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Staying on track – Keeping things running in a high-end scientific imaging core facility

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Abstract

Modern life science research is a collaborative effort. Few research groups can single-handedly support the necessary equipment, expertise and personnel needed for the ever-expanding portfolio of technologies that are required

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across multiple disciplines in today's life science endeavours. Thus, research institutes are increasingly setting up scientific core facilities to provide access and specialised support for cutting-edge technologies. Maintaining the momentum needed to carry out leading research while ensuring high-quality daily operations is an ongoing challenge, regardless of the resources allocated to establish such facilities. Here, we outline and discuss the range of activities required to keep things running once a scientific imaging core facility has been established. These include managing a wide range of equipment and users, handling repairs and service contracts, planning for equipment upgrades, renewals, or decommissioning, and continuously upskilling while balancing innovation and consolidation.

KEYWORDS

core facility, device management, device monitoring, innovation, quality management, training

1 | INTRODUCTION

Scientific progress increasingly relies on ever-expanding sets of technologies, expertise, multidisciplinary approaches and collaborations, as opposed to the traditional single-laboratory environment that used to be the standard in life sciences. Over the past two to three decades, increasing recognition of this problem has led to the development and subsequent implementation of the 'scientific core facility' model, whereby distinct central facilities serve a broad base of users and can focus their expertise and efforts on a specific set of techniques.^{1–3} One key reason for this development is that most research groups will struggle to maintain state-of-the-art equipment in all the technologies they need to employ; another is that research laboratories often have high turnover rates, which can be inconsistent with keeping the expertise long-term in-house for a given device. Importantly, compared to scientists in research labs that can have multiple roles and where there is a risk of expertise aging along with the devices, experts in core facilities can continuously grow with cutting-edge technologies, meaning they can stay at the forefront of transformative technology and support a broader user base.

Consequently, the core facility model facilitates user access to an ever-expanding range of cutting-edge technologies while helping to manage research projects at lower costs and with more efficient resource use and this model has been applied internationally.^{4,5} Well-established examples include scientific core facilities that support microscopy, genomics, proteomics, protein expression and flow cytometry; here, we will focus on microscopy core facilities.

Several resources^{1,6,7} as well as articles in this issue (Zimmermann T. submitted), dissect the process and resources/skills required to successfully establish and operate a scientific imaging core facility.^{7,8} However, there is considerably less literature on how facilities can be sustained once established or on how they can continue to adapt to changing user needs to fulfil their mission. This is becoming increasingly important as the expansion of the core facility ethos of bringing together expensive and thematically clustered equipment in single locations is not yet matched by an appreciation of the necessary management skills required for success. Consequently, we discuss here how to keep the facility running and balance service, usage and innovation to stay cutting-edge while consolidating services for the broader user community. We aim to define the elements that need to be managed in a core facility and provide some insight into practices at a number of institutes as a first step towards generating best practice guidelines for the future.

2 | SERVICES**2.1 | Service improvement**

Imaging core facilities provide various services to researchers (arguably their core mission), including expert consultation, hands-on training, sample preparation, imaging support, data analysis and method development. They also provide teaching background information and instruct about best practices, sample handling and data acquisition. Sometimes, imaging assistance is provided for data acquisition, with staff acquiring high-quality images for users. Data analysis is often supported after

image acquisition, including image processing, quantification and interpretation. Some core facilities collaborate with researchers to develop novel imaging methods and approaches to analysis. Fee-for-service supports service provision and, in most cases, helps to cover some of the costs of maintenance, consumables, and even salaries. Such services enhance scientific investigations by effectively maximising available resources and expertise.

Such service provision requires continuous efforts to develop and maintain high-quality services and support for users, including an understanding of user needs. Services often involve problem-solving, technology scouting,^{9–11} and targeted teaching/training.¹² Open desk sessions can structure interactions, while regular surveys help to adapt to evolving needs. Distinguishing groups of users (such as students and group leaders) in surveys is useful, as they can determine usage and future plans in different ways. Other questions about user distribution, such as education level and background, are also helpful. Surveys should include questions about user satisfaction, service quality, equipment quality, downtime, delays, training timing and resource availability. This feedback can provide critical insights into operations and highlight areas for improvement. Regular surveys help to monitor changes over time and detect service issues at an early stage. They are also an excellent tool for ongoing platform improvements and alignment, and it is crucial for facility heads to be aware of ongoing research and what technical challenges their users encounter, as this empowers them to develop the facility and effectively address the needs of the research community. For this reason, we advocate for continuous and responsive surveying of the user base.

Next to surveys,^{10,13} steering committees and user committees can be instrumental in adapting the services and taking or helping to make strategic decisions, such as the purchase of new equipment (see below). While they can vary widely among institutions, typically, a user committee provides feedback, but decision-making rests with the facility head, while a steering committee might be more of a decision-making body or might have the expectation that its decisions will be implemented. In any case, these committees often share the goals of identifying needs, monitoring performance, providing advice and direction, approving budgets (and timelines) and setting goals. As such, they complement direct user surveys and allow facility heads to better integrate priorities with institutional strategies.

2.2 | Managing expectations and resource allocation

A large part of the core management's task (and a key concept for running a facility) is to manage the expectations

and communicate transparently. Operationally, service provision constitutes usage, and the Pareto principle¹⁴ suggests that 20% of users (with 'exceptional questions') require 80% of available support time at a core facility, while the majority of requests are more straightforward. While clear communication is essential for all users, communicating with a group that requires more service is crucial, and this is where their advice and the sharing of their knowledge and experience of imaging technology can be very helpful in the execution of cutting-edge projects. For a facility with an array of technologies, most training requests should be followed by a discussion with the user about their experimental goals so that the facility staff can direct them to the most appropriate equipment and manage expectations, including the time needed for carrying out the experiments. Often, an intake interview, which is an initial discussion about the project, can be used to discuss experimental goals and identify the most appropriate equipment for this task. Open desk sessions mentioned above can serve as an alternative entry point for users to discuss their imaging needs and develop a strategy for achieving realistic goals. This initial consultation should include information on the state-of-the-art, current literature, online resources, best practices, pricing and go/no-go scenarios for different solutions. Project management frameworks are crucial in this context, as they help determine the appropriate scope and modes of service provision.¹⁵

2.3 | The institutional ecosystem for multicore service provision

Imaging facilities are usually not the only core within an institute, and an understanding of neighbouring facility activities is crucial for multidisciplinary projects. This knowledge facilitates consultations and intake interviews and allows for effective integration of the institute's available options. Complex services involving multiple services/facilities are becoming more popular, such as correlative workflows or combining flow cytometry and imaging. Communicating common interests and efficiencies among cores within an institute is essential. Exploring the campus, regional, national and international landscape for imaging resources can identify synergies and complementarities and provide a forum for developing new approaches (see below).

2.4 | Networking and benchmarking

In addition to local ecosystems, service provision needs to take into account the bigger picture with respect to the scientific community. Networking is an important aspect

TABLE 1 A nonexhaustive list of international networks relevant to scientific core facilities in no particular order.

Coverage area	Name	Webpage/contact point
International	Global BioImaging	https://globalbioimaging.org/
International	European Light Microscopy Initiative (ELMI)	https://elmi.embl.org
European	Euro-BioImaging	https://www.eurobioimaging.eu/
African	African BioImaging Consortium	https://www.africanbioimaging.org/
North America	BioImaging North America (BINA)	https://www.bioimagingnorthamerica.org/
Latin America	Latin America Bioimaging	https://labi.lat/
International	Core for Life (C4L)	https://coreforlife.sites.vib.be/en
International	QUAREP-LiMi	https://quarep.org/
International	Core Technologies for Life Science (CTLS)	https://ctls-org.eu/
International	Association of Biomolecular Resource Facilities (ABRF)	https://www.abrf.org/
International	MicroscopyDB	https://microscopydb.io/
International	Microlist	https://www.microlist.org/

Note: The coverage area, name and their webpages are listed. For more local resources, see Table S1.

and can refer to both internal and external networking. An often underestimated aspect of core facilities is their ability to facilitate networking among research groups by establishing links among users of different groups who are struggling with the same problems. In addition, they provide a platform of expertise that can be consulted by PIs for technical feasibility, and the core can provide feedback, suggest alternative technical solutions and connect researchers to other infrastructures.

Engaging in initiatives that connect people who work on similar problems can be very helpful, enabling comparisons/benchmarking and giving opportunities for horizon scanning. Therefore, networks are an essential part of our services and research and development activities. For imaging facilities, several relevant national and international networks exist. International organisational networks such as Core for Life (C4L)¹⁶ and Core Technologies for Life Science (CTLS) allow collaboration on cross-cutting issues such as quality, metrology or systems maintenance. Technological networks such as QUAREP-LiMi^{17–19} are working to develop standards and quality control in the field of optical imaging. These individual networks often carry out complementary activities, even if some overlaps may exist. Table 1 represents some existing international networks. Some local networks are listed in Table S1.

2.5 | Horizon scanning

Along with networking and (self-)benchmarking, engaging with networks and attending events and workshops also offers opportunities to learn about new developments and device releases. This horizon scanning (also referred to

as tech(nology) scouting) is important for advanced facilities to stay at the cutting-edge. Even if facility staff are not involved in or initiating procurement discussions, they should be aware of key advances in their domains. That way, core facility staff can advise on a new system acquisition and potentially suggest alternatives. Additionally, sometimes funds become available unexpectedly, such as at the end of the financial year. In such cases, facility staff should always be prepared with suitable suggestions for procurement.

3 | RESEARCH AND DEVELOPMENT

3.1 | Innovation mandate

Core facilities play a crucial role in providing services to various departments and stakeholders,²⁰ but without innovation, they risk stagnation and failure to advance cutting-edge science. While a number of publications deal with the background, types and impact of innovation,²¹ here we focus on new techniques, methods, protocols, sample preparation, analysis strategies, resources and training.

For innovation in core facilities, the host institution's perception of the core facility's mandate and the need for continuous innovation is key. A survey conducted during the 2019 VIB Core Facility Management Workshop (<https://www.vibconferences.be/events/vi-core-management-workshop>) revealed that, according to participants, innovation is not fully supported for core facilities in most institutions. Therefore, it is essential to communicate constraints on innovation and find allies within groups and larger organisational units to promote innovation as a central purpose of core facilities.

3.2 | Managing development projects

A development project within a core facility is a temporary endeavour to produce a unique product, service or result, turning a challenge into a solution. As such, development projects vary in complexity – ranging from complete new imaging methods (which generally require advanced optical, mechanical, and software development) to protocol optimisations and technology adaptation where existing technologies are optimised or combined into custom systems or workflows (usually to address a specific need). Tackling the development of a new tool, resource or product is thus a matter of project management, while producing the output is a matter of knowledge, skills, tools and techniques. A successful project with defined requirements can be divided into phases: initiating, planning, executing, monitoring, controlling and closing. However, without clearly defined goals at each stage, projects may fail or never end due to poorly defined objectives ('shifting goalposts leading' to 'endless' projects).²²

3.3 | The innovation balancing act

From an industry/professional perspective, a body of literature exists for project management,²² and projects are considered to be constrained by Performance, Time, Cost and Scope requirements. Values can be provided for only three of these categories; the fourth is determined during execution.²² A typical challenge in executing development projects in core facilities is the duality of performing the technical development work in parallel with managing the facility. When there is a (time) conflict between the two, the facility head typically has to prioritise regular service provision, as it likely affects more users immediately. In the survey mentioned above, an average of 20% of the total staff time was spent on development work, which is reminiscent of some claims about time to be spent on innovation in industry.²³

Development projects run the risk of being tailored to the individual needs of a specific project request/funding deliverable and may not be scalable to the application and implementation of services. This can be mitigated by establishing workflows and enabling solutions strategically, that is, by committing staff time to research activities that will benefit the majority of users in the long term. Developing a road map with go-and-no-go decisions and associated milestones is of great value in making this process transparent.

3.4 | Innovation management

From a job enrichment perspective, it is preferable to have core staff working on both routine tasks and inno-

vation. However, from a budget perspective and for the reasons listed above, innovation is difficult and should be completely separated from fee-for-service. Hence, it is important to keep in mind the overall mission of the core: the intent is not to run a core as a 'shadow' or 'ninja' group leader, but rather as an entrepreneur who creates opportunities within the organisation.

A useful distinction can be made between discovery and development. In life science-based institutes, most labs are involved in discovery-based research, and often, even method development in these laboratories is also discovery-based. However, in the context of core facilities, the establishment or implementation of new techniques and services can be more considered as development. A common issue that can arise is that individuals in leadership positions within core facilities and senior management, although possessing a life science background, may lack direct experience with development projects. Consequently, it is important to recognise that assessing innovation and evaluating research are two distinct activities and should be measured differently. Questions to score innovation can include the number of implementations, technical articles, user and expert scoring of improvements, and technical parameters such as the number of installations in the case of a software or analysis pipeline.²⁴

Imaging core facilities can also benefit from innovation opportunities through industrial collaborations, often structured through nondisclosure agreements and contracts. These partnerships define scope, deliverables, timelines, work location and payment terms.

However, innovation opportunities exist more broadly at technical, managerial and application-based levels. Additionally, training is a core element of a facility's mission and offers possibilities for innovation. The COVID-19 pandemic has led to the widespread adoption of innovative remote-working setups, such as virtual classrooms, in this area <https://www.rms.org.uk/>; <https://www.microlist.org/>; <https://myscope.training/>; <https://globalbioimaging.org/international-training-courses/repository>.

To provide some idea about the degree of innovation carried out in core facilities, Figure 1 shows the distribution of time spent on innovation for 14 international core facilities from both Light Microscopy (LM) and Electron Microscopy (EM) facilities. The contributing facilities are listed in Table S2.

4 | TRAINING AND OUTREACH

To ensure effective support for a growing user base, it is important to provide both theoretical teaching of the techniques and practical hands-on training to enable (new) users to operate the equipment required for a particular

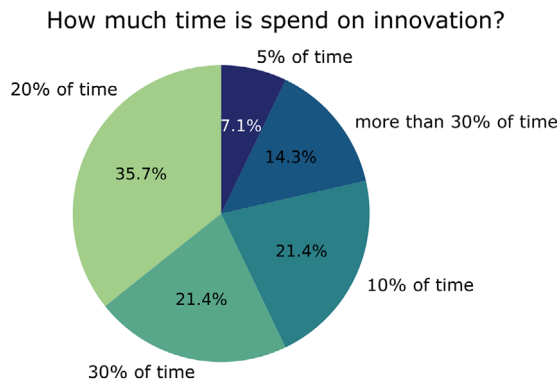


FIGURE 1 Innovation in microscopy facilities. To gain insights into the amount of time dedicated to innovation, a survey was performed among 14 international core facilities from different research institutes at the beginning of 2023. Here, innovation is considered in the broadest sense, including developments of devices but also implementations, and protocol improvements. The results from EM and LM facilities are combined. It is worth mentioning that this assessment reflects self-reported time allocation rather than an official policy. The contributing core facilities are listed in Table S2.

application. This special issue includes an article on this topic by Silvie de Guyader and co-workers.¹²

Here, Figure 2 shows that training should be mandatory for the independent use of devices and that teaching is dependent on core personnel, that is, teaching by a post-doc from one lab teaching other lab members is strongly discouraged by the consortium from this article. Postdocs often have many tasks that may limit the time to become an expert in multiple aspects of a given technology that are not immediately applicable to their project. This bears the risk that training content is only focused on an individual project and misses out on potential alternatives, which is different for a professional working in a core who has a broader view of use cases. Additionally, if operating a system is a legacy task due to time constraints, there is a risk that training is getting outdated/watered down over time, while the field has progressed. Training conducted by core facility staff ensures consistent standards across all users, preventing discrepancies and inequalities in training levels, while also ensuring the implementation of responsible behaviour according to facility standards. Additionally, providing clear expectations regarding instrument usage in a multiuser facility helps reduce stress and potential conflict. An intriguing discussion is whether training should be carried out on the user's samples or generic samples. A user's sample has the advantage of enabling bespoke feedback on the sample preparation, while the quality of the sample for proper training cannot be guaranteed. However, a user having a sample at hand means that the user is ready to start using the equipment, which helps avoid retraining

people due to a mismatch between a generic training time point and the moment when the users need equipment but may have forgotten key messages. On the other hand, starting the training process with a standard sample provided by the core facility allows users to focus on understanding the system's capabilities without being distracted by the quality of their sample. The consortium typically provides hands-on training and structured technical/scientific background teaching. While there is agreement that users are trained on demand, different formulas exist to provide background teaching, including online training that can be carried out by the user in advance (see remote-working setups, such as virtual classrooms mentioned above).

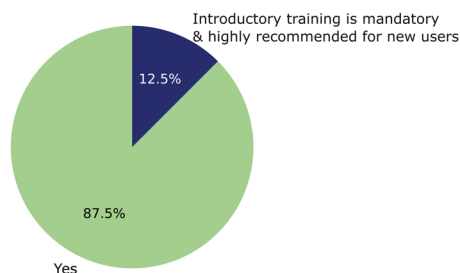
Based on these results, mandatory training is advisable, where possible, on the users' own material/required technique to promote engagement and efficiency.

4.1 | User distribution

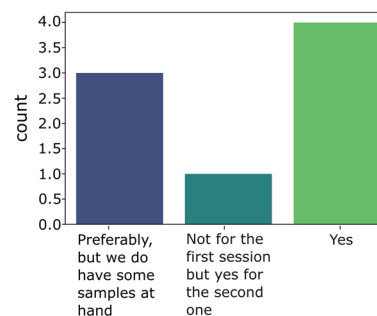
Training, as such, needs to be tailored to the users' background.¹² Many life science programs lack instruction in the fundamental concepts of imaging, such as the Nyquist-Shannon sampling theorem.²⁵ Core facilities should cover these concepts to aid users in obtaining optimal results. There is, of course, a difference between walk-in facilities (where users obtain data themselves) and service facilities, where imaging is performed by facility staff; the amount of background and guidance may also vary depending on the users' career stage. Training in a walk-in facility environment should include teaching the essential concepts and definitions to ensure the acquisition of good-quality data. Outreach activities, such as training courses on advanced techniques, are crucial to increase the user base within the host institution. These courses should target attendees in their early research careers and encourage them to apply these techniques in practical sessions.

Next to user interactions through training, another important aspect is outreach. Next to classic outreach events, including open days, workshops, and the like, social media is progressively being employed. Social media has increasingly become a tool for imaging professionals, facilitating professional networking and collaboration and allowing core facility staff to connect with colleagues worldwide, share insights and discuss challenging cases. Social media also provides a platform for interdisciplinary collaboration, including company representatives. Social media provides access to educational and scientific information, allowing users to stay updated on the latest advancements in imaging technology and best practices. Active participation in social networking increases the visibility of the core and the institute within the online

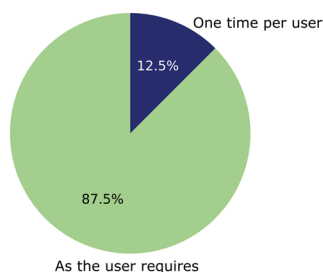
(A) Is training mandatory?



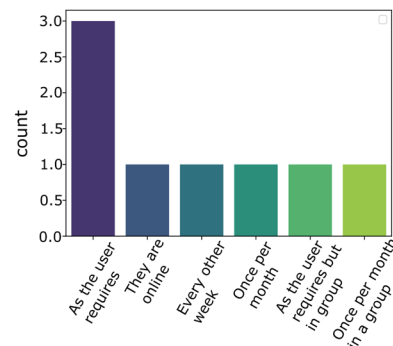
(B) Are users supposed to bring their own samples?



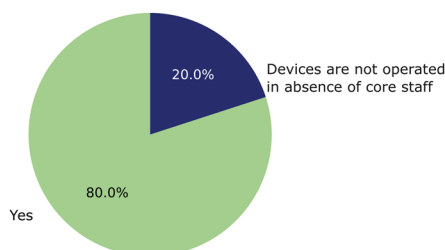
(C) How often do you train hands-on?



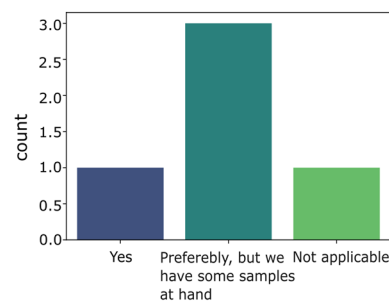
(D) How often do you train theoretical background?



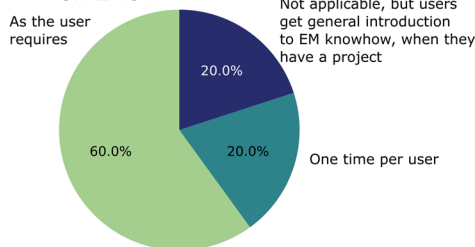
(E) Is training mandatory for EMs?



(F) Are users supposed to bring their own EM samples?



(G) How often do you train hands-on on EMs?



(H) How often do you train theoretical EM background?

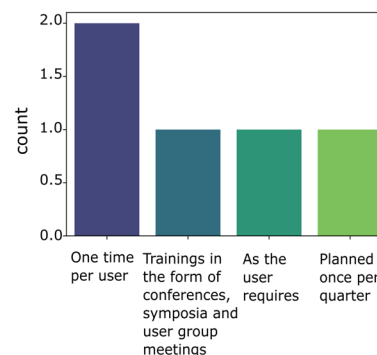


FIGURE 2 Training in Light and Electron Microscopy Facilities. At the beginning of 2023, 14 international core facilities were surveyed to gain insights into how training is organised. The results of the following questions are depicted here. (A) Is training mandatory? (B) Are Users supposed to bring their own samples? (C) How often do you give hands-on training? (D) How often do you give theoretical training? (E–H) The corresponding results from 3 EM facilities. The contributing core facilities are listed in Table S2.

TABLE 2 Overview of categories where imaging core facilities monitor their service provision.

Category	Items tracked
Use	#User, usage hours, etc.
Finances	Income, expenses, etc.
Output	Projects completed, grants, acknowledgements, etc.
Devices	Installations, demos, etc.
Services	Samples, analysis, etc.
Others	Other

Note: Table S3 provides a detailed view, including tools that are used for monitoring.

community, while having the potential to elevate the professional profiles of individual staff. However, balancing professional and personal content can be challenging, and caution must be taken to avoid publishing sensitive data. Consequently, institutes and other professional organisations provide guidelines and recommendations to ensure safe and ethical use of social media. Overall, social media platforms provide a powerful way for core facilities to learn, collaborate and engage with their peers, ultimately advancing the field of life science imaging.

5 | KEEPING TRACK

The core facility must continuously monitor its operations to achieve its goals, including service consolidation, training, hardware management, innovation, research and development and resource support. This ensures an overview of the state of affairs and allows for timely reporting and updates to senior management and administration. To generate this overview (and ensure horizon scanning), many elements need constant monitoring. This monitoring is also essential for the reporting for evaluations, where it is crucial to demonstrate the value the core facility provides to the institute (see below). Table 2 gives an overview of the categories where items are tracked, and Table S3 provides a detailed view of these items. While none of the core facilities that contributed to this opinion piece are monitoring all these elements (the environment and the setup of the core will define the requirements), and while they are all worth considering for efficiency reasons, a selection does need to be made. Usage statistics and lists of outputs are always of use to funders (increasingly, the latter are centralised at the national level), while access records and deliverables are increasingly important in the international context of European research infrastructures (for example, Euro-BioImaging).

As discussed above, not all fields in Table S3 will apply – this depends entirely on the core's setup/composition/mandate. Solutions like Stratocore PPMS, Agendo or

openiris.io can help collect some of the aforementioned data. As most programs are fee-based, it is useful to plan the cost of these solutions into the core's financial plan.

5.1 | Equipment monitoring

Quality control and quality management (see below) are essential for maintaining the efficiency of devices, images, services and results.²⁶ Quality management is a framework that aims to oversee all activities needed to maintain a certain level of quality, while quality assessments measure device performance using various solutions,^{26–33} such as beads, resolution test targets, including quality control solutions, and resolution targets from Argolight, Thorlabs and others. Initiatives like QUAREP-LiMi^{18,19} are gaining traction for developing recognised best practices in this area. Different test samples may be used depending on the question being probed.^{27,28} Individual measurements of a device can be placed into the temporal context of earlier measurements to provide a longitudinal assessment of a device's performance over time. To interpret results effectively, it is important to determine in advance how the evaluation will be quantified and which actions will be taken when certain thresholds are reached. This is ideal for networking and self-evaluation. For example, if the intensity drops by a certain percentage, the laser may need to be realigned or replaced during service by the supplier. This means creating a standard operating procedure for quality control assessment.

Please see Figure 3 for an overview of how the consortium performs device monitoring. All facilities (100%) regularly check their systems, emphasising the need for trained personnel capable of carrying out this task and a job assignment to do this regularly.

5.2 | Quality management

In contrast to clinical imaging and preclinical imaging, quality management regimes are less established in microscopy. However, the creation of standard operating procedures (SOPs, mentioned above) for device use and preparation protocols can lead to a more standardised approach to operations and is already a critical part of quality control and quality management. Over time, different quality management frameworks have been established. The best-known ones are the published ISO standards, which typically involve expert assessment of the framework, on-site visits and accreditation. This creates a quality label that, in turn, can be used for outreach. Most importantly, the quality management in place should include

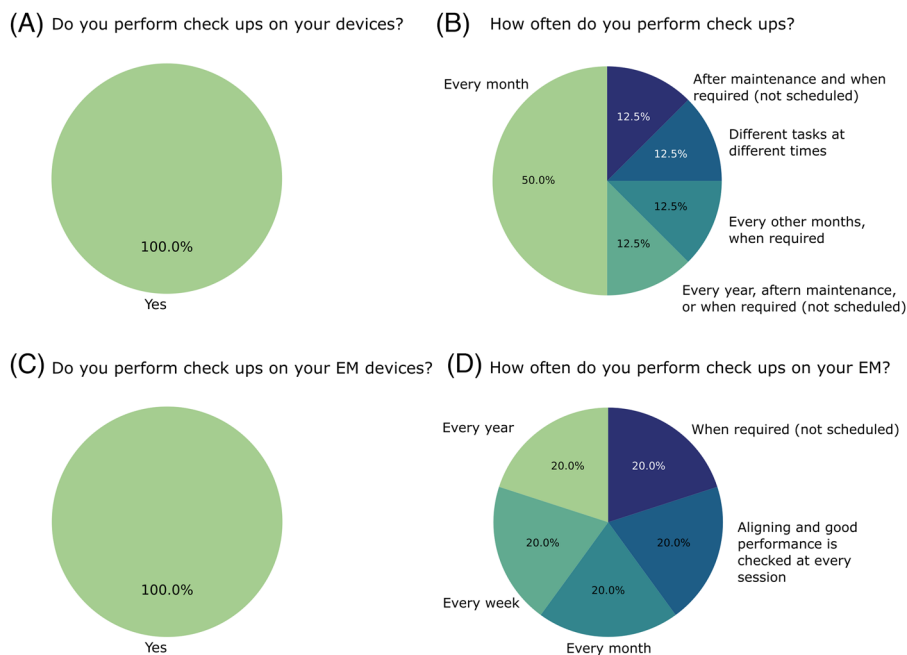


FIGURE 3 Device monitoring in Light and Electron Microscopy Facilities. To gain insights into the monitoring of devices at different facilities, a survey was performed among 14 international core facilities at the beginning of 2023. Here, the results of the following questions are depicted. (A) Distribution of cores performing regular check-ups on devices. (B) How often do you perform check-ups? (C, D) The corresponding results from EM facilities. The contributing core facilities are listed in Table S2.

next-to-measures actions in case of failure. Key points are typically SOPs, monitoring equipment, standardisation of user interactions, internal services, purchasing and establishing clear relationships within the institution, including other services such as building services and upper management. Several core facilities have pursued ISO 9001, as well as the NFX 50–900 certification, which is a French standard designed explicitly for technological core facilities that cover the requirements of 9001 but also includes topics related to research and development (traceability and validation of scientific work, intellectual property, and valorisation, strategic planning, etc.).

Unfortunately, however, most quality management systems have been developed for companies and service providers and are therefore not fully applicable to an academic research environment.³⁴ Consequently, structured quality management is largely absent in the academic environment compared to both clinical and pharmaceutical research. While in academia, there is an abundance of rules and regulations and pressure to improve reproducibility; there is also the pressure to be the first to publish, which can compete with the need for long documentation procedures. Additionally, the typical normative lingo and the mindset to predefine processes are at odds with the explorative ethos of many labs. However, in the context of running a core facility, where the core has to take responsibility for the quality of the services for its users, the introduction of a quality management sys-

tem is an opportunity. Recently, several publications have described quality control and management for the academic environment, with an emphasis on transparent documentation and clear management structures while (most importantly) leaving enough freedom to adapt to local environments.^{34,35} As a result, several core facilities have begun to adopt these systems,³⁶ which also require relatively minor efforts to establish.³⁷

Reproducibility in data and image analysis is also an important topic. However, an article in the same issue by Soltwedel and Haase discusses the implementation of image analysis services and their role in reproducibility.³⁸

5.3 | Finances

Budgeting and future planning are key tasks of a core facility leader. However, core facility heads often come from a technical or biological background and will need to educate themselves on the topic of financial literacy. While many resources and courses provide an introduction to this topic, at different institutes, the amount of financial freedom and cost recovery requirements can vary considerably (up to and including 100%); consequently, cost recovery is often a struggle for many facilities. O’Toole P. and Marri-son published an article on the topic of cost recovery in this special edition, and we refer the interested reader there for a broader discussion of the topic.³⁹

One common struggle for people new to this task is the jargon used by the accountants. Unfortunately, and in contrast to science, no initiatives by accountants exist for outreach (i.e., there is no current 'pint of accountancy'). Consequently, this lingo needs to be learned. Typically, the core elements of budgeting include estimated revenues, fixed costs, variable costs, one-time expenses and cash flow. Estimated revenues are the amount of user fees collected, while fixed costs are expected recurring costs like maintenance and personnel costs. Variable costs are less clear-cut and include supplies and spare parts. One-time expenses are upgrades or purchases of equipment for sample preparation. Cash flow refers to the movement of cash into or out of a business or project.

Future planning as such can be challenging. To provide a reference frame that novices might be more familiar with, the 50-30-20 rule that is typically used for personal budgeting can help.⁴⁰ This rule would divide 50% for needs like maintenance and personnel, 30% for wants like upgrades and lab disposals and 20% for savings. This allows for a reserve budget for repairs or paying off internal loans. However, this can only serve as a rough starting point for a more elaborate plan and the refinement of the plan will depend on the institute's structure. If available, looking into overviews of spending from previous years is advised. Generally, it is essential to have a wide margin for needs and the ability to make positive changes. It is also of note that future budgets are estimates; deviations from the plan en cour de route are not surprising/somewhat expected.

5.4 | Facility evaluation

Most facilities are reviewed on a regular basis by external reviewers, typically every 3 to 5 years.¹⁰ Depending on the institution and the review panel, different metrics will be asked. The section on keeping track can help prepare for the reporting part. In many reviews, user surveys will be a key element; however, the review itself will be the decisive part of the evaluation.

Different metrics have been suggested for evaluating core facilities.⁴¹ However, it is important to emphasise that running a successful facility requires resources and a strong commitment from the institute, both from the faculty and the administration. This is essential for the recruitment, retention and ongoing support of the excellent scientists who will run the core; staff also require competitive salaries and benefits,⁴² and some reasonable guarantee of security, short of tenure.⁴³ Likewise, it is important that the faculty is on board with acknowledging the use and benefits of the core facility and that the tracking of these acknowledgements is facilitated.^{44–47} For the evaluation of core facilities, the metrics mentioned earlier

in the literature also carry a risk. Specifically, when working with strict and sometimes predefined performance indicators, there is a tendency for these to 'fossilise' a facility, and the fixation on the indicators can be counterproductive to a thriving culture of innovation and investment in people. A continuous review of the strategy can be a way to mitigate this (international external advisory boards can be effective here). In this context, the steering and user committees mentioned above can be helpful, and while there may be some committee fatigue, these committees are important for sharing responsibility and working together toward the institution's goal. Here, tracking multiple parameters, as outlined in Table 2 and Table S3, can be helpful in providing insight into multiple aspects of the core for self-evaluation and also for reporting to steering and user committees.

6 | STAFF CAREER DEVELOPMENT AND JOB ENRICHMENT

For staff in a core facility, it is important to see opportunities for growth.^{42,48} In this special issue of the Journal of Microscopy, another section is dedicated to this career development (Kerry et al. planned). In the context of developments, core scientists should be proud of their achievements and consider this as part of their growth. Along the same lines, intellectual contributions to manuscripts should be associated with authorship and recognition for the people in the core.⁴⁹ Balancing development and service on an individual level is crucial, as some people may have a preference for one or the other. Creating roles and job titles can nurture staff and foster internal recognition along with training needs and career paths for facility staff.^{50,51}

Imaging is a rapidly evolving field, and the development and training of soft skills for facility staff is now crucial for their effectiveness and success. These skills include effective communication, teamwork, critical thinking, time management, decision-making, stress management, adaptability, conflict management, leadership, creativity, resourcefulness, persuasion and openness to criticism. These skills enable staff to communicate clearly, build positive relationships, analyse complex situations and develop innovative solutions. Time management and organisational skills ensure efficient resource use, project timeliness, and maintain order in the facility. Stress management and adaptability skills help staff handle pressure and adapt to changing circumstances. Conflict management fosters healthy workplace relationships and effective dispute resolution. Leadership skills empower staff to inspire and guide users and collaborators, while creativity and resourcefulness encourage innovative thinking.

Persuasion skills help influence others and gain buy-in for ideas. Openness to criticism allows staff to receive constructive feedback and continuously improve. Balancing development and service is crucial for managing a facility. It is essential to develop the technical and scientific skills of staff to maintain the facility's edge. Unlike devices, which can be purchased when needed, staff need to be trained and honed to stay competitive in the rapidly evolving imaging technology landscape. This can be achieved through various methods, such as staff training by technology providers, job shadowing, fellowship programs⁵² and development projects. The manager's duty is to foster their team's skills and keep the facility at the forefront of the market. Also, from a hiring perspective, diversifying the team and looking for transferable skills for future development projects can be important. A particularly interesting field for development is the connection and collaboration with other core facilities, or available campus resources like 3D printing, for example, where expertise may already be present and collaborative efforts can be cross-fertilising.

7 | EQUIPMENT MANAGEMENT

7.1 | Turnover, strategy and longer-term planning

Device management is a challenging operational task that combines service consolidation, innovation mandate and operational necessity. It requires a clear strategic plan that aligns with the institute's mission and vision. The core head may present a 5-year plan, which includes a budget exercise and a longer-term vision. This plan is crucial for formulating new ideas and communicating changes in the core's direction. This may include a shift or the addition of a direction, for example, sample preparation, specific imaging techniques, analysis, etc. For devices, the 5-year plan should include a healthy turnover of the machinery park and the decommissioning of unmaintainable devices. The plan should also include analysis workstations and related devices and their software licenses, if applicable. It is essential to plan for a net growth of devices as usage hours and user numbers increase.

A healthy turnover of instruments is critical for a core facility's future viability. Sources of infrastructure funding can be very variable, ranging from institutional funding to external grants obtained by individual PIs. Consequently, the degree of consultation and involvement of the core facility and respective committees in the purchase may vary.

Independent of sourcing, if the instrumentation is aging and service needs are piling up, there is a danger that the core technology will become obsolete and that irreparable

devices will fail, which can lead to prohibitive replacement costs.

This raises the question of device lifetime. In Figure 4, we report feedback from both light and electron microscopy core facilities on device lifetime. Figure 4 shows the average age of the devices and the oldest device.

When setting up a facility, one of the strategies is to negotiate a good price by choosing a single supplier for the majority of instrumentation. This has the advantage that all services are provided by a single source. It also makes it easier to set up interactions with partners from industry, such as a Nikon Center of Excellence and Zeiss labs at locations. However, going even further and running a core facility that is branded by one supplier may present additional challenges and opportunities; more information on this topic can be found in the same special issue.⁵³

However, due to user demand for different technologies, most facilities will have mixed setups from different suppliers (Figure 4) due to their different technology portfolios. In addition, the technological advantages of individual vendors change over time, and their release cycles for new technology vary. This typically leads to a more diversified portfolio of devices and suppliers over time through regular device turnover and new additions.

Similarly, experimental setups are often used in core facilities (Figure 4) due to their uniqueness and user pressure. However, they require dedicated personnel for proper operation and servicing, such as laser alignments. Decommissioning of these setups requires the same rigor as any other service or commercial setup (see below). However, experimental setups can provide a gateway for innovation and lower-cost testing of new services and applications. They can foster collaboration with developers and imaging laboratories, and the addition of staff trained to support these setups can help with future innovation projects requiring similar skills.

7.2 | Managing broken equipment

Communicating when devices are down or unavailable is key, as is managing user expectations for when service and repair can be expected; in turn, this entails having effective and rapid communication channels with manufacturers and service providers.

7.3 | Self-repair

Facility heads and personnel can come from a variety of backgrounds, with some source professions being more suited to reviewing what is wrong with a piece of equipment. However, imaging core facility staff are technological professionals, and diagnosing the source of a

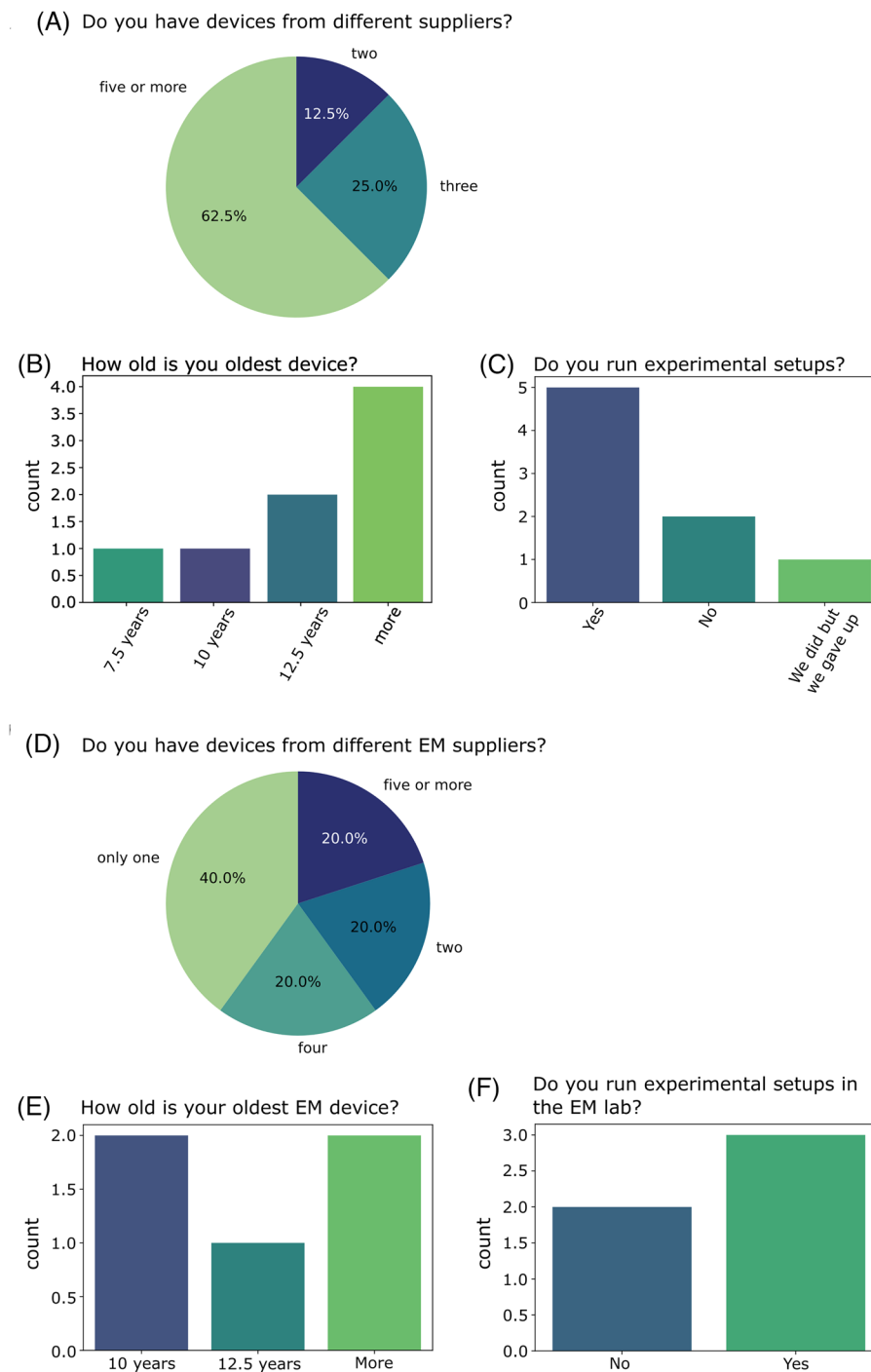


FIGURE 4 Supplier mix, age of devices and experimental setups in Light and Electron Microscopy Facilities. At the beginning of 2023, a survey was performed among 14 international core facilities to gain insights into the number of suppliers, the age of the devices, and the use of experimental setups at different facilities. Here, the results of the following questions are depicted. (A) Do you have devices from different suppliers? (B) How old is your oldest device? (C) Do you run experimental devices? (D–F) The corresponding results from EM facilities. The contributing core facilities are listed in Table S2.

problem can reduce the number of service visits and downtime. Ideally, with prediagnosis by core staff, only interventions can be limited to one visit with the right spare part identified for repairs. Unfortunately, the vendors have not yet fully embraced the elevated technological

background of facilities. In the future, however, specific training of core personnel by companies for smaller interventions could even be envisioned.

With regard to self-repair, again, the mission and leadership of the core are critical. The core mission of a facility

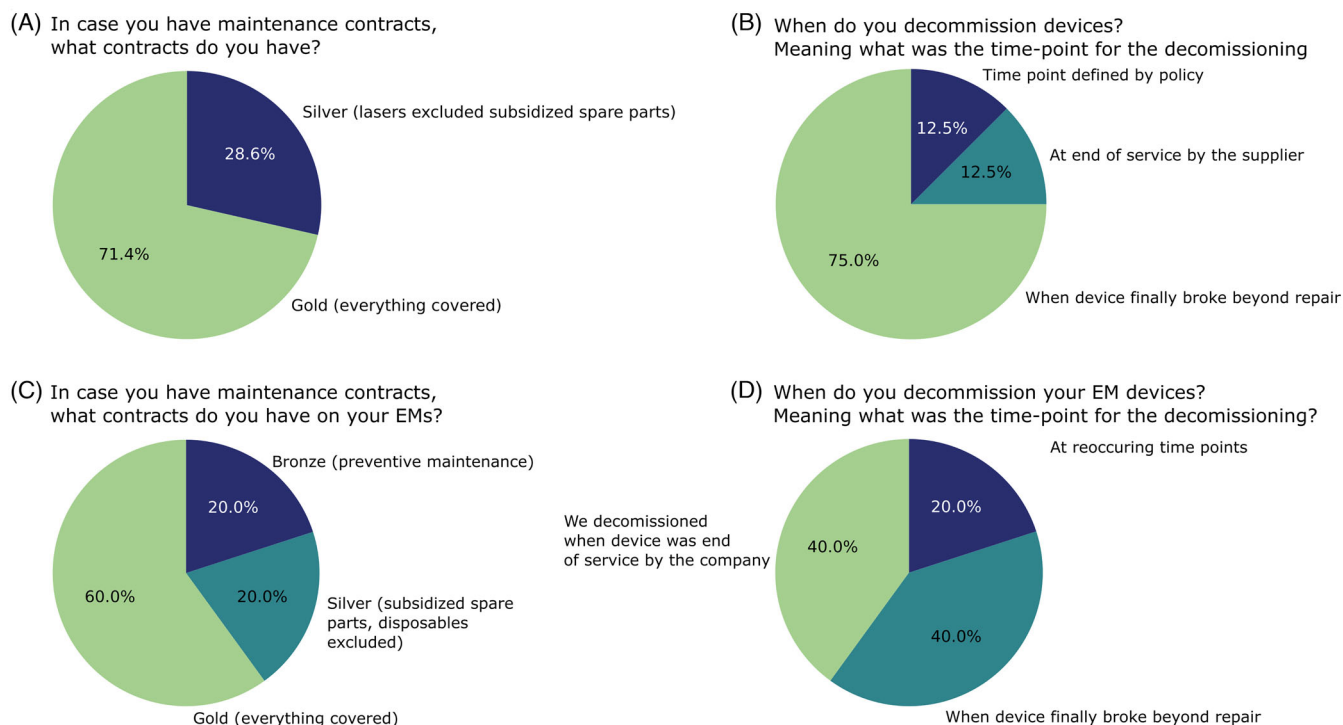


FIGURE 5 Service contracts and decommissioning in Light and Electron Microscopy Facilities. At the beginning of 2023, a survey was performed among 14 international core facilities to gain insights into the type of maintenance contracts used and the policies for decommissioning at different facilities. Here, the results of the following questions are depicted. (A) In case you have maintenance contracts, what contracts do you have? (B) When do you decommission devices? What was the time point for the decommissioning? (C, D) The corresponding results from the EM facilities. The contributing core facilities are listed in Table S2.

is to support and enable users, but repairing or maintaining equipment can take time away from this mission. The decision to repair or maintain equipment depends on the budget and the safety of staff, users and anyone accessing the rooms. Lasers and electronics can pose serious hazards, so repair and maintenance require relevant expertise. There is a training gap for core staff, which is exacerbated by the trend towards open hardware and the ‘Internet of things’, which may lead to more community-driven devices in core facilities. Legal and financial issues related to equipment warranties from suppliers require customised training and guidance from suppliers to core facilities. As mentioned, however, technical exchange with qualified staff can help diagnose problems accurately, reduce downtimes and also make service more efficient for the suppliers. Furthermore, hiring a technical staff member may open possibilities for faster and easier new technology implementations and reinvent the use of underused instruments and components efficiently.

7.4 | Service contracts

In an imaging core facility, providing access and, consequently, usage time on high-end devices is a crucial part

of the service provision. Therefore, the aim is to reduce instrument downtime. To achieve this, it is essential to obtain qualified support from vendors. Suppliers offer various service contracts, ranging from bronze contracts with one annual preventive maintenance visit, to silver contracts with discounted parts and labour, and gold contracts including all services. Lasers, which have a finite lifetime, are consumable, so a budget reserve for their replacement is advisable. The choice of contract for a core facility depends on the long-term cost and usage. A gold contract can reduce administrative burdens and make user fees more predictable. It is important to keep in mind that service contracts do not replace the technical knowledge of staff and vice versa. Figure 5 provides an overview of service contract types across multiple facilities.

7.5 | Decommissioning equipment

Over time, equipment becomes unmaintainable. Suppliers typically offer support and guarantee spare parts for a certain amount of time. Once that time has passed, it becomes increasingly difficult to maintain the device, and the risk of ultimate failure increases, meaning that the service provided to the users of the core must be discontinued

to avoid alienating users. As a result, it can be difficult and time-consuming to get people to stop using it. The time decommissioning takes is typically underestimated. Clear communication is key, and next to setting timelines and repeated warnings that a device will go out of service, care needs to be taken for users that have projects scheduled for publication, and that may need access to address revisions and alike.

Another argument for decommissioning is the opportunity cost associated with keeping old equipment. This means that the core misses out on the potential benefits of a new device when sticking to an older system. In many institutes, space is allocated and cannot be claimed for an underused device, thus eliminating the opportunity to place a device with a higher degree of utilisation. Figure 5 summarises the reasons and timing for decommissioning in several core facilities.

The fate of decommissioned devices can vary from trading them in on new purchases over donations to keeping them as stock for spare parts and reselling them (e.g., <https://www.labexchange.com/fr/mettre-en-vente/mettre-en-vente/mettre-en-vente.html>, <https://www.the-labworldgroup.com/product-category/microscopes/>, in-house equipment exchange, <https://www.labconscious.com/laboratory-equipment-and-supplies-reuse>, etc.). It is of note, that the ownership of publicly funded devices can be complex and varies at different sites. For devices owned by an institute, the price is typically determined by the institute's financial department and will depend on the age of the system.

8 | THE CORE FACILITY VERSUS THE RESEARCH GROUP

8.1 | Operational goals

It is axiomatic in the field of life sciences that institutes, groups and core facilities work side by side to fulfil the mission of the institution and that the individuals working in core facilities, technicians, image analysts and engineers, are scientists. However, core facilities have been established relatively recently, and working in them is significantly different from working within research groups.^{6,54} Operating a core facility like a research group can lead to frustration and sub-par service provision. The rationale for hiring a core facility head and a research group leader can differ significantly, with the former being more dependent on the stage of the facility's life cycle. A newly appointed core facility head faces a similar 'step-change' in terms of deliverables and responsibilities as a research group leader. Understanding the differences in these leadership roles is important as it should reflect the

differences in expectations and responsibilities towards the institution. The differences in these respective roles across major core competencies are summarised in Table 3. It is of note that other factors, including different time constraints and work-life balance, can influence the practical carrying out of the differential roles.

8.2 | Keeping an eye on institutional values

Central to the success of a core facility is the delivery of value to the host institution. As such, the service delivered needs to match the expectations of the host organisation and there is not a one-size-fits-all model for this critical aspect. However, it is also imperative to be clear about what the core offers to the host organisation (and potentially external users), as the operational focus can be derived from this. The major beneficial elements of the core facility model are summarised graphically in Figure 6.

Clear operational frameworks are central to enabling sustainable support from an institution: while investing in a core can be considered an organisational necessity for major institutes to remain competitive, this cannot and should not be taken for granted/justified only in relation to scientific progress in a particular field.

In Table 3, our aim is to identify the diverse set of activities and skills needed by a core facility lead in order to develop the service, research and development, training, 'keeping track', staff career development/job enrichment and the management of devices discussed at some length as operational requirements, while Figure 6 is intended to summarise the 'value themes' that must arise from these collective activities. Therefore, we propose to keep things running, core staff needs competencies in the former and a constant eye on the latter.

9 | DISCUSSION

This article discusses the importance of maintaining a facility's operations and balancing service, usage and innovation. It highlights the role of the institutional ecosystem, research and development, training, performance monitoring and quality management. We also discuss the need for equipment management and future plans in core facilities. As equipment becomes more important over time, it becomes crucial to maintain it, adjust focus, establish a consulting service framework and balance development and service while maintaining operational momentum. The article also highlights the differences between running a core facility and being a research group leader, highlighting the similar competencies in general facility

TABLE 3 Comparison of typical job assignments for the head of a core facility and a research group leader.

Role	Core facility head	Research group leader
Financial management	Purchasing (including obtaining grants), maintenance and upgrade of devices Hiring service-oriented (and maybe technology development-oriented staff) Manage finances between institutional support, usage fees and potential grants	Obtaining grants and hiring project-related technicians, students/postdocs, manage group finances
Personnel management	Team management to support the community	Team management for own group
Project delivery	Carrying out projects mostly with and for users and managing the resulting data without emphasis on first and last author publications or publications at all Advancing science through research and development	Driving their own research projects with the goal of publishing with an emphasis on first and last author publications Advancing the group's science through research and development
Mentoring	Providing service and supporting the research community and core facility staff & supervision of students, technicians and postdocs who could be members of core facility staff	Supervising students, technicians and postdocs
Teaching and training	Hands-on training and eventually teaching various technologies	Eventually, teaching mostly basic science or research group's focused science
Evaluation	On service provision	On scientific output

Note: Here, we have attempted to frame the challenges of managing a core facility in a set of useful schemes that can serve as a set of guidelines for continued success.

The bold lettertype was used to emphasize the difference between the two groups in the two column. Here the relation towards others is described.

management. Overall, we emphasise the need for continuous improvement and innovation in the field of facility management.⁵⁵

A core facility is more than a collection of equipment or a single service – it is typically a centralised or shared resource or infrastructure that provides access to instruments, technologies, resources and services together with domain-related expertise in an academic environment, be it a university, a clinical environment or a research institute.^{7,42,43} The most important component of a core is the people within it (who are also often the largest cost to the institution^{56,57}). It is important for an institution to recognise that these people are a rare breed of people with excellent technical skills who are good communicators, educators and teachers but who have chosen not to become PIs and are affected by a kind of helper syndrome to advance science by supporting users and projects. Consequently, models of current staffing and career progression, recognising this dimension with a focus on sustainability, have been explored.^{57,58}

When it comes to how things are handled at different facilities for training, the majority of cores have mandatory practical training and training as the user requires (Figure 2). The theoretical background is more diverse, and the training may be performed on user samples or those provided by the core (Figure 2). There is unanimity about checking the devices with more diversity on the time point (Figure 3). This is likely also coupled with the amount of

usage the device has. It is clear that a facility may have more suppliers, and some machines will have a long legacy (Figure 4). This is also reflected by the decommissioning of some of the devices at a 'breaking' point, and generally, there is a tendency for relatively inclusive maintenance contracts (Figure 5).

With this article, we aim to provide resources for those working in and aspiring to set up a core facility, and we hope that the resources presented here will be useful to both of these groups (especially those who wish to establish a core facility where the biggest challenges still lie ahead of them). The main challenge lies in turning observations into decision-making and potentially changing the course of the facility. Finding the pivot point where the facility can stay cutting-edge and has the best future for enabling the best science in a changing scientific environment is hard and a constant struggle. Mismanagement and added costs can lead to unfit machinery parks, while dissatisfied users may find other resources, such as outsourcing imaging to distant Euro-BioImaging nodes or running their own equipment. Making decisions while actual users and colleagues with future projects are using the machines is difficult, and the associated opportunity cost can be difficult to estimate. Predicting future usage and making decisions about the future park that will suit future users is an additional challenge that requires time and commitment. Overall, it is crucial to ensure users understand the added value of running a core (see also Figure 6).

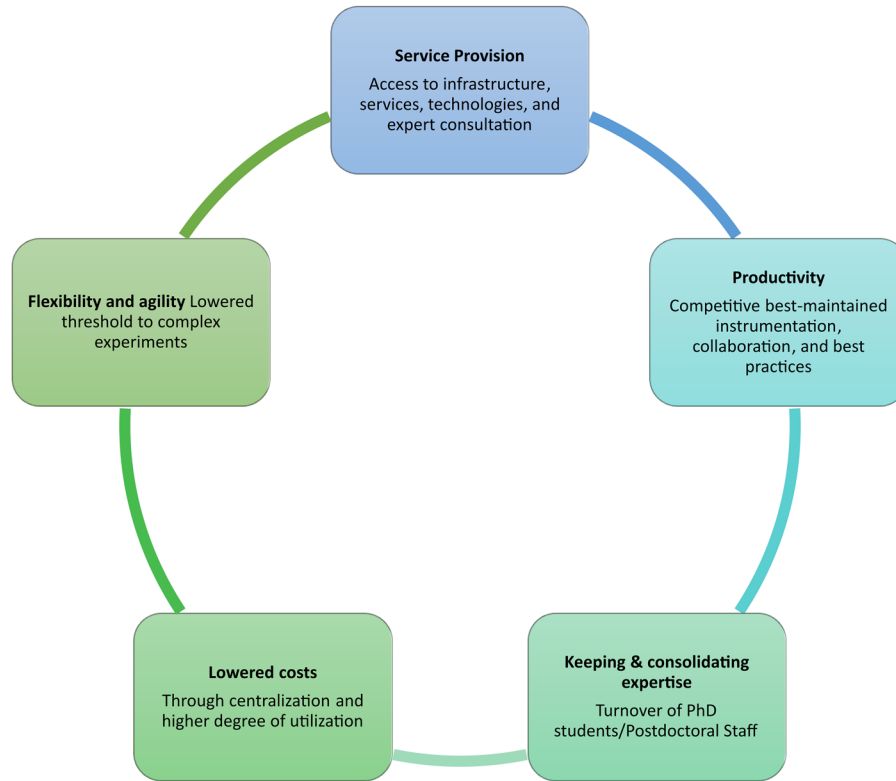


FIGURE 6 Benefits of a core facility. Here, different aspects are depicted as interconnected aspects for the users, the groups, the host institute and potentially external users.

Service provision: access to instrumentation, services, technologies and expert advice. For scientific imaging core facilities, this typically includes support to the research community ranging from experiment design to data acquisition, analysis and data management, embedded in an accessible infrastructure with booking systems and suchlike.

Productivity: providing a portfolio of state-of-the-art and well-maintained devices allows users and core facilities to stay at the forefront of technological development, enabling increased collaboration and cross-fertilisation across disciplines.

Keeping and consolidating expertise: Expertise and knowledge maintained within the platform team (vs. turnover of PhD/postdoctoral staff) and dissemination of knowledge to users (regular training, courses). This enables quick starts for newcomers at user and group levels and also established groups.

Lowered costs: providing access to expensive equipment in a cost-efficient manner, and with devices used at higher degrees of utilisation as compared to individual labs, provides higher flexibility of hardware and software solutions, in contrast to a scenario where only a single setup is affordable for individual labs. Cores typically have sufficient resources to offer multiple technologies, allowing users to choose the best suited for each project, and cores are in a better position for negotiation and maintenance due to the knowledge, experience and good relationships between core and company staff.

Flexibility and agility: enabling more risky projects as the purchase is already de-risked.

However, not optimising usage risks being financially unsustainable.⁴¹ The institution also needs to understand that it may lose the investment it made and consider coordinating the feedback it gives to facility heads. It is also clear that there is no one-size-fits-all approach to the relationship between the core and the institution and that large and small institutions will have different needs. Cores can range from offering a broad portfolio of services to focusing on specific applications. The ‘core themes’ pertain to various domains⁵⁹ and depend on the institution’s scientific build-up and the funding environment, which may include core facilities or more supporting device grants for laboratories.

In today’s scientific environment, innovation is crucial for facilities to stay ahead of the curve.^{21,24,60} However, it is essential to find a middle ground, and while there can be many benefits from (for example) running an imaging lab or becoming a contract research organisation, there are also the risks of losing the service aspect or being too narrowly focused on commercial user needs and thus deviating from the original mission of the core and losing broad user support. Therefore, clear communication and service focused innovation are essential to stay cutting-edge.

When it comes to innovation, a challenge for the facility is horizon scanning to anticipate in which new technology, service, etc., it needs to invest to add value for users. The

importance of horizon scanning for informing research and innovation policies has long been recognised at the European level.⁶¹ Likewise, networking is crucial to continuously learn about the best practices and innovations in other places and to benchmark oneself against the environment. Overall, we hope to describe a parameter space that allows tuning the facility to today's needs and challenges.

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