised workflows and interoperable data systems

Solutions for Australian researchers currently rely on building capacity and capability with other NCRIS Partners that provide digital solutions.

6. SKILLED WORKFORCE

Microscopy Australia aims to strengthen its role in developing a skilled workforce, helping to ensure increased recognition, career development, and sustainability for research infrastructure specialists and technical experts driving national science and innovation.

Microscopy Australia has just been awarded NCRIS funding to promote the Technician Commitment in Australia, as well as to promote professional development and training opportunities to National Research Infrastructure workforce through the Academy for Collaborative Research Infrastructure.

Internally, Microscopy Australia will focus upskilling initiatives on the national science and research priorities, including alignment with Critical Minerals, Energy Transition and Frontier Technologies, and Health and Agriculture. Microscopy Australia will continue to provide opportunities for our staff to develop their skills to ensure they can provide high-quality cutting-edge support to Australian researchers. We will continue to develop capability by productively and proactively supporting industry-led projects and partnerships.

7. KEY QUESTIONS

We seek targeted input from researchers, facility users, and industry partners on the following questions:

1. **Priority Areas**
   Do these priority areas reflect where microscopy investment can have the greatest national impact over the next 5–10 years?
   Are there important national priorities or research areas missing from the plan?

2. **Infrastructure Investments**
   Which proposed investments would have the greatest impact in your research?
   Do the proposed investments address the major capability gaps facing your research community?
   Are there important technologies missing from this plan?

3. **Digital Research Infrastructure**
   Which digital capabilities would deliver the greatest benefit to your research?
   What are the most significant challenges you experience when managing, analysing or sharing microscopy data?
   Are there opportunities for Microscopy Australia to work more closely with other NCRIS facilities to deliver digital infrastructure and AI capabilities?

4. **Skilled Workforce**
   What skills are most urgently needed?
   What skills or expertise will become increasingly important over the next 5-10 years?

8. NEXT STEPS

Feedback from this consultation will be incorporated into:

- a refined Microscopy Australia Future Technologies Investment Plan
- informed investment prioritisation incorporating national and international perspectives
- national funding submissions

Stakeholders are encouraged to provide written submissions and participate in online consultation sessions.

9. CONCLUSION

Microscopy Australia is positioned to play a critical role in enabling Australia's scientific, industrial, and economic future. Strategic investment in infrastructure, digital capability, and workforce will ensure the nation can fully leverage its strengths in critical minerals, energy transition, and biomedical innovation.