

e-DREAM: the European Distributed Research Infrastructure for Advanced Electron Microscopy

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The European research and innovation infrastructure ecosystem is diverse in its scale and scope, comprising facilities and services that include major scientific research equipment, resources such as collections, archives of scientific data, e-infrastructures such as data storage and computing systems, communication networks, as well as pilot and demonstration sites and living labs.

Over the last twenty years, the expansion of research infrastructures (RIs) in the European landscape has been enormous. It has been made possible through national investments and, more recently, through a coherent approach to pan-European RI development with the support of the European Strategy Forum on Research Infrastructures (ESFRI). Strategic objectives, such as avoiding duplication of effort, pooling of resources, the rationalisation of RI use and the standardisation of processes are core elements that are intended to provide Europe with sustainable world-class RIs. By following this approach, ESFRI has been successful in developing a medium to long term vision for the needs of European scientific communities, leading to the consolidation of a roadmapping process on a European level. The European Research Infrastructure Consortium (ERIC) regulation has also contributed significantly to the structuring of the European RI ecosystem.

The rate of technological development of many RIs (in particular large physics and analytical facilities) is accelerating, making the European landscape for RIs dynamic and competitive. While economic pressures have led to a reduction in capital funding for research, investment in infrastructure remains essential, both to underpin research and to drive advances in sectors that are critical to the economy.

However, the pan-European RIs that have been implemented, such as ESFRI projects and ERICs, weigh on national budgets, raising the question of their long-term sustainability. Furthermore, European funding programmes typically only cover a fraction of the costs of integrating and opening national RIs and of the initial development of pan-European RIs through grants and loan guarantees.

Despite these pressures, in order to remain at the cutting edge globally European analytical RIs need to provide increasingly customised, multidisciplinary, impact-oriented and integrated services for users, while supporting open science.

In the overall landscape of European RIs, transmission electron microscopy (TEM) plays a crucial role, since it provides an indispensable set of advanced characterization techniques that are used to explore the structural and chemical properties of materials across a wide range of disciplines, including materials science, physics, chemistry, nanoscience and nanotechnology, engineering, biology and medicine, with sub-Angstrom lateral resolution and meV energy resolution. However, Europe's expertise in electron microscopy is currently fragmented across different scientific disciplines, sectors and national (often regional) efforts, which are - on an international scale - often subcritical.

Over the last few decades, several national initiatives in Europe have highlighted the need for supporting new developments in electron microscopy at many levels. For example, in 2009 France established the national network METSA, which brings together French advanced TEM (and atom probe) laboratories and provides access to their facilities and expertise to academic and industrial users. Spain established the ELECOMI network with similar aims.

In materials science, European-Union-funded Integrated Activities, such as three successive ESTEEM projects in FP6, FP7 and Horizon 2020 (www.esteem3.eu) have provided transnational access to advanced TEM instrumentation across Europe with great success in research output and networking, contributing significantly to excellent science and user-driven research. Major breakthroughs have also been achieved in methodology development and instrumentation within the framework of joint research activities, which have constituted an essential part of Integration Actions funded under Horizon 2020. In structural biology, Instruct-ERIC provides a concrete example of a successful RI that has an important cryo EM component.

At the same time, rapid technological developments and increasing demand for state-of-the-art TEM instrumentation beyond that available on a laboratory scale are resulting in a critical gap in capacity and sustainable access to advanced instruments. Researchers in materials science and biology increasingly require access to advanced TEM infrastructures that offer flexible combinations of state-of-the-art techniques in fully interoperable experimental arrangements, as well as to correlative, multi-modal and multi-scale experiments with complementary techniques (*e.g.*, X-rays, ion beams and optical techniques) for both routine and highly specialized studies.

A ground-breaking step change is required to initiate a new era in electron microscopy, which is based on the science-driven development of cutting-edge instrumentation, overcoming technical challenges that cannot be tackled by the electron microscopy market alone.

Future user communities require access to optimal and flexible services that can be used to perform innovative experiments, making use of technologies and knowledge that can be transferred effectively across the landscape of TEM facilities and to cooperating scientific infrastructures and specialized laboratories. Such developments are required to establish a future-oriented, sustainable electron-microscopy-based European RI.

Accordingly, e-DREAM (the European Distributed Research infrastructure for Advanced electron Microscopy) was formed in 2021 as a non-profit initiative to promote cooperation between European advanced electron microscopy laboratories, collaborative research and transnational user programmes. It supports the European electron microscopy community through strategic initiatives, applications for funding for access and joint research and contact to policy makers, politicians, other electron microscopy organisations and other scientific communities. It works closely alongside the ESTEEM3 project, the European Microscopy Society, the Analytical Research Infrastructures in Europe (ARIE) and other consortia such as Instruct-ERIC. Its specific aims are:

1. Promotion of science with electron microscopy, with the objective of establishing electron microscopy as a brand recognized by stakeholders, and highlighting the scientific, societal and socio-economic impact of science with electron microscopy;
2. Coordination of exchanges with national, European and global organizations and stakeholders (including users and funders), with the objective of contributing to the shaping of future policies;
3. Coordination of technical development strategies to profit from collective expertise and avoid duplication of efforts, with a view to addressing the scientific and societal challenges of the future in the most efficient manner;
4. Joining efforts in expanding existing and supporting new user communities, both by topic and by geographical origin, with the objective of strengthening Europe's electron microscopy expertise;
5. Promotion of access, based on the principles of the European Charter for Access to Research Infrastructures, with an emphasis on standardization for an improved user experience;
6. Achieving greater coherence in the development of data policy, data handling, data storage, data analysis and data access along FAIR principles, and promoting open science, while protecting intellectual property rights;
7. Coordination of training activities by facilitating staff mobility, with the objective of facilitating international career paths and developing skills in electron microscopy;
8. Facilitating industrial access and collaboration, with the objective of fostering innovation within the European Research Area and the common market for the benefit of society.

In order to achieve these aims, it has established four working groups:

- European strategy to address short-term and long-term perspectives and sustainability for electron microscopy in the European landscape of research infrastructures.
- Data policy to address data management, storage, access and file formats, with a focus on open science.
- Software for data acquisition, analysis, simulation, instrument control and remote access.
- Hardware standardisation of instruments to improve interoperability of multi-vendor and self-made equipment to enable an open ecosystem that fosters innovation.

Since 2021, e-DREAM has participated in five European Union proposals addressing Horizon Europe scientific missions and is undertaking discussions with policy makers and politicians on the positioning of electron microscopy in the work programme for research infrastructures in Europe and national roadmaps. It is also in the process of formalizing its status as a legal entity. After this step is completed, it will open its doors to a wider community of members. Further information can be found on the e-DREAM website: <http://e-dream-eu.org/>.