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Future proofing core facilities with a seven-pillar model

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Abstract

Centralised core facilities have evolved into vital components of life science research, transitioning from a primary focus on centralising equipment to ensuring access to technology experts across all facets of an experimental workflow. Herein, we put forward a seven-pillar model to define what a core facility needs to meet its overarching goal of facilitating research. The seven equally weighted pillars are Technology, Core Facility Team, Training, Career Tracks, Technical Support, Community and Transparency. These seven pillars stand on a solid foundation of cultural, operational and framework policies including the elements of transparent and stable funding strategies, modern human resources support, progressive facility leadership and management as well as clear institute strategies and policies. This foundation, among other things, ensures a tight alignment of the core facilities to the vision and mission of the institute. To future-proof core facilities, it is crucial to foster all seven of these pillars, particularly focusing on newly identified pillars such as career tracks, thus enabling core facilities to continue supporting research and catalysing scientific advancement.

KEYWORDS

career tracks, community, core facilities, core facility team, technical support, technology, training, transparency

1 | THE ADAPTATION OF CORE FACILITIES IN RESPONSE TO EVOLVING USER NEEDS

In his highly influential paper '*How to Choose a Good Scientific Problem*' Uri Alon defines the feasibility of a research question as a function of the skills of the researcher and the technology the researcher has access to.[1] In modern-day research, the broadness of different technologies that are frequently applied to one single scientific breakthrough is immense. Consequently, the needs of the scientific community have gone from solely the access to innovative centralised equipment to now the expanded need of access to centralised technology facilities that are equipped with innovative instruments and staffed with instrument experts and data collection experts. This in combination with the prohibitive cost of advanced technologies and finite research funds has led to the creation of centralised technology centres, better known as core facilities, in most scientific institutes around the world.[2] Combined, these broadening needs are driving an evolution in how core facilities are staffed and managed.

In the last 20 years, core facilities have gone from a novel idea to an essential infrastructure that many scientists rely

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on for their daily research. Today, core facilities play a crucial role in providing access for researchers to technological tools and experts, which, in turn, attracts talented international researchers and helps institutes remain competitive. By centralising infrastructure and expertise, core facilities become the go-to place for anyone in need of access to, training on, and support for a diverse range of technologies. The immediate benefit that core facility users receive from expert advice is the efficient and appropriate development of action plans for technology-based projects and the assurance of high-quality experimental design, data acquisition and analysis in line with established standards. Beyond that, centralised core facilities serve as hubs for users to share their knowledge, which facilitate collaborations among researchers who can mutually benefit from joint projects and technology development.[3]

As the authors have experience in microscopy, the examples given herein will focus on microscopy only to illustrate the intended message. Light and electron microscopy are technologies well suited for centralised core facilities. In general, microscopy requires a significant and constant investment in equipment and building infrastructure to ensure proper conditions for accurate scientific data collection. The pace at which microscopy technology is advancing makes it challenging for researchers to stay informed about technological innovations, while remaining experts in their own research field. Additionally, the microscopy field has embraced the need for data analysis. As computer power and tailored analysis solutions became available, state-of-the art microscopy experiments need to be coupled to substantial know-how about image analysis.[4] Altogether, it makes financial and practical sense to co-locate microscopy equipment and microscopy experts in centralised core facilities, which is why this approach is gaining popularity.

2 | ADAPTING CORE FACILITY OPERATION TO MEET THEIR UNIQUE ROLE IN RESEARCH

Over this last decade, it has become evident that the overarching goals of core facilities differ from the goals of research teams and as such the two can no longer be formed with the same model and policies. For clarity, we define the overarching role of core facilities as facilitators of research. Core facilities exist to ensure research scientists have access to cost-effective, high-quality specialised technologies and access to a dedicated team of *technology experts* and data analysts to obtain high fidelity results. This contrasts with our overarching role definition of research science teams wherein a dedicated group of *topic experts* aims to expand human understanding around a central research question, and to train the future generations of research scientists in the process.

One of the substantial changes that has been observed is how people are recruited to manage infrastructure. In the past it used to be that a knowledgeable and helpful PhD student, postdoctoral fellow or other research lab member would be assigned responsibility for a piece of equipment. In time, a second and a third piece of equipment would be added to the person's responsibility list. After some time, these scientists found themselves performing a full-time role of helping other scientists on many different pieces of equipment from a similar technology, and voilà – a core facility had been born and someone with a research assignment had fallen into the role of managing the centralised infrastructure. It is now becoming more common to find technical staff in core facilities that have chosen a career in technology support. These technical staff are being recruited for clearly defined core facility positions[5] and the era of 'accidental' core facility staff is ending.

Another change has been how authorship on publications is handled. There have been many discussions about this topic[5–8] which is greater than the scope of this article, but the authors feel the authorship debate can be summarised as follows: authorship on publications should be given when there is a strong intellectual contribution, regardless of the affiliation (meaning research scientist or core facility scientist) or how the work was funded (meaning if the facility work was charged or not). Authorship should be based solely on scientific merit and not on affiliations or financial parameters.

As the role of core facilities has diverged from the classical research track, we propose there are seven equally weighted, essential pillars that support the mission of core facilities. These pillars are: Technology, Core Facility Team, Training, Career Tracks, Technical Support, Community and Transparency (Figure 1). Supporting the pillars is a solid operational, framework and cultural foundation. The operational foundation includes topics like the core facility budget and facility leadership. The framework foundation includes a modern human resources team that is evolving with the needs of the community. The cultural foundation refers to an institute strategy of a clear vision and outcome focused policies. This multistep foundation, among other things, ensures a tight alignment of the core facilities to the vision and mission of the research institute.

Each of the foundations and pillars contains principal elements that combine to support the core facilities to reach their potential of being technological centres that facilitate research. Yet, it must be said, particularly for the pillars, that there is a lot of cross over. For example, collaboration is a topic that will weave its way around and through all the pillars. Let us explore each foundation step

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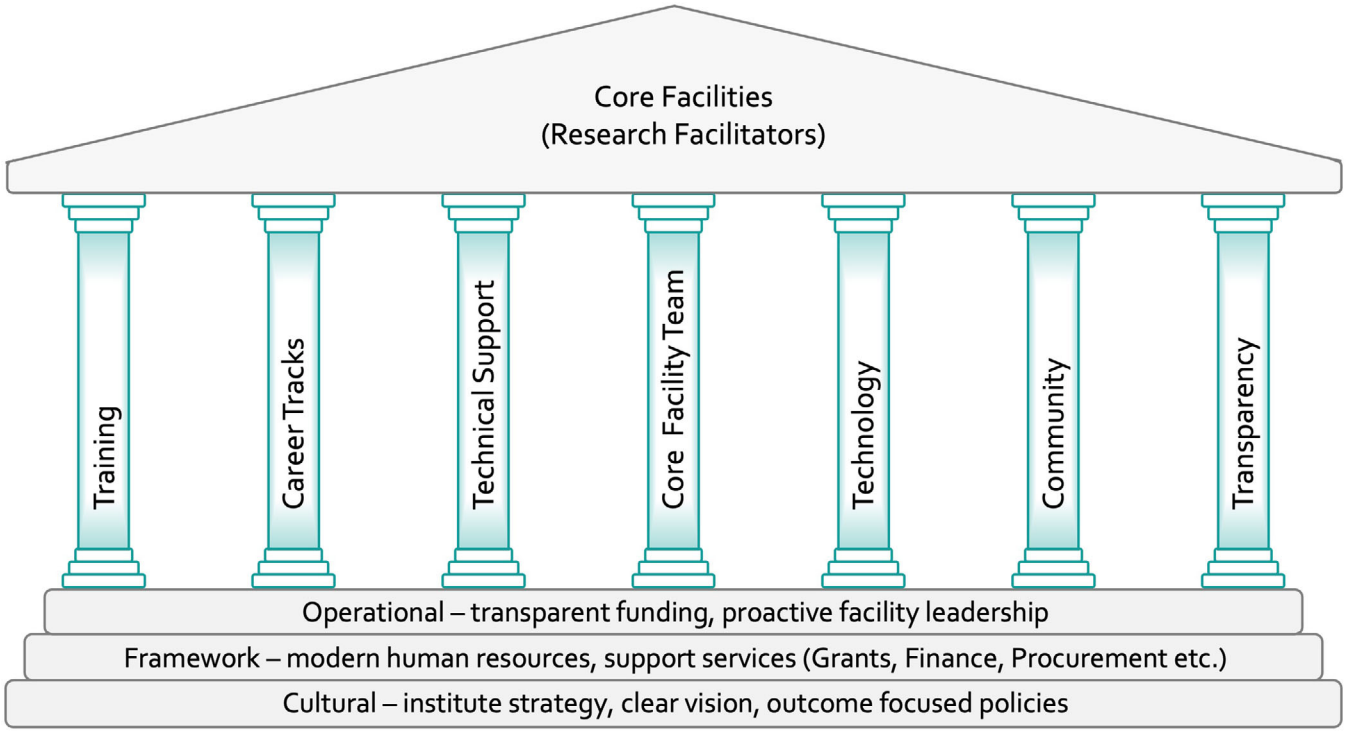

FIGURE 1 The seven equally weighted pillars enabling Core Facilities are Technology, Core Facility Team, Training, Career Tracks, Technical Support, Community and Transparency. Supporting the pillars is a solid operational, framework and cultural foundation.

and pillar, some in more detail than others as they are new, developing topic areas.

3 | OPERATIONAL FOUNDATION

The operational foundation includes the core facility budget and facility leadership among other things.

In cases where budgets are not clear, where there is little transparency about future funding programs, it is extremely hard for a core facility to provide a stable service portfolio and support the needs of the scientists. In some cases, core facility funding may be marginal. The essential element is that the levels of funding are transparent year to year so that budgets can be planned, equipment maintenance strategies can be defined, and staff recruited with some stability.

A proactive and well-trained facility leadership will provide the best possible support to all the pillars needed for a successful core facility. There is room for improvement in this area as many core facility leaders are excellent scientists and technology experts that may not have received training for a role with these requirements. Consequently, there are growing efforts to train core leaders in the business aspect of a core and in the soft skills that are necessary.[5]

4 | FRAMEWORK FOUNDATION

The framework foundation includes a modern human resources team that is evolving with the needs of the community, and an active grants office to help identify calls and support funding proposals. Other elements of the framework that are essential are the purchase and ordering team to help with instrument procurement, the communication team to help with outreach and sharing of important milestones such as new publications, awards, grants or the arrival of a new instrument, and the finance team to help with the accounting process for core facility users.

5 | CULTURAL FOUNDATION

The cultural foundation refers to an institute strategy of a clear vision and outcome focused policies as well as a culture of training and collaboration across core facilities, and within core facilities. Within this foundation would be policies for authorship on publications. A strong culture of investment in core facilities and an understanding of their value will encourage equipment sharing in place of isolating equipment in single research laboratories.

Standing on these three foundations are the seven pillars of the core facilities.

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6 | THE TECHNOLOGY PILLAR

Technology is the central pillar around which a core facility is built. This is not to say it is more important than the other pillars, but if you take away the technology, core facilities lose their reason for existence. Stated directly, a core facility needs to contain specialised, often advanced, equipment that is well maintained and ready to be used by scientists at any time.[3]

Within a core facility, there are two broad categories of equipment: foundational equipment and advanced equipment. Foundational equipment is the bread-and-butter type of equipment that is used by many different researchers in many different lines of research. In the case of microscopy, these are screening microscopes, or sample preparation equipment. Easy accessibility to foundational equipment helps ensure that researchers can try different technologies to determine the approach that is most appropriate to address their research question.

Advanced equipment is more specialised than foundational equipment. Although the definition of 'advanced' may differ between groups, advanced equipment often requires more knowledge to operate, requires more specialised building infrastructure (tighter environmental control, less mechanical and electrical disturbances, etc.), and is more expensive to operate and maintain than foundational equipment. These technology systems come with the benefit of state-of-the-art methodology often with higher sensitivities, often performed in faster workflows thereby supporting fast-paced innovative research. The type and number of advanced instruments that are purchased will depend on the institutional vision, the overarching research focus, the needs of the users and the available budget.

Core facilities well equipped with both foundational equipment and advanced equipment help to democratise science by enabling a baseline access for all researchers to comparable tools. In research landscapes with limited funding, by having instruments in a centralised facility, this can reduce duplication of systems that will not be heavily used while ensuring access for many scientists.[9] Furthermore, this approach can result in a broader portfolio of available technologies to support the research community working on a minimal budget.[9]

Although instrument development is essential to keep pushing technology forward, the primary mission of a core facility is service and support, not technology development. Consequently, the place of newly developed systems is not in a core facility. Instruments in the development phases are often not yet streamlined for ease of use and reproducibility of data acquisition. These systems are works in progress and need extensive support from their developers to operate. As such, these instruments are best located in specialised development teams that can optimise the technology and bring it to maturity. When the development has reached a technology-readiness-level that can be integrated effectively into service-focused core facilities then these instruments should be integrated.

7 | THE CORE FACILITY TEAM PILLAR

Regardless of how advanced the technology is, if there is not a skilled group of experts to operate the instruments, those instruments amount to little more than sophisticated pieces of glass, metal and plastic. The core facility staff should be the expertise bridge between the research scientists and the instruments. By no means is this meant to imply that research scientists are uneducated when it comes to technology. Rather the intended message is that the core facility staff are there to help an instrument be used to its full scientific potential and operational capacity in a way that is hard to achieve in a research group focused on defined research questions. By intentionally dividing roles, and assigning instrument responsibility to core facility staff, research scientists can focus on their research questions with confidence that the core facility staff will help them apply the technology in the best possible way.

Today, the hiring of a core facility staff member is strategic. Although it might be tempting to hire someone with exceptional technical skills, it may be more beneficial to hire a less technically skilled person who has the right soft skills. As an example, the mindset of supporting others in their research and finding solutions for someone else's project is paramount in a core facility. Every member of the core must embody this spirit of willingness to facilitate the best science without the need for recognition or for following their own research interests. Additionally, a genuine inclination towards engaging with others should be inherent in one's nature to thrive in an environment that relies heavily on interpersonal interactions and communication. One must love human interactions, be able to address a broad range of scientific questions and combine many different tasks into a coherent role. The expertise of the staff is continuously needed to solve issues and challenges of all kinds, even to the point where one could say that it goes beyond flexibility and a solution-focused mindset into the realm of improvision. Conflict management, dealing with people in stressful situations, and overcoming the unexpected (power cuts, instrument failures, unexpected VIP tours, failed experiments, etc.) are all essential roles of a core facility staff member.

Staff working in core facilities often come from diverse backgrounds but generally exhibit a strong affinity for both technology and scientific curiosity. In the case of microscopy core facilities, each facility has its own unique

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history and team composition, but it is typical for a microscopy core to consist of several team members, each specialising in a particular technical aspect. This is driven by the fact that microscopy encompasses a wide range of complementary modalities, each of which requires extensive expertise.

As the core facility environment has continued to evolve, it has created the opportunity to successfully integrate individuals each with diverse knowledge backgrounds and skill sets. As an example, a decade ago, most members of imaging facilities would have received training in imaging, life sciences or material sciences. Now it is increasingly common to find professionals with backgrounds in bioinformatics, computer science or mathematics to specifically address the growing demand for advanced image analysis capabilities in microscopy cores or closely affiliated image analysis cores.[4] Additionally, backgrounds in chemistry and engineering are also essential to address the growing complexity of sample preparation and instrument operation/maintenance, respectively.

Beyond these diverse scientific backgrounds, a core facility can offer a continuum of distinct roles that match different responsibilities and even personalities. For example, in an electron microscopy core, there are roles for people who like to perform very precise routine tasks such as ultramicrotomy, and there are roles for people who like to work with users at the bench, troubleshoot problems, tailor applications and/or push technology to its limits. And there is everything in between. This diversity of roles appeals to a different group of people than what is found for a classical research career, and that is what necessitates a diversity of career tracks for core facility staff.

8 | THE TECHNICAL SUPPORT PILLAR

As was already described in the introduction, a vital role of the core facility staff is supporting scientists with their research and providing technical support. It is not enough to have just a core facility expert with knowledge of the equipment and protocols (the *Core Facility Team* Pillar). There must also be a facility culture (and one could argue duty) to provide a broad portfolio of technical support options which is why the authors feel the *Technical Support* Pillar should exist. Without technical support, an essential element of core facilities is lost.

Continuing the example above, microscopy core facility staff are frequently consulted for advice on experimental design, which instruments to use, and how to perform the data analysis. The scope of interaction between the core user and the microscopy core staff has expanded from simple instrument usage advice to case-by-case consultancy throughout the entire workflow, centred around the scientific question rather than solely the technique. In some full-service models, the core facility staff may execute the work at the bench by preparing routine samples, optimising specialised sample preparation methods or testing different data collection strategies. This makes technical support an essential pillar within the core facility model as this aspect has expanded far beyond simply providing advice about an instrument.

9 | THE TRAINING PILLAR

Technology is demanding, complex and always evolving. Therefore, training, with its many different variations, is another pillar of an effective core facility. There is training of the core facility team in both technical skills and soft skills such as communication and conflict resolution. There is the training of the core facility users on how to perform the techniques or operate the equipment. There is training of the public and other key stakeholders in what a core facility is and does. Consequently, there is the training of the core facility team on how to be trainers of these groups with diverse backgrounds and knowledge levels.[10]

Training the core facility team is needed to enhance the collective technical knowledge within the core facility, which is driven by the ongoing evolution and expansion of technologies. In the case of the microscopy community, enhancing technical knowledge can take various forms ranging from attending conferences to see the latest microscopy developments to participating in hands-on workshops or learning directly from topical experts. In this regard, the efforts of the imaging community have been crucial, and that is why *Community* is another pillar of effective core facilities to be discussed below.

Providing microscopy training, regardless of the kind of microscopy, requires more than just being up to date with the technology and conveying information to the user.[10] Microscopy cores frequently offer general informative training workshops to cover basic and essential microscopy techniques through classroom teaching and, in some cases, e-learning. A good trainer possesses a talent in communication to transfer complex knowledge in a clear and understandable way; patience and adaptability to keep the user engaged; passion and enthusiasm for the subject; and the ability to evaluate the trainee's progress and provide personalised guidance and feedback.

When core facility staff support users by engaging in workflows, this necessitates complex experimental organisation and user coordination to ensure seamless workflows and access to the core facility. When the core facility staff host tours with guests ranging from school students to famous dignitaries, clear, concise, engaging and personalised knowledge sharing is required. Core facility staff

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must possess organisational skills, manage user interactions, provide feedback to scientists, secure budgets for equipment sustainability, prepare for future applications and more.

As this need of a specialised skill portfolio was identified by the core facility community, multiple opportunities to attend workshops and training sessions on these transferable skills began to be developed. Today, societies like the German BioImaging Society,[11] the Royal Microscopy Society and the Core Technologies for Life Science Society, to name just a few, have all set up specialised practical courses for core facility staff. These courses are often targeted at the general core facilities community rather than focusing solely on a specific technology platform. Participants are introduced to the soft skills needed in a core facility environment. Beyond the structured learning program, these courses offer an opportunity to network with staff from other core facilities at different institutes and/or technology platforms and thereby strengthen one's core facility community.

That said, attending a workshop on communicating results, for instance, does not automatically transform one into a proficient communicator. The consistent application of these skills is crucial for personal growth in becoming a good communicator, efficient organiser, decision-maker, negotiator or other domains of soft skills that one wishes to develop. The training process involves identifying areas for personal development, finding the right way to learn those skills (for example, by identifying a course, doing job shadowing etc.) and receiving the right feedback and mentorship, together with working in an environment that cultivates personal development. This is why the *Training* pillar particularly relies on a strong cultural and framework foundation as it is important to nurture a culture that promotes and values training of all members of an institute, where team members regularly engage in self-evaluation and are actively working to improve in targeted areas.

10 | THE COMMUNITY PILLAR

No core facility stands on its own. Core facilities are surrounded by the community of researchers that the core supports, and the community of support services (grants, purchasing etc.) that support the facility. Beyond that, the global core facility community provides the opportunity to share experiences and knowledge between core facilities that can be essential in challenging projects or implementing innovative technologies. Lastly, the connection and partnerships with the companies who are building the technology are essential for a core facility to remain state of the art. The community around the core facility is part of what makes the core facility strong and should not be undervalued.

In the case of microscopy, a nice illustration of this is how the community's openness and the dedication of many individuals has led to extensive training opportunities. It is not unusual for individual core facilities to offer training events or to build networks and this has facilitated knowledge sharing between microscopists from all backgrounds, be they core facility staff or researchers in laboratories. Here, the *Community* pillar and the *Training* pillar collaborate in the form of community workshops and training sessions that often yield immediate results. An example of this is the community wide impact Euro-Bioimaging has had. The primary goal of these activities is for knowledge experts in the community to deliver necessary information that attendees can promptly apply in their own research. This has resulted in knowledge sharing and the support of an untold number of research projects because of a community mentality.

11 | THE TRANSPARENCY PILLAR

Transparency is also a pillar as it allows all stakeholders to understand the possibilities and limitations of the core facility, which is essential for the successful operation of core facilities.[8] Key areas that need transparency are pricing and facility procedures – for example, who can access which facilities?[12] And how does one access the facility? Clarity is essential as to what technologies are available and what services the facility can provide. For small teams it may not be possible to provide full-service support on all the equipment because the core facility team is understaffed. That should be clear for all involved. Transparent role definitions of the core facility team will help avoid conflicts as each individual should know their own roles and responsibilities, and those of their colleagues. This will also avoid conflicts with users as it is clear to both facility staff and researchers accessing the facility what can be requested and who should be responsible for what. Clear procedures and transparent guidelines will help the facility operate smoothly.

12 | THE CAREER TRACK PILLAR

In scientific research, where knowledge generation moves quickly, and masters' and PhD students as well as post-doctoral fellows transition from one lab to another, it is unusual to introduce strategies for staff retention. However, staff retention in core facilities translates to stability within the core, to consistency of high-quality technical support, and to knowledge transfer between transitory

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communities. Staff retention is often facilitated by career development strategies, and it is becoming evident within the core facility community that there is a need to establish a comprehensive program for career development.[13]

A program for career development in core facilities should allow for growth in terms of responsibility and expertise of the core facility team, supported by a strong cultural foundation of training and personal development. All team members should have the ability to progress within the career development program at their own pace and according to their individual goals. The career tracks should give each core team member different possibilities while remaining in the context of a coherent, productive core facility team. In core facilities, where numerous skills and responsibilities are required, it makes sense to have multiple career tracks in place leading to multiple different responsibility levels that are in alignment with the facility work packages. Implementing an institute wide program with tracks and progression opportunities would ensure that people do not become stagnant within the hierarchy and that opportunities for advancement are available.

A core facility career development program should provide a future perspective for all facility members, without necessarily being a single route aiming for the main core leadership. It is wrong to assume that all core facility staff wish to be in senior leadership roles. Many people have chosen a career in a core facility because they love the technology and thrive on working with many projects and research questions. They may wish to stay at the bench close to the science and there should be career tracks that support growth in such a role. A career track leading in a single direction towards the leadership position will not appeal to every core facility staff member. The consequence could be that some of the staff 're-route' to different professions taking their extensive technical and soft skills with them.

Defining and then implementing a multiple career track program will involve defining several levels of responsibility and providing clear role descriptions. Once the program is in place, there will be a need to continuously monitor the development of individuals as they move through the program in relation to the individual's goals, and in relation to the entire team as a unit. While career development certainly involves enhancing one's skills, whether through training sessions or on-the-job learning, it goes beyond that. Career development requires individuals to follow a path aligned with their interests, work towards specific goals and experience a sense of progression and accomplishment. Once growth and progression has been made, it is important to acknowledge and celebrate that achievement. Therefore, the career program must include a well-defined plan with clear objectives and milestones for staff promotion. With the support of the institute leadership and the institute human resources, the director / head of the core facility plays a vital role in the career development of the staff in their core. As a team leader, continuous and careful consideration of the team's composition and its evolution over time is necessary. If the career development of the staff is recognised as part of the facility's mission and the leaders' role then it ensures that time and attention are dedicated to defining short- and long-term goals for all team members, thereby providing direction and motivation to the entire team.

The strategic goal of this personalised approach is to create a team of motivated, engaged and more flexible core facility staff who are happy and competent in their role. A clearly defined program that allows flexibility, specific milestones, and has clear lines of promotion makes the profession of a core facility staff scientist motivating and aids in recruiting and retraining individuals with different profiles and personal objectives into the core facility team. This practice can assist in customising the facility's service portfolio to meet the needs of the research community, and it is one of the actions that can contribute to future proofing the core facility.

Advocates against staff retention often claim that low turnover can lead to knowledge stagnation.[14] To combat this, it will remain essential that the core facility staff are well suited for their role, and they will be evaluated on their growth using modern performance metrics, such as 360-degree evaluations. The *Training* and *Community* pillars will be essential in keeping core facility staff motivated to continue developing and expanding their technical and soft skills. Careful and well-structured recruitment will remain essential to select the right people for the required roles. Together, these efforts should work at keeping stagnation at bay in a stable core facility community.

Every institute will have its own approach to a career track program that should be aligned with the central mission of the institute and fit within the legal regulations of the country the institute is located in. This suggests there will not be a one-size-fits-all program that can be cloned from institute to institute. The 2022 article by Lippens et al. details the core facility career tracks at the VIB.[15] In brief, there are four career tracks for core facility scientists: Core Facility Technician, Technology Expert, Technology Specialist, and Head of Core Facility. Within these career tracks, there are multiple levels that are differentiated by six variables: the responsibility in the function; the level of experience in that role; the flexibility of the employee; the level of independent work; the extent of the role in communication/reporting to users; and the extent of the supervising role. Although the program at the VIB is still in its initial stage, the early results of its implementation have led to a noticeable impact on the core facility

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community at the VIB.[15] The VIB program is a solution well structured for the VIB and, consequently, it may not fit well within other research organisations with different structures. Nonetheless, it is hoped that the VIB program will offer inspiration for other models beyond the classical research career tracks for core facility staff and be proof that the implementation of such an approach will enrich the core facility community.

13 | FUTURE PERSPECTIVES

The role and organisation of core facilities has changed a lot in the last 10 years, and it will be interesting to see how core facilities are positioned 10 years from now. We believe that if focus and effort is placed in these seven pillars of Technology, Core Facility Team, Training, Career Tracks, Technical Support, Community and Transparency, then core facilities will continue to grow their reach and catalyse science and innovation. Some of these pillars need more investment and development than others – for example, the core facility career tracks. It is hoped that in 10 years the core facility career tracks are such a common approach that the pillar is moved down and incorporated in the Human Resources role of the Framework foundation. For now, this growing area, along with the six other pillars, are needed to support the overall mission of core facilities, which is to facilitate science. By remaining focused on our mission, supported by our seven pillars, standing on a solid operational, framework and cultural foundation, we, the core facility community, can catalyse research in ways that has not been seen before.

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CONFLICT OF INTEREST STATEMENT

EMT is a consultant for hfp-consulting and has been a trainer in several core facility management courses. SL declares no competing interests.

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