New Big Science in Focus

Perspectives on ESS and MAX IV

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PERSPECTIVES ON ESS AND MAX IV

LUND STUDIES IN ARTS AND CULTURAL SCIENCES 8

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JOSEPHINE V. REKERS AND
KERSTIN SANDELL (EDS.)

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1. New big science: Opportunities and challenges

Josephine V. Rekers & Kerstin Sandell

Two large experimental facilities are being built in Lund: MAX IV, a synchrotron radiation facility, which started construction in 2010 and produced its first X-rays in June 2015; and the European Spallation Source (ESS), a neutron source, which started construction in 2014 and is scheduled to send the first neutrons through the instruments in 2019. Both are designed to be at the forefront of science, using the brightest light and the strongest beam of neutrons to investigate the structure and dynamics of matter at the molecular and atomic level, reaching down to the subatomic (in the range 10^{-4}–10^{-15} m). These facilities are large in their physical footprints, their costs, and their ambitions. They are also newly built, and thus able to take into account the latest advances not only in technology, but also in sustainable design, research data management and protection, and collaborative organizational forms. In other words, these facilities, which are prime examples of 'new big science', involve complex projects that are about much more than just physics and engineering.

The facilities in Lund are two of the most recent examples of a major investment in scientific infrastructure. Science has a long history of wanting large-scale facilities—expensive experimental structures that take time and effort to build and that promise to be able to carry the field into new, unexplored dimensions of nature. This has long been referred to as big science within the scientific community, and has its predecessors in astronomy, but most notably, in the Manhattan Project during the Second

World War and CERN in the post-war period. The 'new' about new big science that concerns us in this anthology is the fact that facilities are expanding in several ways. Firstly, they are so large and expensive that they are beyond the scope of most regional and national budgets, and instead require several countries to collaborate. Secondly, they are expanding in terms of their multidisciplinarity. In addition to scientists from physics as well as chemistry and the life sciences, new users come from disciplines such as archaeology, geology, and medicine. Thirdly, they are expansive in their ambitions to contribute to society, and are thus shifting the way promises are made. Current investment in large-scale research infrastructure is largely justified by referring to innovation and economic development, and future research findings are expected to contribute by addressing grand challenges such as global warming, energy efficiency, healthy aging, and food preservation. Although interest in the societal impacts of large-scale research facilities has always been a part of big science, one could argue that these goals are far more pronounced in the current context. In a knowledge-based economy, policymakers at various levels have chosen to position large-scale research facilities as elements in the development and dissemination of solutions to the problems of science and society alike.

The construction of MAX IV and the ESS provides the opportunity to investigate these complex projects as they are being built and from new viewpoints. In this anthology, we approach new big science from a range of disciplinary perspectives and traditions, including law, sustainability studies, the sociology of science and technology, history, human geography and information studies. We have a shared analytical sensitivity to the opportunities presented by the newness of new big science. Compared to older facilities that are upgraded, the new facilities in Lund are, hypothetically, less bound to existing buildings, networks and cultures, and more open to an expanded group of stakeholders. They can therefore from the very start employ advanced technologies, materials, and analytical tools that can lead to scientific breakthroughs; construct buildings that feature environmentally sustainable and creative spaces; and invest in organizational and institutional forms that support a more open facility that is better integrated with the rest of society. Such features of new big science are not easily implemented, however, even when the facilities are designed and built from scratch. As our respective essays illustrate, there are constraints on doing things in new and different ways, and challenges arise when coordinating an ever-expanding group of stakeholders.

The anthology is the result of thematic research done under the aegis of Lund University's Pufendorf Institute for Advanced Studies in the academic year of 2014–2015, and, as such, a project that was interdisciplinary, exploratory, and short-term. Our aim has been to identify emerging areas of interest in new big science, to present initial findings from our empirical investigations, and to indicate interesting themes for the future. For us, this has been a unique time, both for being able to study these facilities as they are constructed, and for being able to work together across disciplines. Our research project focused on five areas where thinking differently is the *raison d'être* of the facilities and central to the various stakeholders' expectations. These are (*i*) regional development; (*ii*) sustainability; (*iii*) instrument design; (*iv*) the conceptualization of data management; and (*v*) intellectual property rights. In these integrated sub-projects, we could take advantage of a rare opportunity to develop research topics in the social sciences, humanities, and law in tandem with on-going efforts to realize new, advanced research facilities for the natural sciences, engineering, and life sciences.

Our aim with this anthology is to present different perspectives, each strongly rooted in its respective discipline, on our common research subject of new big science, and thus speak to different kinds of readers. One audience we have in mind comes to big science from the field of science and technology studies, but is perhaps unfamiliar with other disciplinary perspectives or the kind of new facilities being built in Lund. For these readers, the main point of this volume is its breadth: the essays offer alternative points of view and concentrate on hitherto overlooked aspects of the organization of big science—its environmental impact, for example, or its legal status. Accordingly, this volume will provide an introduction to the perspectives of societal stakeholders, who will have an increasingly important voice in science policy and thus shape the organization of science in years to come. A second group of readers we have in mind is familiar with one or several of the disciplinary perspectives presented here, but perhaps not with big science per se. For this audience, the individual essays provide an introduction to big science and set it in a context that demonstrates its relevance to society and research.

Finally, we seek to address the general reader who is interested in Lund, the county of Skåne, and the Öresund region as a whole, and wants to learn more about what is going on in the north-east part of this medieval university city. Previous anthologies, such as Hallonsten's *In Pursuit of a Promise* (2012) and Kaiserfeld and O'Dell's *Legitimizing ESS* (2013), provide overviews of the inception and launch of the ESS in Lund, and in the current anthology we continue this by tracing the ways in which the ESS and MAX IV are being built and embedded in the region. For these readers, this collection of essays will give a broad perspective on the facilities, but also provide an introduction to the wider debates in which they operate—some of which are taking shape in scientific and political communities far from this particular site in Sweden.

The facilities: MAX IV and the ESS

This anthology is about big science facilities and the communities that launch, build, use, host, and benefit from them. More specifically, it is about the design and construction of two such new large-scale research facilities next to each other in the university city of Lund in southern Sweden: MAX IV and the ESS.[1]

The MAX IV laboratory is a synchrotron facility, a Swedish national laboratory where X-rays are used to investigate the properties of materials. There are many synchrotron facilities around the world—in Europe, two prominent ones are the European Synchrotron Radiation Facility (ESRF) in Grenoble and the Diamond Light Source in Oxford. A synchrotron facility consists of a linear accelerator, or linac, that speeds up electrons. These are fed into a synchrotron ring, where they are kept at high speed. When their trajectories are bent, X-rays are produced. Due to the wave–particle duality, light exhibits properties of both waves and particles, where

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[1] The history of MAX-lab from a science policy perspective has been covered by Hallonsten 2009, 2011. Thomas Kaiserfeld (2013) has written about the history leading up to the site decision for the ESS. For the timeline of the ESS, see also Berggren and Hallonsten 2012.

the particles are called photons. These beams of X-rays/photons can be taken out of the synchrotron ring at different places, making it possible to have numerous instruments, or beamlines, on the same ring. MAX IV is the fourth generation of synchrotrons built in Lund. It consists of two rings, one with the energy 1.5 GeV (circumference of 96 m) and one with 3 GeV (circumference 528 m), and able to host 30 beamlines altogether. Currently, 14 beamlines have funding.

Construction work began in 2010, and the facility will start to operate in June 2016 and be fully operational in 2026. As an organization, the MAX IV laboratory has been part of the research milieu in Lund for over 25 years and falls within the organizational structure of Lund University. MAX IV is financed by the Swedish Research Council (VR), VINNOVA (Sweden's innovation agency), and the Wallenberg Foundation. The MAX IV laboratory is governed by a board appointed by Lund University in consultation with VR and VINNOVA. VR and Lund University contribute most of the running costs, including the rent of the buildings, currently estimated to be SEK 500 million per year, and the construction of the accelerator and synchrotron rings (SEK 1.3 billion), while the Wallenberg foundation has contributed SEK 400 million for the first seven instruments, with co-financing of SEK 160 million from twelve Swedish universities. At time of writing, 140 people are employed at the MAX IV laboratory.

In contrast, the ESS is a multinationally financed facility that currently involves no fewer than seventeen partner countries. In this facility too the linac is fundamental, accelerating protons that hit a tungsten target in collisions that produce the desired neutrons. Moderators are used to adapt the energy of the neutrons that are taken out in beam ports to the different instruments. It is anticipated the ESS will have 22 instruments.

Lund was chosen as the site for the ESS in May 2009, construction officially started in September 2014, and the facility will be inaugurated in 2019 and fully operational by 2026. Neutron facilities are more expensive and far less common than synchrotrons. The ESS has been an idea in the making since the late 1990s, ever since the OECD recommended that three new generation (spallation) neutron facilities be built, each on a different continent. The Spallation Neutron Source (SNS) was built at Oak Ridge National Laboratory in the US (it began operating in 2007), and J-PARC in Japan (which began operating in 2008, but was damaged during the earthquake of 2011). The total construction cost of the ESS is currently estimated to be €1.8 billion. Sweden (35 per cent) and Denmark (12.5 per cent) have taken the lead in financing the ESS, followed by Germany (11 per cent), UK (10 per cent), and France (8 per cent). The process of design and construction is largely organized as contributions in kind, where labs in the partner countries contribute work and material (now estimated to be 35 per cent of the construction cost) instead of cash. The governance of the facility is in a state of transition: ESS Scandinavia started out as part of Lund University, but soon established itself as ESS AB in 2010. In October 2015, the ESS became a European Research Infrastructure Consortium (ERIC), which has a legal status similar to that of an international organization. All partner countries are represented in the board. Currently, just over 300 people are employed at the ESS. Until the ESS comes into operation, Europe's main neutron facilities are the Institut Laue-Langevin (ILL) in Grenoble and ISIS at the Rutherford Appleton Laboratory in Oxford.

In both of the Lund facilities, when the beams of X-rays/neutrons are taken out of the source, the instrument will start. Each instrument will treat the beam differently in order to take a variety of measurements, using different components to shape the beam. Each instrument will finish with an end-station where the experimenter mounts the sample, and where there is equipment to expose the sample to different conditions. Lastly, there will be the detectors, placed to capture the energies and directions of the photons/neutrons after they have interacted with the sample. The data from the detectors will then be processed in different ways and later analysed by the researchers. By knowing the physics of how photons/neutrons interact with atoms and electrons on the molecular, atomic, and subatomic levels, the researchers can use the data to reconstruct the structure and/or dynamics of the material they are investigating.

Both facilities will use the beams of X-rays or neutrons to probe materials, investigating their properties, structures, and dynamics. The materials can be anything from atoms to metal alloys to proteins. They will be investigated in different phases—solid, crystalized, or liquid—and under different conditions in terms of temperature, gas environment, and pressure, for example. The users will be drawn from many different fields and disciplines, including physics, chemistry, biology, materials science, geology, engineering, and medicine.

Both MAX IV and the ESS will be multidisciplinary user facilities. This means that each instrument will have users from different disciplines and research fields. It also means that almost all users will be visitors, coming to the facility to do their experiments, while being employed elsewhere. They will apply for beamtime for a proposed experiment that is evaluated and prioritized in a peer-review process. Some of the beamtime will be reserved for the resident staff working on that particular beamline. Private companies can buy beamtime, although this is probably going to represent a fraction of the total.

These two facilities are being constructed in a region that has major universities, including Lund University and the University of Copenhagen, where a variety of courses and projects encouraging the use of synchrotron and neutron techniques are underway. One example is the interfaculty project CoNeXT at the University of Copenhagen.[2] In addition, the region has been keen to prepare for the construction and launch of MAX IV and the ESS, and it coordinated its arrangements in TITA, a large regional development project (2010–2012, budget €5.3 million) which brought together stakeholders to create the right conditions for growth and employment in the wake of the establishment of the research facilities. In June 2015, a three-year cross-border initiative was approved with a budget of SEK 178 million (€19 million) funded by INTERREG, Sweden's Region Skåne, and Denmark's Region Hovedstaden, involving higher education institutions, regional government and the local authorities, to create networks and research programmes related to the ESS and MAX IV. Finally, Science Village Scandinavia AB is a joint venture between Lund University, the City of Lund, and Region Skåne to coordinate the development of 18 hectares of land between the MAX IV and the ESS facilities as a science village, an area that is intended to provide the infrastructure to support the new facilities, including research facilities, institutes, business centres, laboratories, services, and housing.

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[2] <conext.ku.dk>.

From big science to new big science

An anthology about *new* big science begs the question of what big science is.[3] The term was popularized by Alvin M. Weinberg, then director of Oak Ridge National Laboratory, in 1961, as a way of explaining what the biggest research laboratories were about. One central aspect Weinberger sought to address was the way in which big science transcends the ordinary confines of science, which are (predominantly national) educational and research institutions that are self-governing in terms of peer review and the allocation of research funding. Big science moves beyond these scientific communities, up to the highest political level and out into society, implying that there is a need to achieve legitimacy in the public domain. This changed the ways in which investments in science and scientific infrastructure are framed and justified, entangling science much more with politics. Major investment in science involves an ever-greater number of stakeholders and decision makers who are not scientists—and who can have very different perspectives on the role of science in society—and these views were added to the already heterogeneous set of views that existed within the scientific community.

Big science originally grew out of collaboration between the US government, the military, and academe. This collaboration was forged in the Second World War and continued in the cold war, fuelled by the five M's: money, manpower, machines, the media, and the military (Capshaw and Rader 1992). From the 1950s to the 1970s, big science grew into a vast worldwide array of projects pursuing fundamental research, a testament to a certain cultural and (at times by inference) military superiority. During this era, the biggest projects were devoted to high-energy physics: Fermilab and SLAC in the US, KEK in Japan, and CERN in Europe.

Of course, some of these features still characterize the big in new big science to this day. Large-scale research facilities require large sums of money, and they are often physically big machines, taking up a great deal

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[3] For a detailed discussion of big science, see Peter Galison and Bruce Hevly's anthology *Big Science* (1992), and for a historical and methodological reflection on the use of 'big' see Westfall 2003.

of land (the MAX IV ring is as big as the Colosseum in Rome, for example). Big science also continues to demand long-term commitment from individual scientists as well as the scientific community. Facilities are designed to be in operation for several decades, thus shaping future research as well as careers. Since the 1970s, however, big science has expanded in other ways as well, as is most evident in the communities that finance and use these big science facilities. While big machines are sited in particular locations, the large sums of money, albeit still public money, are increasingly found from many different scales—from universities, regions, governments, and supranational bodies (see Elzinga 2012 and Benner 2012). The range of users has expanded within the universities and the facilities are generally keen to engage a larger and more diverse body of industrial partners. Thus these facilities involve more, and more different, interested parties than the military alone, which was once the main stakeholder.[4] In our knowledge economy, investment in scientific infrastructure holds out the promise of impact far beyond science and the military, to society at large, where there will be benefits for industries, environment, and societies of the future. The discourse used to invoke such expectations refers to innovation processes and the economic development of continents, nations, regions, and localities: future research findings at such facilities are expected to help us address the grand social challenges of our time.

Furthermore, new facilities often cater to larger and more diverse user communities. Whereas the largest facilities in big science were once devoted to a single discipline—high-energy physics—the largest machines under the umbrella of new big science are versatile, multidisciplinary user facilities, open to a variety of disciplines and industries. This means, as Olof Hallonsten points out, that users are often engaged in what could be called small science—working within ordinary-sized projects as individuals or in smaller research groups at standard university departments (Hallonsten 2009). Finally, the geographical reach of big science has expanded. On the one hand, investments frequently surpass national

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[4] Although this shift happened more slowly than often is assumed. When atoms were put to peaceful ends with CERN, the US and the USSR still were engaged in the cold war and the space race, including the 'Star Wars' programme launched by the US president Ronald Reagan (Guidice 2012)

science budgets, and therefore rely on international collaborations, especially in Europe. On the other hand, the particular locality in which facilities are sited plays a more prominent role in the organization of big science today. In order to deliver on expectations, large-scale facilities are now more open, accessible, and integrated into society, rather than closed-off from their surroundings, impervious to factors that might affect the purity of scientific research. Whereas big science facilities were often fenced-off, secretive institutions with only tangential ties to universities and local communities, new big science facilities are located in dynamic areas and are integrated into major universities and local economies. In other words, what is big about big science today is not only the money, manpower, and machines involved, but also an expanded set of stakeholders, users, and expectations.

Opportunities and constraints in new big science

All the contributors to this anthology share an analytical sensitivity to the opportunities presented by the newness of new big science. These opportunities are not easily realized, however, even when the facilities are designed from scratch and are in the process of construction, as is the case in Lund. There are constraints on doing things in new and different ways, and challenges arise when coordinating an ever-expanding group of stakeholders.

The most obvious opportunity offered by new big science is that new facilities mean bigger, faster, and brighter, or, in other words, better machines than the previous generations of facilities. With brighter and more intense light or neutron beams, we can see more, and with more data and faster experiments we can advance our knowledge more quickly. Moreover, in addition to extending the existing technological capabilities of facilities incrementally, new facilities can employ state-of-the-art materials, technologies, and engineering expertise to develop novel techniques that are different from what came before. New user demands may call for radically different experimental stations or beamline manipulation options; new and better-suited materials can be incorporated into the designs; advanced research data management systems can extend the data's value in answering future questions (see Haider and Kjellberg in this volume). The opportunity to advance the hardware of large-scale research facilities, however, is constrained by the trade-off between stability and risk. The use of untested, experimental technologies and materials comes with considerable uncertainty about their performance, cost, and longevity, which, given the long-term commitment of large sums of money, carries a risk. Furthermore, new facilities need to balance innovation and continuity: the opportunity to build for new research questions is rightly constrained by the ambition to provide continuity in order to advance our knowledge of current questions (see Sandell and the interview with Rheinberger in this volume).

A second opportunity for new big science is the anticipated outcome and impact, which are most clearly articulated by policymakers when justifying their investment decisions: new knowledge will advance science, but is also expected to result in spillovers in the form of innovation, growth, and the development of regions, nations, and continents (see Rekers in this volume; Valentine 2010). Similarly, the visibility of such scientific capabilities—in the shape of Nobel prizes, publications, and media coverage, for example—will further their image as science regions. However, these impacts and the creation of (economic and social) value are highly uncertain (Horlings 2012). Scientific discoveries often rely on serendipity, as Ulrike Felt and Helga Nowotny illustrate in their research on the discovery of high-temperature superconductors (1992). Moreover, the incentives for the private sector to take part in this are constrained by a lack of established institutional frameworks for intellectual property rights, technology transfer, and innovation beyond individual contracts (see Maunsbach and Wennersten in this volume). The institutional change that is emerging in this area (see the interview with Sotarauta in this volume), where the legal framework on an EU level is negotiated in tandem with building bigger and better machines, will be a major concern in the coming decade.

A third opportunity offered by new big science is the concentration of resources and greater levels of collaboration that are required across both national and disciplinary boundaries. Research infrastructure roadmaps such as ESFRI have been developed to coordinate and prioritize investment, so science is firmly on the agenda of policymakers at the regional and national scales as well as the supranational. The visibility of large-scale infrastructure also attracts talent and has the potential to feed into general scientific literacy; similarly, it can serve to strengthen the influence of science in society, in policy, and in public debate, and the ways in which facilities tackle the question of sustainability, for example, could be one such opportunity (see Kaijser in this volume). The concentration of resources is constrained by the overall resources available, of course, and comes at a price—which can end up being paid by healthcare and education. New facilities take up a large share of budgets, which are then spent on a single facility or project. At times of crisis and strict austerity measures, the question of what public money should be spent on is pertinent. Aside from the question of coordination, there is also stiff competition for resources: between science and other areas, but also between scientific communities, where some call for these new facilities and others are indifferent. A concentration of resources in new big science often means that fewer resources are available for so-called small science (Petsko 2009). The question of who should have the power to set such priorities, of how science and its outcomes should be valued, remains (see the interview with Asdal in this volume; Vermeulen et al. 2010). Policymakers and funding bodies are likely to have a different notion of what is valuable (the demand side) than scientific communities do (the supply side). Concerns about science's dependence on politics, and the loss of scientific autonomy as a result, are long-standing (Weinberg 1961; De Solla Price 1963), which Vermeulen et al. (2010, 421) summarize as 'the dominance of science administrators over practitioners, the tendency to view funding increases as a panacea for solving scientific problems, and progressively blurry lines between scientific and popular writing in order to woo public support for big research projects'.

Contributions to this anthology

The particular strength of this anthology lies in its breadth. All the authors draw on theoretical frameworks, methodologies, and vocabularies from their own disciplinary traditions, yet speak to the common themes of our project: the opportunities and constraints associated with the newness of new big science.

In the first essay Catherine Westfall explores the origins of the ESS in comparison to several US national laboratories from the point of view of an institutional historian. In particular, she focuses on how user communities formulate their advocacy for better tools and how resources are mustered to build the resulting new facilities. Her underlying question is the extent to which geographic locale shapes nationally and internationally funded facilities.

Josephine V. Rekers approaches the ESS and MAX IV from the perspective of human geography to ask 'how close is close enough' for the interaction between research facilities and other societal actors such as universities and industry. Using a matrix of different kinds of proximities, she teases out the different regional stakeholders' expectations and their strategies for closeness in order to make the facilities matter in terms of regional development, scientific practice, and knowledge transfer. As she argues, it is amply evident that geographical proximity is far from enough.

Sustainability is one of the buzzwords in the environmental debate, and Anna Kaijser takes on the challenge of exploring how the requirement that all such facilities be sustainable is being handled by the ESS and MAX IV in their environmental policies, and put into practice in their planning and construction. She also investigates how local urban planners and environmental organizations are responding to the ways sustainability is made to work at these facilities. She identifies three central areas of concern: energy use, the safe handling of radiation and toxic materials, and land use.

In Kerstin Sandell's essay, the focus is the instruments that are going to be used for future experiments. Sandell uses Hans-Jörg Rheinberger's concept of experimental systems to investigate how the instrument scientists who are central to the design and realization of the instruments strive to keep open the possibilities for new, as yet unimagined, experiments. At the same time, however, instruments have to be sufficiently stable and reliable to cater to existing user communities and more routine types of experiment.

One of the challenges facing both the ESS and MAX IV is the handling, protection, and processing of data. Yet a definition of what constitutes (valuable) data, now and in the future, remains elusive. In their essay, Jutta Haider and Sara Kjellberg ask the question 'When are data?' They explore research data management using documents and interviews with key figures at the ESS and MAX IV, and suggest a processual view of data. They explore the difficulties this poses for capturing data in policies and regulations, quite apart from the issue of temporality and usefulness in relation to current demands for data storage for the future.

Related to this growing concern about data storage and protection, Ulf Maunsbach and Ulrika Wennersten confront the fairly surprising insight that data as such cannot be protected by intellectual property law. They explore whether scientific data collected in a database can be protected by copyright or the *sui generis* protection of databases. They point out that contracts could offer stronger data protection, and that unprotected databases might benefit from stronger protection than databases protected by copyright or the *sui generis* right.

In addition to the essays by the participants in the project, we present three interviews with distinguished scholars who participated in the seminars at the Pufendorf Institute. In the interview with Hans-Jörg Rheinberger of the Max Planck Institute for the History of Science, we explore in greater depth the concept of experimental systems. With Kristin Asdal of Oslo University we discuss the theoretical concept of valuation and how best to use documents to trace it. Finally, with Markku Sotarauta of the University of Tampere we consider the institutions that provide stability in scientific fields, and the entrepreneurship needed for institutional change.

Looking ahead

What then, in all this, of our own research environment, and more particularly the practice of studying a case in real time and working across disciplinary boundaries? As we come to the end of this short but intensive research project, we see several paths forward.

What became clear early on is that our research environment in Lund, as elsewhere, relies on a certain open-mindedness and patience in order to achieve the desired degree of learning through interaction. This is most obvious in relation to our object of study: large-scale, complex research facilities in the making. It took time for us to grasp fully what these facilities are for, what kind of science they are doing, and what possibilities, constraints, and risks this entails; how their physical and organizational structures are designed and implemented; which communities have stakes in launching these facilities, what their interests are, and their ways of engaging. It was essential to gain at least a basic level of understanding about these issues in order to be able to start our own research. Our proximity to the facilities—and the ready willingness of ESS and MAX IV staff to discuss their work—offered us unique opportunities to observe and engage with new big science. This was a crucial factor in the success of our project, reliant as it was on people's generosity with their time and insights.

It also took time to learn how best to communicate across the disciplinary boundaries within our own research group. The challenges of working in an interdisciplinary environment are the lack of a common vocabulary, literature, and theoretical framework. Establishing various ways of interacting proved essential, and took the form of presenting and discussing one another's projects, from initial thoughts through the first drafts of essays and beyond, into the design of future research projects. Furthermore, reading literature from one another's fields, and discussing it with openness, curiosity, and a great many questions, allowed us to discover and rediscover alternative perspectives from which to view our own work. In a similar vein, we invited prominent scholars who have a relevant theoretical approach—though not necessarily themselves doing big science—to join us for open discussions in order that we could learn from their approach (looking at experimental systems, valuation, and institutional change) and perhaps inspire in our turn. One key contribution made by this project thus lies in its breadth and the collaborations it has generated, primarily at the Pufendorf Institute for Advanced Studies, but also at the second Nordic Science and Technology Studies (STS) conference in Copenhagen in May 2015, where we organized sessions as a group.

At a point in history with growing demands for rapid scholarly output, time is a scarce commodity. Current conditions in academe do not encourage one to plunge into an interdisciplinary project such as this, studying phenomena that are unfamiliar in our home fields, and whose outcomes are less than predictable. The Pufendorf Institute has offered a unique, generous, and open space in which to learn and explore. A space that might just pose more questions than it answers, and thus, in the words of Rheinberger, functions as a question-generating machine in a experimental system comprising the social sciences, humanities, and law. We will present some of these questions here.

The study of large-scale facilities that are in the process of being built, as we have done in this anthology, can be especially challenging, but we would argue it turned out to be one of our strengths. It is true of both Lund facilities in almost every respect that expectations abound and are in constant production: expectations concerning the science that will be carried out at the facilities, its application, and contribution to facing societal challenges such as health and sustainability; the role of scientific infrastructure in regional development; and so on. At the same time, people are understandably apprehensive. Where do these expectations come from? Which stakeholders are able to help meet them? Will the facility be able to deliver, will it be worth the investment? Who will evaluate whether expectations have been met, and how? Based on our research thus far, we would argue that we can make a useful contribution that would benefit from being followed up over a sustained period of time during the realization of these facilities—at the juncture where expectation meets reality. More often, studies are done when facilities are up and running, and evaluations are done in retrospect, when stakeholders, indicators, and mechanisms can be clearly identified and neatly delineated. In contrast, what could be captured by *in situ* research are the deliberations, initiatives, mistakes, and successes that are forgotten almost as soon as they are settled, as new issues emerge along the way.

We would even go so far as to contend that there are some specific temporalities associated with new big science. Arguably, new big science is the kind of big science that currently is in the making. If this were true, new big science would by definition always be in design, in construction. This in-the-making allows a constant engagement in the future, where promises wait for later realization, promises of things bigger and better, of knowledge, and of technology as a solution. As an effect of this, the realization of big science constantly shapes and shifts its promises. We think that this ever-changing zone, where things are transformed beyond recognition or consigned to oblivion, and only at times into what was promised, would be most interesting to chart. Another aspect of the specific temporality of big science is the dislocation between a fast-changing world, with its new ideas, discoveries, and inventions, and the sheer time it takes to realize these facilities—and, of course, the length of time they are supposed to be operational.

One of the challenges with such *in situ* research is how best to identify the implications for policy or how things could be done more effectively, especially when the stakeholders in new big science are so numerous, varied, and dispersed. One of our important findings suggests that a dialogue between the different perspectives has much to offer in this regard. The overlap in areas of interest within our particular project turned out to be much stronger than we would first have expected, even though our vocabulary might be different. Furthermore, our fieldwork demonstrates the relevance of introducing perspectives from the social sciences, humanities, and law into the dialogue with researchers from very different fields who plan to use the ESS and MAX IV. This suggests there is value in expanding interdisciplinary projects to muster perspectives from an even greater range of fields, and across 'wet' and 'dry' faculties. Big science is attracting new users in the hard sciences, but also involves audiences in politics and society at large, and that demands knowledge and literacies on the part of a much wider range of stakeholders than before. While this volume marks the conclusion of our project, we would hope that in future it will also serve as a starting point for those who are viewing new big science with fresh eyes.

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2. From the ground up? Launching the ESS, Fermilab, JLab, and the APS

Catherine Westfall

In many ways, large scientific projects are not products of a specific locale. Since research is a shared international activity, even tools that are nominally 'national' (such as those built at the federally funded US national laboratories) are a resource, at least theoretically, for the entire worldwide scientific community, as are internationally funded facilities. In any event, given the widespread geographical reach of expertise and talent, a facility cannot be a success unless it boasts an international community of users. In line with this far-flung constituency, large-scale facilities are also commonly designed, built, advocated, and managed by staff members who were born far from the facility's site.

And yet scientific projects are also in some ways rooted in a defined geographic locale. They grow in the backyard of some who live close by—would-be users who will likely benefit from easy access and those with businesses or homes in close geographical proximity who will feel the impact, both positive and negative, of having a newcomer to their neighbourhood. In addition, the considerable expense of such projects is shouldered by certain citizens within a specific political context. Given this geographic rootedness, does it make sense to view these facilities also as non-international products—that is, are they in some way shaped by that which is local, whether people, communities, or landscape, in a specific geographic locale? And how do nationally funded projects compare in this respect with those that are internationally funded? On the face of it, we might think that internationally funded projects are shaped less by their geographical location due to the greater importance of international financial bonds. But is this true?

There would be many ways to examine this issue, and I believe studying the connection between geographic roots and the development of big science facilities would ideally be addressed by an analysis that interweaves multiple studies of numerous, diverse cases using a variety of methodologies. Indeed, a better understanding of such a connection from the multiple perspectives made possible by such thorough analysis would likely, in my opinion, lead to a more complete picture of the relationships linking various aspects of place with the process of designing and using large equipment.

This essay is meant as one contribution to this more comprehensive discussion. In the hope of shedding light on how geographic locale shapes nationally funded and internationally funded facilities, I will consider how those who launched big science projects in the US and Europe gathered the resources to proceed from initial idea to the planning stage, then to an accepted proposal, and then to obtaining funding for a large research facility. In the process I will focus in particular on the extent to which a particular facility was shaped local people, communities, and landscape.

My discussion will highlight facilities built at three federally funded US national laboratories. They are the high-energy physics laboratory created in the late 1960s, the Fermi National Accelerator Laboratory (Fermilab); the nuclear physics laboratory built in the 1980s, the Thomas Jefferson National Accelerator Facility (JLab); and the accelerator built for materials and biological science in the 1990s at the Argonne National Laboratory, the Advanced Photon Source (APS). For the sake of comparison, my discussion will also consider the development to date of the European Spallation Source (ESS), a project being built in Lund, Sweden, for materials and biological science in 2015.[5] Along the way I will focus in

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[5] In what follows, for Fermilab, see Hoddeson et al. 2008; for JLab, see Westfall 2002; for Argonne's APS, see Westfall 2012; for the ESS, Kaiserfeld 2013 and Hallonsten 2015. Note that Hallonsten's essay provides a good critique of the risks to Swedish research as a whole due to the heavy Swedish investment in the ESS.

particular on the similarities between the US laboratories—built at different times and for different purposes—that contrast with the ESS. I will end by reflecting on what these cases suggest about local factors and the formation of international facilities, and suggest potential fruitful avenues for further investigation.

I bring to this essay the perspective of a specialist in the history of the US national laboratories who has only recently started to learn about the formation of the ESS based on writings and interviews.[6] I make no claim that this is a thorough or complete analysis. My discussion is necessarily limited by the information I have at hand and what I understand. All four of the facilities I consider are accelerators, even though there are other types of large scientific facilities, such as space telescopes. In addition, all my examples of federally funded large facilities come from the US, all of these facilities were funded by the Atomic Energy Commission (AEC) or its successor agency the Department of Energy (DOE) (the source of support for most but not all large US equipment since the Second World War), and I consider only three cases (although I have tried to pick examples that are diverse and yet representative). And for comparison I have considered only one facility with international funding. My aim here is to assess how local factors shaped accelerators in the US and the ESS in a way that is reflective, exploratory, and suggestive; this is not the culmination of a rigorous comparison, but rather, I hope, the starting point for future discussion.

From desire to ideas

A look at the ESS, Fermilab, JLab, and the APS suggests that ideas for accelerator projects tend to germinate in similar ways, and that efforts are not strongly affected by people, communities, or landscape in one specific locale at that stage. In all these cases, a group of scientists over a wide

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[6] My own interest is in the historical development of large-scale devices built at large laboratories, how these and other projects shaped the development of such laboratories, and how these laboratories, in turn, have shaped the research enterprise. See, for example, Crease 1999; Heilbron & Seidel 1989; Holl 1997; Hermann et al. 1987; Krige 1990, 1996; Westwick 2003.

geographic area (Europe, the US, and in some cases Japan) undertook a series of investigations using a large facility (in materials science in the case of the ESS and APS, in the exploration of fundamental particles in the case of Fermilab, and nuclear structure in the case of JLab). These investigations led them to devise tools that would be more appropriate to their research. In the case of the APS this meant developing a synchrotron radiation source capable of imaging atoms and compounds. In the case of JLab, this meant obtaining more precise measurements of the nucleus using a 100 per cent duty factor continuous-wave electron accelerator. In the case of the ESS, it meant developing a more intense spallation neutron source to better explore a wide variety of substances. And in the case of Fermilab, it meant developing a higher energy proton accelerator to explore smaller distances for the sake of discovering rare particles.

In each case, the desire for a more capable tool in turn prompted a discussion aimed at defining what that facility should be. Nascent ideas that would result in the ESS, Fermilab, JLab, and the APS were part of these discussions. But these ideas did not develop in a vacuum. In the case of the ESS, those with reactor and accelerator experience discussed various options for an accelerator-based spallation source. Similarly, in the case of Fermilab, JLab, and the APS, there was discussion of other types of accelerator designs; in all three cases, in fact, some suggested accelerator designs that were somewhat less capable but more readily built and/or less expensive.

Since the devices under consideration would be large and expensive, it was clear that not every idea could be pursued. In each case, specific groups of scientists rallied around ideas for a particular facility, and discussion eventually winnowed choices down to a small number of designs that the group as a whole considered the most appealing. To actually set in motion the process of obtaining a specific facility, the scientists advocating each project had to find a way to advance their ideas to the next step: developing a detailed plan that could then be assessed along with the other options to see which should be built. In addition to devising the facility itself, they needed to figure out how to get the necessary resources—expertise, approval, money—so that the desired project could come to life.

From planning to proposals

The ideas for the ESS, Fermilab, JLab, and the APS germinated in a similar way, and in all four cases a planning stage evolved into a formal proposal for building the project. The planning stage sometimes had a local focus—that is, a particular existing facility that had people associated with it who wanted to host the new project. But in general, planning included scientists from many locations. In addition, any tendency towards a local focus was attenuated at this stage, because the planning expanded to include officials from government and other institutions, since such projects require the allocation of public resources—in particular, funding.

Despite these similarities, the planning process for the US projects differed in significant ways from the process for the ESS. In the case of the US projects, planners knew they would need to get funding from the AEC or its successor the DOE, the sole funding source for large accelerator projects. In addition, they knew that that the funding process had well-defined requirements, which they followed. First, they ensured that they had support for their design from those who favoured the development of that particular facility. They also convinced committees of elite scientists convened by their federal sponsor that their project was worthy in comparison to other types of projects vying for funding within their funding category. In addition, they obtained the support of officials from various elements of the funding bureaucracy and within Congress to optimize the chance that legislation would be signed into law.[7] In the course of fulfilling these requirements, proposals emerged for the US projects.

When the ESS Council (the first group to promote the ESS) formed in mid–1993, it faced a very different situation than the one that greeted the planners of the US projects. In a very general sense, the ESS proposal germinated from the tumultuous political changes of the late 1980s and early 1990s, which included the fall of communist regimes, German reunification, and the first steps in forming the European Union with the

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[7] The difficulties encountered by planners for the Advanced Light Source show what could happen if those planning a project did not meet all these requirements (see Westfall 2008).

Maastricht Treaty. At a time of growing optimism about what Europeans could profitably produce in concert, the idea arose that European scientists could together create an accelerator with exceptional capabilities that was too large in scope and complexity for one nation to build. However, since there was no international funding agency, the resulting international group could not appeal to a single funding source, nor did they have a defined process to follow in order to obtain the funding they needed. Instead, initial efforts focused on stimulating interest in the project. Indeed, the ESS Council itself grew out of efforts by an elite international group of scientists and policy makers to develop international collaboration for large-scale projects. Once formed, the ESS Council further promoted such efforts, including to the OECD's Megascience Forum. This organization's Working Group on Neutron Sources issued a recommendation to build advanced concept neutron spallation sources in Europe, Japan, and the US, with the idea that this geographical spread would serve the entire community of international users of such facilities. This plan was, in turn, endorsed by the OECD's ministerial conference in Paris in 1999.

By the time of the 1999 endorsement, the ESS Council had for three years had a published feasibility report for a high-power neutron spallation source in place. As European scientists struggled to find a way to proceed to get funding for the project, neutron spallation source projects elsewhere got the green light: on the heels of the 1999 endorsement, the US DOE announced it would build the Spallation Neutron Source at Oak Ridge National Laboratory in Tennessee, and about a year later the Japanese government followed suit, proclaiming it would build an equivalent facility, the Japanese Spallation Neutron Source, at the Japan Proton Accelerator Research Complex in Tokai. These developments spurred efforts to proceed from more general planning to the proposal stage. By mid–2000s, proposals were being drafted.

An accepted proposal emerges

The planning for the ESS, Fermilab, JLab, and the APS moved on to the proposal stage. In each case, multiple proposals were drafted, and ultimately one proposal was accepted as the basis for soliciting construction funds.

By the time the accepted proposal emerged, each project was led by a particular group of people who wanted to build a specific facility at a chosen location. To what extent did local forces—that is, people, communities, or landscape in each geographic locale—shape the projects at this formative stage?

When answering this question, it is important to realize that, in the US cases, the arrangements of the original proposers of the accepted proposal were considerably scrambled as the projects proceeded, complicating the prospect of identifying local factors. In the case of Fermilab, the original accepted proposal, which was expensive but avoided risk, came from researchers from the laboratory built by Ernest Lawrence in the 1930s in Berkeley, California. Since the Berkeley laboratory site was too small to accommodate the new project, the Berkeley proposers suggested two sites a short distance from their laboratory.

It came as no surprise that elite reviewers recommended design funding for a proposal from Berkeley, with its long and fine reputation for accelerator building, at the expense of other proposals. However, to the surprise of the Berkeley proposers, their proposal subsequently failed to get the support of would-be users, who complained that the laboratory favoured internal researchers. Although this had been an acceptable (if annoying) practice in the past when several similar accelerators had been available nationally, times had changed by the 1960s. Realizing that because of its size and expense only one such accelerator would be built in the US, potential users lobbied for a 'Truly National Laboratory' that would be accessible to the entire national community of researchers based on merit.[8] As a result of this pressure the AEC mounted a site competition (the first of its kind) to find the best location for such a laboratory. At this stage, members of Congress and local citizen groups from the states and regions where the proposed sites were located became involved in advocating or opposing the siting. Eventually, the Commissioners chose a site near Chicago despite the fierce opposition of various local groups, such as those who would be displaced when the new laboratory was built. The project

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[8] For details of the advocacy for outside user access to the US national laboratories, see Hoddeson et al. 2008, ch. 3 & 4.

did have the political support of the Illinois congressional delegation, which began lobbying for construction funding through the legislative process in Washington as part of the national political give and take of the time.[9] In the meantime, most of the Berkeley designers declined to move there to build the proposed proton synchrotron. As a result, a new team was assembled in Illinois under the direction of Robert Wilson, who produced a design that was inexpensive but risky. Even though the Berkeley proposal was used to secure design funding for the project, Wilson's design was responsive to demands to cut costs, and thus it was the one used to solicit construction funding for Fermilab.

In the case of JLab, the federal sponsor (by then the DOE) on the recommendation of elite reviewers chose the proposal by a small team from the University of Virginia for a pulsed stretcher ring design based on conventional technology. When the team struggled to obtain the political support needed for funding, the DOE recruited a new director, Hermann Grunder. In the meantime, in line with the precedent set with Fermilab, a site competition was held. After an assessment process, Newport News, Virginia, was selected as the location of the new project rather than the University of Virginia site favoured by the design team. The University of Virginia team continued to help with the project, but Grunder radically changed the accelerator's design to increase its capability by employing state-of-the-art (and risky) superconducting radio frequency components. This was the design that was used to solicit funding, a task made easier by strong support from the Virginia congressional delegation.

In the case of the APS, the original idea for the synchrotron radiation source arose in meetings intended to rally flagging user support for another, less powerful radiation source. Although enthusiasm rose for the device

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[9] Many physicists and others believe that the Chicago site was chosen as part of a political deal made by Everett Dirksen, who got the site in exchange for signing up to civil rights legislation. As noted in 'The Site Contest for Fermilab' (Westfall 1989), I judge that there was no such quid pro quo, and instead the decision was a response to concerns about funding such an expensive project, given the California congressional delegation's lack of enthusiasm for the project and the pressures from physicists worried about access to the one-of-a-kind accelerator. I also agree with Daniel Goldberg that the choice of the Chicago site inaugurated what was then 'a new politics of science', in which accelerator projects were expensive enough to feature in national political negotiations (1999, 268).

that later became the APS—and although the design for the device had its advocates—the idea initially was not championed by a particular existing laboratory or by a group that wanted to build the device at a new laboratory. After the idea repeatedly received high priority from the DOE's elite reviewers, several laboratories did float preliminary proposals to build the device. However, only one laboratory—Argonne National Laboratory—submitted a formal proposal to build the synchrotron radiation source, and no proposal competition followed.

Although Argonne (in contrast to the laboratories that had submitted preliminary proposals) had no previous experience in building synchrotron radiation sources, its bid was considerably strengthened by a deal struck by a high-level DOE official, Alvin Trivelpiece. In a meeting with directors of several laboratories, including Argonne's director Alan Schriesheim, it was agreed that each laboratory would be allowed to build one project apiece and that the other laboratory directors would not compete for that project. This 'Trivelpiece Plan' was provisional; Trivelpiece could use his influence to optimize the chance that proposals would be funded through the legislative process, but he lacked the authority to grant funding. Nevertheless, his plan ultimately held, with DOE officials being the champions of funding legislation for the Argonne proposal. No competition arose and therefore their efforts were neither advanced nor opposed by local citizen groups or the Illinois Congressional delegation.

The fact that the arrangements of the original proposers were considerably changed in the US cases does not change the fact that in the end each laboratory grew from a particular location. When looking for local factors that shaped each project at the proposal stage, we can see that in the two cases in which there was a proposal competition (Fermilab and JLab), politicians as well as some local community members lobbied to have the project built nearby, convinced that the projects offered advantages (particularly the prospect of jobs) for their area. In addition to the help from the Virginia Congressional delegation, JLab also got help from the City of Newport News. These local politicians raised funding to provide accommodation for users, a step the JLab builders appreciated, since federal rules forbade such funding. In both cases this local support improved funding prospects and thereby the respective site's chances in the site competition (although in the Fermilab case there was also local opposition to the project).

In the Fermilab case, Wilson made much of the setting for the Illinois laboratory. Revealing real rhetorical flair, he used the prairie landscape—and the fact that he was raised in Frontier, Wyoming—to pique interest in a site many found unappealing. By evoking images of a frontier where heroic efforts would be undertaken, he was able to recruit the experts who were desperately needed when the Berkeley designers baled out of the project. Although this shows the success of his rhetoric, the effect of the actual landscape is questionable since the site actually lies in the suburbs of Chicago. When explaining why they selected the site, in fact, the AEC stressed its proximity to Chicago as a key advantage, since O'Hare airport made the facility easily accessible, in line with pressures to accommodate the entire national community of users.

In any event, if we look at the three US cases, we can see that that each project literally grew from a particular patch of ground within a certain community. It is less clear how much local communities were deeply or continuously involved in influencing decision-making for these projects. Instead, the key decisions about what device to build and where to build it were made, in each case, by the DOE in consultation with its elite reviewers. It is also the case that none of the US cases grew from the efforts of people with ties to the area. The initial efforts for Fermilab came from Berkeley. Wilson was from Wyoming, had never worked in Illinois, and he used frontier imagery to recruit an international cadre of experts. Schriesheim was not from Illinois either, and Grunder was Swiss-born. And as with Fermilab, so the APS and JLab efforts were successful due to experts drawn from all over the world.

As in the planning stage, those promoting the ESS faced a different situation from that in the US when they went on to an accepted proposal to be used as the basis for soliciting construction funds. Again, efforts were complicated by the fact that the ESS proposers were not appealing to a single funding source, nor did they have a defined process to follow in order to get international funding.

When assessing the extent to which local forces—the people, communities, or landscape of a specific locale—shaped the ESS at this formative stage, it is important to remember that the project grew from international efforts based on the conviction that the project was too large and complex to be built by a single European nation. When the ESS proposals began to be drafted in earnest around 2000, similar projects had already been given the green light in the US and Japan. These developments aided the arguments made by the group of international ESS advocates that scientists and policy makers in Europe needed to band together to gather the necessary resources (including funding) so that the long-desired facility could come to life. At the same time, those advocating the project faced the challenge of getting European nations to come together in a collaborative endeavour that sometimes conflicted with the priorities of a more limited national scope. As Olof Hallonsten explained, ‘Every European nation has a somewhat ambivalent attitude towards collaboration, as they both realize its necessity for preserving unity, avoiding conflict, and building critical mass to achieve global competitiveness, and seek to preserve national sovereignty, and national competitiveness’ (2012, 96).

In the midst of these pressures, design ideas were updated and various detailed proposals took shape. In 2002 five proposals were presented at the users’ meeting of the European Neutron Scattering Association. Two proposals came from Germany, two from the UK, and one came from the ESS Scandinavian Consortium, which had the support of regional and local governments, most large universities, numerous research institutes, and users groups in Sweden, Denmark, and Norway. To the surprise of some, given earlier strong interest, there was resistance at the meeting to the ESS plans because leading neutron researchers were worried that their governments’ support for the ESS would undermine funding prospects for an upgrade to Institut Laue-Langevin, an internationally funded reactor for neutron research located in Grenoble, France. At the meeting, the teams from Germany and the UK pulled their proposals, apparently deciding given this opposition to prioritize projects being built in their respective countries.

Even though some thought the proposed project was now dead in the water, the ESS Scandinavian Consortium continued with a handful of people to work on further improving their proposal. In the next few years new competitors for the project emerged: Debrecen in Hungary and

Bilbao in Spain. The ESS Scandinavian effort was not funded by the Swedish government, but the ESS Scandinavian Initiative did get some money from the Swedish Research Council, Lund University, and local and regional officials and governments. In 2004, the effort had gained enough attention in Sweden for the government to appoint Allan Larsson, chairman of the Board of Lund University, who had served as Swedish finance minister and as a high-level official in the EU, to investigate the possibility of siting the ESS in Lund. The following year Larsson delivered a report that recommended that the Swedish government formally endorse the Initiative and actively work to locate the ESS in Lund, with the proviso that Sweden would shoulder a portion of the costs in line with the socio-economic benefits to the nation.

In 2007 the Swedish government formally announced that it endorsed the ESS Scandinavian Initiative. This announcement also declared that Sweden would actively work to have the project located in Lund and appointed Larsson as Sweden's chief negotiator to accomplish it. Thanks to contacts and experience gained from his high-level positions in the Swedish government and the EU, Larsson wielded considerable influence, both in Sweden and in Brussels. In an interview on 7 May 2015, Larsson remembered deciding to set about the task in three rounds. In the first round he made trips to about twenty countries to visit national officials at all levels—from state secretaries to civil servants—responsible for research. Since he did not have a scientific background (his training was in journalism), he took two Lund University neutron scientists with him. Based on the strategy of taking steps too small to elicit a flat refusal, during these visits they described the device and explained that the Swedish government planned to provide part of the funding to build it in Lund. They then asked what decision-making process for obtaining further funding would work best for each government. For the next round, Larsson recruited the eminent British neutron physicist, Colin Carlile, who had just finished a stint heading the Institut Laue-Langevin. Capitalizing on his scientific contacts, Carlile visited European laboratories to ask scientists what they wanted to contribute. The original idea for the final round was to do what was necessary to fund the facility and site it in Lund. As Larsson recalled, the campaign, although time-consuming, was working quite well up to 2008. At that time the EU's European Strategy Forum for Research Infrastructures formed an international panel of expert reviewers to visit each site and report their impressions to research ministers from interested European countries.

In the meantime, the Swedish government continued its support. The secretariat that Larsson led at Lund University began to receive money from the Swedish government, channelled through the Swedish Research Council and pledged to cover 30 per cent of the ESS construction costs. This pledge of support did prompt concern in Lund: some worried that the ESS would undermine funding prospects for a long-standing Lund University project, the smaller but internationally known synchrotron radiation source, MAX IV, which was funded solely by the Swedish government. By 2009 these concerns were allayed when Lund University, the Swedish National Agency for Innovation Systems, the Swedish Research Council, and a regional government authority, the Skåne Regional Council, agreed to jointly fund MAX IV.

However, as Larsson recalled, by this time a substantial obstacle had emerged: the financial collapse in late 2008, which made it infeasible for research ministers to successfully request funding from their respective national finance ministers. As Larsson noted, at this stage—as before and after—the most important consideration was keeping the project alive. Therefore, at his insistence, plans for the third round were changed: research ministers were asked to make a decision about siting, but not funding, with the understanding that the winning site would provide an updated, site-specific budget at a later (and presumably more propitious) date. In 2009, a group of European research ministers indeed chose the Lund site.

It is striking the extent to which, in contrast to the US projects, the ESS was driven by local forces. It is true that the idea for the project arose from pan-European meetings and deliberations, and funding support for the fledging project had to be obtained from countries throughout Europe. Nonetheless, during the proposal stage the successful effort to launch the ESS was centred in the Lund area. When the proposed project seemed to have died after the 2002 meeting in Bonn, funding from the Swedish Research Council was augmented with money from Lund University and local and regional government. When the Swedish government got involved in 2004, it brought in Larsson, a Lund University official who was an alumni of the university. Larsson's subsequent efforts to secure the project for Lund and to solicit national and international construction funding for the project continued to draw financial support from Lund University and regional government.

In some of the US cases, communities joined the effort to convince the DOE and its elite reviewers to locate a project in their neighbourhood—and in the JLab case, Newport News did sweeten the deal by providing money for user accommodation. However, in all the US cases, such local efforts were influential only in a minor and temporary way: US projects are sustained or killed based on the decisions made in Washington—at times with regional and state politicians leading the charge—in consultation with elite reviewers. By contrast, in the case of the ESS, efforts in and around Lund sustained the project so that it survived and emerged from the proposal stage with a future. As was the case for US projects, the ESS grew from a particular patch of ground within a certain community. But in the ESS case, the local community played a crucial role in bringing the project to life. In other words, in a very literal sense, the successful the ESS proposal—and the project it produced—grew from the Lund landscape.

Obtaining funding

During the construction phase, big science projects in the US invariably suffer from the reality that the construction of such complicated facilities must proceed according to a detailed multi-year schedule, but construction funding comes from the federal government in allocations that have to be approved by the legislature on a yearly basis. Fermilab, JLab, and the APS—like every US project I have studied—struggled to compensate for funding delays that complicated (but did not doom) their launches. At the same time, the funding source (the AEC or its successor agency the DOE) as well as the funding process was clearly defined, and while the cancellation of the multi-billion-dollar Superconducting Super Collider for high-energy physics showed that construction funding could be halted once started, as a general rule (both before and after the ill-fated SSC project) construction funding signals the federal commitment to completing a project. Indeed, Fermilab, JLab, and the APS all proceeded from initial funding to completion.

Founding the ESS has been a decidedly more precarious process. Even the first stage—proceeding from an accepted proposal stage to initial funding—was far more time-consuming for the ESS than for the US projects. Whereas the bilateral and multilateral negotiations needed to yield international agreements for the ESS's €1.8 billion construction costs would take nine years, proceeding from an accepted proposal to initial construction funding took one year, four years, and three years for Fermilab, JLab, and the APS respectively.

Although the Swedish government and communities in and around Lund continued to be deeply engaged in the project, keeping the project afloat while international funding agreements solidified the required international funding called for a new organization to manage and coordinate the growing effort. The Danish government agreed to help, and by 2011 planning efforts for the ESS moved from Lund University to a Lund-based Swedish–Danish company with a steering committee with representatives from seventeen European nations. As the 2012 Conceptual Design Report noted, this was 'a shareholding company under Swedish law with Sweden holding approximately 75% of the shares and Denmark holding the remaining 25%.' The company was ultimately successful in obtaining the necessary international funding commitments. In 2014, eleven countries, in addition to Sweden and Denmark, made binding pledges to fund the project. The project that had taken root in Lund had grown into a project with wide international support.

Reflections

When asked whether the ESS was in any sense a Swedish project, Larsson insisted that the project was thoroughly European, not Swedish. He argued, persuasively as usual, that after all, the ESS had started when European scientists formed the ESS Council when the zeitgeist was celebrating European collaboration, and that the project subsequently developed in the midst of European discussion and deliberations. He emphasized that his effort to bring the ESS to Lund was successful, at least in part, because he recruited Colin Carlile and other non-Swedes to help with his Lund proposal. When I pointed out that Swedish—and in particular Lund—resources had nurtured the project, he responded that such support was needed because of the time it necessarily took to negotiate international funding. The view that the ESS is thoroughly European, yet at the same time specifically Swedish and Lund-based, is nothing new. As Mats Benner noted, the ESS has long been presented 'as a boundary object, between nations and regions, manifesting European collaboration', all the while 'manifesting the location (Lund) as a hotspot and hothouse in the globalized, knowledge-based economy' (2012, 169).

As I grappled with the notion of a facility that is essentially international and yet distinctly local, I began to think about how geographic locators can become necessary rhetorical and conceptualizing tools in the successful launch of large facilities, and how an increase of facility scale can trigger the necessity. When Fermilab was being set up, it needed to be thought of as a 'Truly National Laboratory', reasonably accessible to the entire national community of users, so that the national funding agency would support it. And indeed, Fermilab paved the way for subsequent large US facilities by instituting policies to prevent inside users from getting preferential treatment in the allotment of beam time—the days of national funding for facilities for local or regional users were over. Similarly, the ESS needed to be thought of as a *European* spallation source that was too large and complex to be a national facility, so that Larsson and others could successfully complete the difficult and protracted negotiations required to get pan-European funding in place. In other words, it is hard to see how the ESS could have come to life without being conceptualized as a European project.

And yet, ironically, the length of time it took to work through the international negotiations to get an accepted proposal to be built at a specific place with international funding meant that the ESS is truly rooted in a particular patch of ground in a certain community in a way that none of the US projects are. This is because the fledgling ESS project had to rely heavily not only on support from Sweden, but also on support from Lund University and surrounding areas. Thus, the ESS is rooted in the local environment with neighbours that are engaged in decision-making in ways no local community is involved in federally sponsored US laboratories. For example, it is hard to imagine local US environmental groups being involved in the way local citizen groups have been in the deliberations about the ESS site, as described by Anna Kaijser. US laboratories are fenced sites with signs designating the land as federally owed and controlled. And even in those cases when congressional delegations or citizen groups from a particular state or region get involved in advocating or opposing a siting decision, siting (and all other) decisions are made in Washington in line with national regulations as part of the national political dialogue. As a result, opportunities for local input are very limited.

My study of the US national laboratories taught me that despite the close connection to the US government, these laboratories are not really just truly national laboratories—they serve and are enriched by the contributions from an international community. And as I have discovered while comparing the ESS with Fermilab, JLab, and the APS, the ESS is really not just a European laboratory; it also serves and is enriched by its local community. In fact, this service and enrichment is greater for the ESS than for the US laboratories.

My new-found knowledge about the ESS makes me wonder if all international laboratories are served and enriched more by local resources than are national laboratories. I also wonder to what extent (if any) facility scale triggers a change in the geographic locators used to conceptualize both types of laboratories. Answering these questions would require investigating how local communities interacted with other internationally funded European laboratories such as CERN and the Institut Laue-Langevin at the time they were launched. It also would be interesting to expand the geographic scope of such an investigation and compare the European cases with the Synchrotron-Light for Experimental Science and Applications in the Middle East. This would give us the opportunity to judge whether local and international pressures and an increase in scale play out differently in the Middle East than in Europe. At the same time, it would interesting to narrow the geographic scope and look at the launch of the Swedish-funded 'national' project, MAX IV, in relation both to the ESS and the US national laboratories. Did MAX IV experience the same pressures to be 'truly national' as the US projects did? And is MAX IV as closely tied to the Lund community as the ESS is? I hope that these and other questions are raised and studied so that we can learn more about how local factors shape the facilities crucial to international science.

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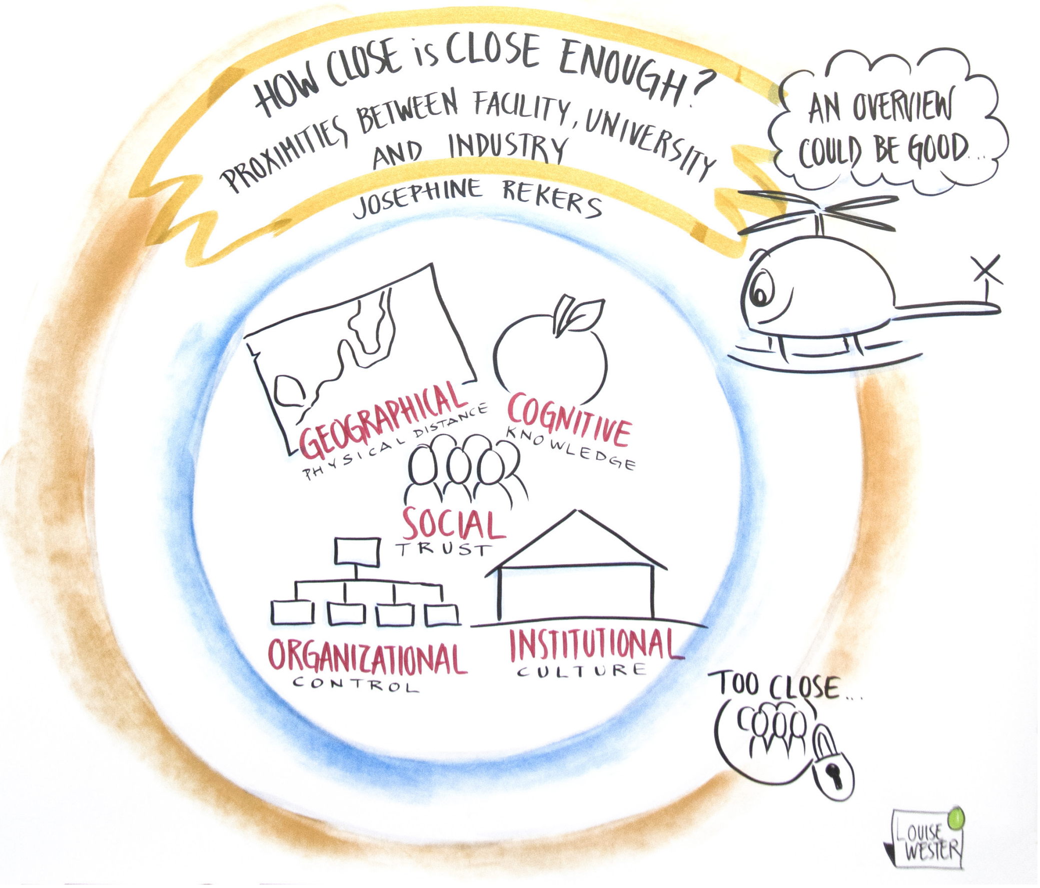
HOW CLOSE is CLOSE ENOUGH?
PROXIMITIES BETWEEN FACILITY, UNIVERSITY AND INDUSTRY
JOSEPHINE REKERS
AN OVERVIEW COULD BE GOOD...
GEOGRAPHICAL
PHYSICAL DISTANCE
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KNOWLEDGE
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ORGANIZATIONAL
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INSTITUTIONAL
CULTURE
TOO CLOSE...
LOUISE WESTER

3. How close is close enough for interaction? Proximities between facility, university, and industry

Josephine V. Rekers

Today, big science facilities attract attention from a wide range of stakeholders. Scientific users and funding bodies still comprise the core audience, but politicians, universities, industries, and the communities that host facilities are also looking at what big science means (and could mean) for them. Their voices, activities, and stakes are increasingly relevant in shaping the environment in which big science facilities are launched and operated, and they place additional expectations on facilities. Furthermore, and from a geographical perspective, new big science involves new levels of cooperation between stakeholders at various scales: facilities are often multinationally financed and governed, serving increasingly global and multidisciplinary user groups, but they are also localized in particular regional environments. Expectations are therefore likely to vary according to place and scale.

Expectations have become particularly pronounced in terms of the facilities' impact on society, which can range from their impact on urban planning and the environment, to science policy priorities and employment. In this essay, the expected societal impact that is considered in greater depth is limited to the ways in which facilities contribute to the development and diffusion of solutions to scientific and societal problems. To facilitate this process, a large number of other organizations are expected to interact with these facilities—including universities, government agencies, and industry—to explore and exploit new knowledge. Facilities are therefore to be embedded in strong research environments, not kept in isolation. Moreover, interaction is easier when organizations are in close proximity to one another, which makes the regional scale especially important to consider. The question is, then, how close is close enough, and is being geographically proximate sufficient for interaction? Interactions between facility, university, and industry are not necessarily straightforward, and relationships need to be initiated and built. Facilities are quite different from universities and industry, in terms of their technological complexity and scientific mission for example, and these differences will have to be overcome in order for fruitful knowledge exchange to take place. There are, in other words, various gaps between the facility, universities and industry. Minding these gaps will be essential if expectations are to be met, and future work will need to consider what these gaps are, how can they be spanned, and whose responsibility this is. The material presented in this essay is a step in such a direction.

Empirically, the essay uses the construction of the facilities MAX IV and the ESS to explore the expectations, opportunities, and challenges that are perceived by stakeholders in the Öresund region. The region is not the only scale at which these are formed, however. In order to place these in context, I will consider source material including policy and media reports collected through desktop research to provide a sketch of the multiplicity of expectations at various scales. I then zoom in on the regional scale to identify factors that shape the interaction between different organizations, building on the proximity framework developed in economic geography. A description of the research design follows, including desktop research and nine semi-structured interviews with experts from the university, industry, and the regional authority and facilities, followed by an account of the findings about perceived opportunities, challenges, and strategies to overcome them, broken down by the different dimensions of proximity. These suggest that while universities and firms are geographically proximate to the facilities, cognitive, social, organizational, and institutional distance will need to be overcome, the implications of which are discussed in the concluding section.

Expectations at different scales

Large-scale research facilities are increasingly financed through multinational funding arrangements, and they serve multidisciplinary user groups that collaborate in networks that often span the globe. However, facilities are also localized in particular regional environments. This section disentangles the expectations articulated at the supranational and regional scales.

At the supranational scale, investments in scientific infrastructure are motivated with reference to their contribution in advancing scientific knowledge and the development of technologies, and thereby the competitiveness of industries and nations. This was evident back in the late 1990s, when policymakers reviewed the state and potential of neutron scattering facilities in light of their 'centrality to fundamental scientific studies as well as many areas of science important to national needs' (OECD & ESF 1998, citing a statement by the American Physical Society in November 1997). They went on to elaborate on the wide range of application areas that would suffer damage if neutron scattering facilities were not enhanced soon, 'important technologies that depend upon the knowledge gained from neutron scattering studies—including the development of new polymers, superconductors and chemical catalysts and the use of neutron probes to study the stresses and impurities in materials that affect the performance and safety of structures such as bridges and aircraft—are increasingly at risk' (OECD & ESF 1998). Similar justifications can be found in more recent documents, such as the European Commission's assessment of projects on the ESFRI roadmap in 2013, which noted that research infrastructures 'bring together a wide variety of stakeholders to search for the solutions to the scientific problems being faced by society today … they play an increasingly important role in the advancement of knowledge and the development of technology to help Europe compete in an increasingly globalized economy' (EC 2013). Research infrastructures do not do this by themselves, but rather 'research infrastructures should … continue their opening to, and partnership with, industrial researchers to help address societal challenges and support EU competitiveness' (EC 2013). These overarching expectations, articulated at the supranational scale, view facilities as participants in knowledge and innovation systems, where their competences are combined with those found in firms, universities, and other actors. While the expectations are clear, the route to get there is much less so. Financial resources are needed to build, upgrade, and maintain advanced technological infrastructure, but there is much less written about the resources needed to support collaboration and network infrastructures.

At the regional scale, expectations are articulated in more specific terms. Using the case of Lund and the Öresund region as an example, there are clear statements of the perceived advantages associated with the construction of the two new large research facilities, MAX IV and the ESS. The regional authority seeks to catch spin-off effects: 'In a broad perspective, there will be opportunities to strengthen the innovation climate, research collaborations and increased competitiveness of industries. This will yield new business opportunities and the ability to attract highly skilled people' (Region Skåne 2015). In the Öresund region, policymakers discuss how the ESS can be a '*språngbräda* [springboard] for jobs, growth and innovation' (Öresundskomiteen 2014), while Copenhagen Capacity views the ESS and MAX IV as 'growth-motors in the capital region' (2014). Furthermore, Lund University has mobilized the construction of MAX IV and the ESS in Lund to reflect the 'strength and attractiveness' offered by the university's research environment, adding brand power (Lund University 2015).

In addition to these visions, we also find concrete initiatives. At Lund University, a doctoral school 'Imaging of 3D structures' seeks to promote scientific activities surrounding the facilities being built in Lund by training young scientists in the use of synchrotron and neutron techniques; at Copenhagen University, the interfaculty project CoNeXT aims at 'fertilizing the ground and harvesting the full potential of the new neutron and X-ray research infrastructures' (CoNeXT 2015) by uniting scientists in cross-disciplinary research projects. The regional authority launched a platform to support industry by providing information on opportunities for firms in the region through workshops, by providing courses to enhance skills and competence in relevant areas, and by providing a meeting space to initiate collaborations between firms in the region and elsewhere (Industriell Plattform 2015). In addition, several projects have been proposed that seek to increase cross-border cooperation between universities and other public sector organizations. Concrete initiatives in these projects include training programmes and cross-appointed young researchers to strengthen interdisciplinary research environments and spread competence in using the facilities. In other words, based on a scan of regional initiatives (though not an exhaustive search, as the number of initiatives is great and an overview is lacking), there appears to be an ambition to invest in network infrastructure and skills development in order to supplement the 'hardware' of large-scale research infrastructure.

It is not surprising that it is at the regional scale that we find the articulated expectations to be most specific. Economic geographers always make the point that the world is not 'flat', and that we observe that economic activity remains remarkably concentrated in a limited number of places, despite advances in information and communication technologies. Moreover, knowledge spillovers have a limited range (Jaffe et al. 1993; Audretsch & Feldman 1996; Feldman 1994). The reason for this continued 'stickiness' of activity is that social dynamics tend to have a natural spatial bias. Interactive relationships between different organizations are more easily established and maintained when actors are geographically close to one another, when they are more likely to be aware of one another's existence, can come into contact with one another in various settings, and do so repeatedly over a period of time (Maskell & Malmberg 1999; Gertler 2003; Malmberg & Maskell 2006). To harness the societal impact of scientific research necessitates the cooperation of government, industry, and academia, which benefits from geographical agglomeration as 'spatial concentration is intended to encourage frequent interaction and rapid feedback … among the elements of the technical system, research, development and industry' (Kargon et al. 1992, 336).

However, it is also at the regional scale that one should be sceptical of the ability to realize such expectations. Scholars stress the indirect, uncertain, and not wholly predictable nature of innovation processes, and the role that facilities are to play in this is therefore difficult to plan. This leaves us to question what advantages are potentially associated with 'being close', what the likely challenges are that will need to be overcome, and what kinds of strategies might be able to address these. In order to structure this empirical investigation, the proximity framework provides guidance.

Different forms of proximity

How close is close enough for fruitful interaction? Despite the importance awarded to place, localized learning, and the limited range of knowledge spillovers (Morgan 2004), a growing body of work in economic geography on proximities recognizes that being geographically (or physically) close does not in and of itself ensure interaction between different organizations. Building on the French 'Proximity Dynamics' group of the 1990s (for example Torre & Gilly 2000), economic geographer Ron Boschma (2005) and colleagues developed the now oft-used proximity framework to suggest that in addition to geographical proximity, economic actors are likely also to share other forms of proximity that support interactive learning and innovation. This section provides a brief overview of different forms of proximity—geographical, cognitive, social, organizational, and institutional—which are also summarized in Table 1.

Form of proximity	Key dimension	Description
Geographical	Physical distance	Spatial or physical distance between actors
Cognitive	Knowledge	A shared knowledge base is needed in order to communicate, understand, absorb, and process new information successfully
Social	Trust (social relations)	Socially embedded relationships at the micro level: trust based on friendship and experience, which encourages commitment and sharing of tacit knowledge
Organizational	Control	The capacity to coordinate interaction: the extent to which relations are shared in an organizational arrangement in or between organizations: no ties, networks, joint ventures, strong ties, etc.
Institutional	Culture	Common language, shared habits, a legal system, all of which provides stable conditions for collaboration and interactive learning

Table 1 Different forms of proximity, adapted from Boschma (2005).

Put simply, cognitive proximity refers to the degree to which two individuals share the same knowledge base (see Nooteboom 2000; Cohen and Levinthal 1990), which allows them to communicate effectively and efficiently (if not too distant) and learn from each other (if not too proximate). Social proximity here refers to the socially embedded relations between agents at the micro-level, where individuals trust one another based on friendship, experience, and reputation (Granovetter 1985; Grabher 1993; Henry and Pinch 2000; Grabher 2002). Organizational proximity refers more explicitly to the boundaries of organizational arrangements, and is associated with the costs of transactions, transfer, and exchange of knowledge in markets versus hierarchies (Lam 1997). Institutional proximity on the other hand, refers to the situation where people share sets of values at a more macro-level, including a common language, shared habits, a legal system, and so forth (North 1990; Snow 1959; Lowe and Phillipson 2009; Gertler 2010). Boschma concludes that all forms of proximity, 'each in their own way, but most likely in combination' (2005, 71) should be considered mechanisms that bring together actors within and between organizations. Furthermore, he argues that 'although geographical proximity facilitates interaction and cooperation … it is neither a prerequisite nor a sufficient condition for interactive learning to take place' (Boschma 2005, 71).

In other words, being close on all these dimensions makes interaction between two actors easier. As, for example, when you are in the same city and can meet regularly, work in the same scientific field, have strong ties, and belong to the same social network, work in the same firm or organization and share a language and routines. Actors can thereby be 'close' in many ways, and which form or combination of proximities is more important depends on the task at hand, the stage the project has reached (Hansen 2014), the accessibility of partners (Grillitsch & Nilsson 2015), the type and complexity of knowledge to be exchanged between the partners (Mattes 2012), and a range of other factors that are subject of a growing body of research. The absence of proximities, on the other hand—when two organizations are very different in terms of their knowledge base, belong to different networks, and have thick organizational boundaries and very different practices and incentive structures for collaboration—can pose different barriers to fruitful interaction.

However, assuming that these proximities are not static but rather can change over time (Balland et al. 2015), an important question is how they can be achieved in a way that supports interaction between actors. Given the interdependence between different forms of proximity, it is reasonable to assume that they are mutually reinforcing. Building the notion of 'collaborative capacity', the psychologist Pennie G. Foster-Fishman et al. (2001) suggest that consortia with a diverse membership are more likely to have access to the range of skills and knowledge needed for collaboration (cognitive proximity). This diversity, they suggest, can be recruited, or it can be supported through training and a focus on member capacity building. Second, collaboration requires broader relational networks as well as new ways of interacting with current contacts (social/organizational proximities). Third, initiating a new form of collaboration requires strong leadership and the establishment of routines, roles, and communication channels (organizational/institutional proximities). Strategies to overcome the lack of some forms of proximity are therefore likely to build on strengthening other forms of proximity.

Applying this proximity framework to the empirical case of large-scale research facilities in Lund, the empirical questions that structure the material below are as follows: What are the perceived advantages of being geographically close to the facility? How close is close enough, and what other distances remain? Do early strategies address these distances, and if so, how?

Case study of a strong research environment in Lund

As described in more detail earlier, MAX IV was given the green light in 2010 and will start operations in 2016, while the decision to build the ESS in Lund was taken in 2009, construction started in 2015, and a user programme should begin operating by 2023. The construction of these two new large-scale facilities provided a vehicle for the City of Lund, and the Öresund region more generally, to further their image as a science region and a concentration of research activities. The new facilities join a milieu that includes leading universities, the IDEON science park, and industrial strengths in life science, ICT, clean technology, and food, amongst others. The regional authority and various industry associations identify the advent of the new facilities as regional strengths to attract new activities, residents, and investment.

The MAX IV synchrotron facility is a new physical structure, but as an organization the MAX IV laboratory has been part of the research environment in Lund for thirty years. The MAX IV laboratory is a Swedish National Laboratory and falls within the organizational structure of Lund University. Currently, 140 people are employed at MAX IV. As described in the introduction to this volume, a large portion of funding for the facility comes from the National Research Council (VR) and is dedicated to the running of the facility, not for outreach activities towards new user groups or industry. The ESS is a neutron spallation source and a European project with at least seventeen partner countries financing and contributing to its construction in Lund. The ESS is a new organization and will be new to the region, although designs that had it in Lund have been circulating since the early 2000s. The organization has grown rapidly over the last few years, from 7 in 2007 to just over 300 today.

In other words, the two organizations share a regional context and geographical proximity to potential interaction partners in the university and local industry. They also share a general lack of cognitive proximity to these partners. However, as MAX-lab has been in the region for three decades and is part of the organizational structure of the university, we can expect there to be more social and organizational proximity between the MAX IV facility and organizations in the region, compared to the ESS which is new to the region and a stand-alone organization. For both facilities, an institutional logic of the scientific field is dominant, but the MAX IV laboratory is likely to be a bit more ‘Swedish’ in its culture and routines.

Methodology

The research design involved two stages. The first built on desktop research to identify current expectations of regional stakeholders, and the early initiatives to realize these expectations. It soon became clear that there are many on-going projects, initiatives, consortia, and funding applications, all dedicating human and financial resources to 'preparing' the region to take advantage of the opportunities associated with being geographically close to the newly constructed facilities. These vary widely in terms of their ambition, the number of stakeholders involved, duration, and the amount of funding they receive.

Taking stock of these initiatives would be a valuable but time-consuming task, as there appeared to be relatively little overview or coordination by any one organization. The second stage of the research therefore went on to investigate a subset of these initiatives in greater depth through semi-structured interviews. Nine interviews were conducted in total: eight in Lund and one in Oxford, where there is a research environment comparable to what Lund aims to have, with a synchrotron (Diamond Light Source) and a neutron facility (ISIS). The average duration of the interviews was 62 minutes, the shortest being 45, the longest 114. Interviewees came from the university (2), the regional authority (2), facilities (3), and intermediary organizations that facilitate the industrial use of facilities (2). They were asked about their perceived opportunities of being located in close geographical proximity to the new facilities, the perceived challenges in realizing these opportunities, and details of the initiatives they have taken—including who they collaborated with, where the idea came from, the difficulties they encountered, and their next steps. Within each type of organization, interviewees were selected for their perspective, in order to ensure diversity. Some aimed to enhance researchers' use of the facility, others focused on the industry–facility relationship; some initiatives were of a very specialized nature relating to particular beamlines, others were more general in their aim; some interviewees sought to bring together a diverse set of stakeholders, others hoped to expand the level of competence in a very specific and homogeneous community. The interview material is therefore meant to suggest the range of activities going on in the region, rather than provide a generalizable overview of the expectations held by different regional stakeholders. This diversity, between as well as within organizations, reveals the breadth of initiatives in aggregate.

Proximities between facility, university, and industry

This section uses the different dimensions of proximity to identify perceived opportunities, challenges, and strategies to answer the question of how close is close enough. The findings suggest that while universities and firms are geographically proximate to the facilities (the opportunity), cognitive, social, organizational, and institutional distances will need to be overcome (the challenges). The findings are summarized in Table 2.

Geographical proximity

Material presented at the beginning of this essay illustrated some of the expectations—expressed at the regional scale—associated with being geographically close to the new large-scale research facilities. These perceived opportunities were echoed in the interviews as well: 'MAX IV and the ESS as catalysts and regional motors of growth … it is a unique opportunity for the region to be at forefront of research and education, as well as innovation and knowledge-based industries' (Regional authority 1). There are certain potential advantages to being geographically close, for both, academic as well as industry users.

Although beamtime is allocated in a peer-review process aimed at giving time to the best projects and not to favour particular locations or universities, the geographical proximity enjoyed by local scientists allows for interaction with the beamline scientists during the development of a proposal: 'You can meet face to face, meet the scientists, have a good Q&A' (University 2). This relationship with the beamline scientists can also result in access to last-minute, spare, or cancelled beamtime, which can be of great value for pre-testing (University 1). Additionally, local university scientists can benefit from being geographically close to the experiments being carried out at the facility by visiting researchers: 'there will be need for scientists who can support and prepare experiments, which often requires local laboratories. This situation gives Swedish researchers a unique opportunity to participate in the exciting work' (University 1). In order to be able to fulfil this function, however, this requires a strong research environment in the region, which needs to be built up by attracting skilled people.

Similar advantages can be identified for local industrial users when compared to non-local users: ‘projects with non-local firms were more difficult, communication by email and in English proved difficult, they couldn’t come visit the facility before writing the proposal or before they had beamtime’ (Facility 1). In contrast, local industrial applicants ‘could walk the 200 m to see MAX-lab, talk to scientists to discuss problems and possibilities, try some things out when beamtime was available, even last minute and unplanned’ (Facility 1). It is important to stress that the advantages derived from geographical proximity are only an advantage once firms are actually trying to interact with the facility. In other words, it assumes a certain level of interest and awareness—or cognitive proximity.

The references to literal geographical proximities facilitating face-to-face interaction was even more apparent when considering the small size of the city of Lund: ‘One thing that’s very important about being in Lund is that you can go everywhere by bike … In Stockholm I would have to go by metro and I’d have to set a time that, you know, will you be there when I get there. Now I can more or less just knock on the door and say “I just read or heard you’re good at this or that; could I take some minutes of your time?” ’ (Intermediary organization 1). Geographical proximity, combined with the relatively small size of Lund and ease of access, yields certain advantages for interaction to take place.

Cognitive proximity

One of the most clearly observed barriers to fruitful interaction between facilitates and other organizations in the region, is the lack of awareness and a shared knowledge base. Given the complexity of the facility’s tools, having some experience in using synchrotron light or neutrons in research, as in industrial R&D activities, is required to recognize the potential value of using the facility in the first place. This experience was considered minimal in both the academic and the industrial communities, for according to the interviewees ‘there is no local tradition and there is a very small user group’ (University 2), there is ‘a need for showcases to demonstrate how techniques at facilities could be valuable' (Facility 3), and a general 'need to raise awareness' (Facility 1). As the following episode demonstrated, the knowledge gap is often a barrier, but it can be overcome: 'I said, no we've never done that, I don't even know what that is. And then he explained what it was, and then I realized it would be perfect for a project that we were actually running. So we used it then, more or less in the same week as I had been informed … If I don't know that such-and-such a method exists in the first place, I will never think of it' (Intermediary organization 1). There have been projects such as Science Link, designed to remove the financial barriers to industry using large-scale research facilities, but they do not address this lack of cognitive proximity: 'We can lower or remove the financial barrier for industry to use the facility, but there is still a gap: the facility does not have the time or human resources to help companies as much as they need—there needs to be more translation between the needs of the company (develop new products) and what kinds of problems can be solved at the beamline (material properties)' (Facility 1).

There are initiatives that address this gap, particularly when it comes to university researchers. Courses and summer schools that provide training in how to use these techniques bring together young researchers from different backgrounds and disciplines to increase awareness and skills, which also increase the chances for creative new ideas (University 1). Such educational strategies therefore have multiple goals—'to learn about methods, to meet other researchers, to develop a multidisciplinary environment' (University 2)—all of which will increase the likelihood of fruitful interaction. Building a critical mass of engineers and scientists trained in the use and development of techniques is a priority for the university as well as the regional authorities: 'We need to strengthen the regional competence base in research and industry' (Regional authority 2), and 'the goal is to increase the number of young researchers who can carry out experiments … at the ESS and MAX IV, and to ensure this increased competence benefits academia, industry, and innovation in the region' (Regional authority 1). In an alternative strategy to providing training opportunities to increase cognitive proximity to the facility, organizations have turned to hiring those with relevant skills: 'we hired a postdoc; she knows neutrons … I was thinking that we could maybe learn a bit more about that through her' (Intermediary organization 1).

Social proximity

A lack of social proximity is seen as a considerable barrier, especially in the absence of cognitive proximity: 'If you [as a firm] don't know what to ask for in very specific terms, you need to know the people' (Intermediary organization 2). If there are personal contacts with someone at the facility based on prior interaction, this is considered an asset, as 'the professor at the department here knew who would be responsible for the beamline there' (Intermediary organization 1), while potential industrial users would write 'more successful applications if users know current or former facility scientists' (Facility 1), presumably because they consulted this individual in their network when preparing the application.

It is therefore not surprising that many of the current regional initiatives feature some form of network-building ambition: 'There is a need for dialogue and network meetings to bring together actors round the table' (Regional authority 1). Repeated interaction between individuals yields a level of social proximity and trust, 'so that when I have an issue, I go to the ILO [Industrial Liaison Officer] function [at the facility], and we know each other well, they understand fast, we've done these things together before' (Intermediary organization 1). Developing such relationships does require a clear access route, a low level of turnover, and an awareness of who is who, as the following scenario demonstrates: 'A recent example—yeah, we [the facility] can do the experiment for you, but we will not have time to do the analysis … but then we realized there's this group sitting in Chalmers who are specialists in this, they know us, and they've done this type of experiment before, so we phoned them up, "Could you help us?", so we formed this three-party collaboration … they will pay us for the beamtime, they will pay you for the analysis, and everybody's happy. So, we could do a lot of that, but that requires someone who knows where these groups are' (Facility 2). Other proposals that seek to enhance social proximity include co-financed positions between facilities and universities (University 2), and a service where local Ph.D. students and postdocs can be used as bridges between teams of visiting scientists and the local environment: 'someone who knows local conditions, the hospital, has access to equipment' (University 1).

Organizational proximity

Organizational proximity refers to the capacity to coordinate interaction and the extent to which relations are shared in an organizational arrangement within or between organizations. These arrangements between organizations can take the form of a network or official joint venture, and as noted above, there have been numerous such initiatives in the Öresund region. The lack of organizational proximity has been identified as an obstacle to achieving expectations: 'together, partners have to a large extent all the competences that are needed to use [these techniques] in research and industry, but these competences are found in small and fragmented research environments' (Regional authority 1). When these pockets of expertise are hidden or not clearly linked, they are not accessible: 'We need clear access routes; to know who to call' (Facility 3). Some interviewees associated this with the lack of clearly identified, hierarchical, and centralized organizational forms: 'communication can be a problem in a flat organization, you don't know who to call' (University 1).

To this end, regular meetings, platforms, and networks have been set up at various universities to bring together scientists who are found spread out in different research groups (Lindgärde 2010), and building networks is seen as the most important task 'to overcome the fragmented competence base amongst universities' (Regional authority 1). This strategy runs the risk of replicating the problem, however, leading to congestion and confusion over the division of labour between networks, and some have argued that 'we don't need more umbrella organizations in the university; instead, we should use the ones we have in a better way' (Björck 2013). As for industry, a similar process of network building has been taking place over the last few years. In order to build up a regional critical mass of firms that are able to contribute to the facilities' construction and become users, regional authorities on the Danish and Swedish side are collaborating: 'By planning activities around information diffusion, competence development, and collaboration together, this can be more cost effective' (Regional authority 2).

Putting together collaborations, in other words, requires a coherent, critical mass of competence that is accessible, but also strategy and resources, as another interviewee suggests: '[In Denmark] they have developed industrial portals, they have a much closer connection between academia and industry. Lots of collaborations and money being funnelled into academic groups working with industry … they have local facilities, they help to get into bigger facilities, it's a whole strategy' (Facility 2). The responsibility for creating and investing in these organizational arrangements, however, is much less clear, as will be discussed in the concluding section.

Institutional proximity

The lack of institutional proximities between facility, academia, and industry is often simply referred to by interviewees as different 'cultural differences' (Regional authority 1). Differences between academia and industry when it comes to timelines, incentive structures, and so on, are not surprising (Caplan 1979; Dunn 1980): 'Business to business is much easier than business to academia … you know you can have a confidentiality agreement, you will get an invoice … it's professional' (Intermediary organization 1). When asked to be more specific about the differences between academia, industry, and facility, they suggest that relationships can be relatively cool due to 'differences in organizations and different measures of success' (University 1), and that this is evident in facility–industry collaborations in particular: 'that is an issue now, of course, that [beamline scientists] don't want to do this because they don't get any credit for it in their science' (Intermediary organization 1). Such differences in incentive structures and culture need to be managed during the collaboration.

As facilities (are expected to) increase their openness to industry users, this is the interface where institutional differences are most pronounced. Inside the facility, there is a need to build legitimacy for industrial users (Facility 1), and strategies here include the clearly articulated support from the facility leadership (Facility 3): 'This person or those people should then have a really good communication internally so that these beamline scientists are happy to do this for them' (Intermediary organization 1). In addition, the outward interface, from facility to industry, must be managed to speak to industrial users: 'it's not just having the right paperwork or IP [intellectual property] contract, you also have to have an attitude … that is different form "this is how you can approach us" ' (Intermediary organization 1). Defining this 'attitude' is difficult, however. Furthermore, which organization has the necessary human, financial, and time resources to manage this facility–industry interface?

A relatively new type of organization that has entered this field and seeks to bridge the institutional gap between facilities and industry, is a so-called intermediary or mediating organization. These organizations maintain relationships with facilities and meet with companies to identify their needs and the opportunities of using large-scale research facilities: 'they have the capacity to take a firm with a problem, do the analysis, design the experiment, do the experiment, and analyse the outcome and report back the result … and they do that for different users, and they build up competence and experience too' (Facility 2). These mediating organizations perform a translation function 'from the firm's need to the facility's possibilities to assist' (Facility 1), or, put differently, 'we know where the answers might be and we know what the problems are' (Intermediary organization 1). This function requires specific human resources: 'Competence and experience in both academic research and industrial R&D are an advantage. When the contact person understands both worlds … has a fundamental knowledge of relevant experimental methods … and sees it is a sales process; [industrial] research departments have limited money and time. They seldom have the opportunity to try new techniques just because it is exciting' (Intermediary organization 2). These individuals, in other words, have a knowledge base that yields sufficient cognitive proximity to both industry and facility, and through repeated interaction they build up social proximity with the facility. In addition, however, there are certain personality traits that interviewees highlighted as an asset: 'I hire people who are good at solving problems (Intermediary organization 1); 'you need talent with soft skills' (Facility 3); and 'you need to be persistent, active, and a good listener (Intermediary organization 2).

In the literature on innovation intermediaries, they are defined as 'an organization or body that acts as an agent or broker … between two or more parties' (Howells 2006, 720), able to bridge between distinct epistemic backgrounds. The boundary between two settings can be a significant barrier to knowledge flows: members of an organization share a common coding scheme and technical language, which throws up obstacles to communication with other areas beyond (Harada 2003). It is therefore a challenge to find individuals who are capable of translating between contrasting coding schemes, because the more embedded they are in outside networks, the less able they are to transfer this to relevant insider knowledge, and vice versa. In the case of the large-scale research facilities in Lund, there are similar barriers between the facility and, for example, industry.

Research suggests that this intermediation consists of two activities: to recognize and identify something of potential value in one setting; and to effectively communicate this to another setting. These activities are not

	Challenge	Strategy
Cognitive proximity	'There is no local tradition and there is a very small user group'	'Need to raise awareness', 'to strengthen the competence base': training, workshops, courses.
Social proximity	'You need to know who to call', 'we know each other well, we've done these things together before'	Co-financed positions, repeated interactions
Organizational proximity	'Competences are found in small and fragmented research environments', 'you don't know who to call'	'Need to overcome fragmented competence base': networks, platforms, portals
Institutional proximity	'Cultural differences', 'different measures of success'	Build legitimacy, leadership, translation (through mediating organizations)

Table 2 Perceived challenges and strategies associated with different forms of proximities.

necessarily done by the same individual or organization, as they rely on different skill sets and resources. The ability to perform the first activity depends in large part on how different this new activity or knowledge is from previously acquired knowledge. Cognitive proximity is an asset in this, because the more familiar the new idea is, then the easier it is to understand and appreciate it. The second activity, in contrast, requires a key insider. This individual has often worked in the organization for a long time, is intimately familiar with its routines, and is the go-to person for other members of the organization—an internal communications star (Harada 2003). The second activity echoes the role of the facility leadership to incentivize beamline scientists to assist industrial users.

The first activity therefore relies on people with a very particular skill set, and who have credibility and understanding in both academic and commercial cultures (Malecki 2010)—or who have the skills and resources to generate that delicate mix of cognitive and institutional proximities, which is often supported by social proximity, those 'extroverted, talented gatekeepers … whose personalities are social and whose job descriptions must permit seemingly frivolous socializing necessary to understand tacit knowledge and its numerous signals' (Malecki 2010, 1043). These qualities and traits are also echoed in the source material collected for this essay, for, as one respondent noted, 'you need to have people who want to do it, who are curious about this, and think that it's something fun and interesting' (Intermediary organization 1). Attracting, training, and retaining this skill base is therefore as important as investing in competence development programmes: 'We constantly need to train these guys [from mediating organizations] so they can actually support more methods, but finding funding for training is hard! It's a responsibility that we share with universities … Some of that skills base needs to be built up … to make sure that [the facility] gets used' (Facility 2).

Concluding discussion

It is evident there is a wide range of activities going on to prepare regional stakeholders for the launch of the two large-scale research facilities in Lund, MAX IV and the ESS. Although there are different perspectives on the ways in which these facilities will impact society, in both positive and negative senses, this essay has focused in particular on a subset of expectations: how these facilities can contribute to a strong research environment in Lund, and to the Öresund region more generally. Geographical proximity to these facilities offers certain advantages, but it is also clear that this is not sufficient to ensure fruitful, interactive relationships between the facilities, universities, and industry. There are additional gaps between facilities and other organizations in the region that pose obstacles to interaction, and the range of on-going activities seek to overcome these. In this essay, these challenges and strategies have been discussed using the proximity framework, in which, it is argued, cognitive, social, organizational, and institutional distance has to be overcome, despite the advantages offered by geographical proximity. The material suggests that regional stakeholders perceive distinct challenges associated with all the forms of proximity needed for interaction. For example, courses, workshops, and training programmes seek to increase the competence of researchers and industry in the region (cognitive proximity), while platforms, networks, and portals should make it easier to bring together fragmented communities (organizational proximity).

However, there are also potential risks associated with this plethora of initiatives. First, the question of who does what can be very muddled, congested with competing and overlapping initiatives, or ideas can fall through the cracks when everyone thinks that some other organization or network is following it up. This highly decentralized form of initiative-taking is also felt to be a drawback by the organizations involved: 'In Sweden it is more decentralized, the responsibility lies in very many places, very few have a holistic perspective' (Facility 2). This could inhibit interactive relationships from developing in the future. Striking a balance between allowing decentralized and specialized activities to emerge while maintaining some form of coordination is indeed a challenge, but an important one.

Moreover, different individuals or layers within an organization or regional stakeholder constellation need to overcome different kinds of gaps. Collaboration agreements are made on one level, but carried out on another. Committing to a collaboration requires more general organizational knowledge and decision-making authority to overcome some gaps, especially those that are organizational and/or institutional in nature; collaborating on the ground may require specialized knowledge and capabilities to overcome other gaps, chiefly those that are cognitive and/or social.

Finally, it is unclear whose responsibility it is to ensure that effective interactive relationships develop between these new facilities and organizations in the region such as universities and industry. Phrased differently, one must consider who has the necessary skills, resources, and incentives. Despite the discourse of justifications for investing in new big science, it is clear that the responsibility does not wholly lie with the facilities themselves. As one member of the university pointed out, 'Facilities are much too small and the university is huge. At a facility, 200 people know everything about beamlines; the university has a broader infrastructure' (University researcher 1). Meanwhile, another type of organization, the mediating organization, aims to fill this role, and they have the right human resources to achieve the necessary cognitive, social, and institutional proximities. This organizational form is one that is emerging—there are only a handful of such intermediaries in the region today—and there are no clear institutional arrangements in place to structure their activities, their funding, or their relationships with the facilities. This currently under-defined institutional space allows them to create bridging opportunities that facilitate interaction in new and relevant ways. However, to ensure the growth and upscaling of such initiatives in the future, these new organizational forms will need to be monitored, their function and activities will need to be better identified and understood, and they will need to be supported by facilities as well as by industry, university, and regional authorities.

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University researcher 2, 27 March 2015, Lund.
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Facility 2, 6 May 2015, Lund.

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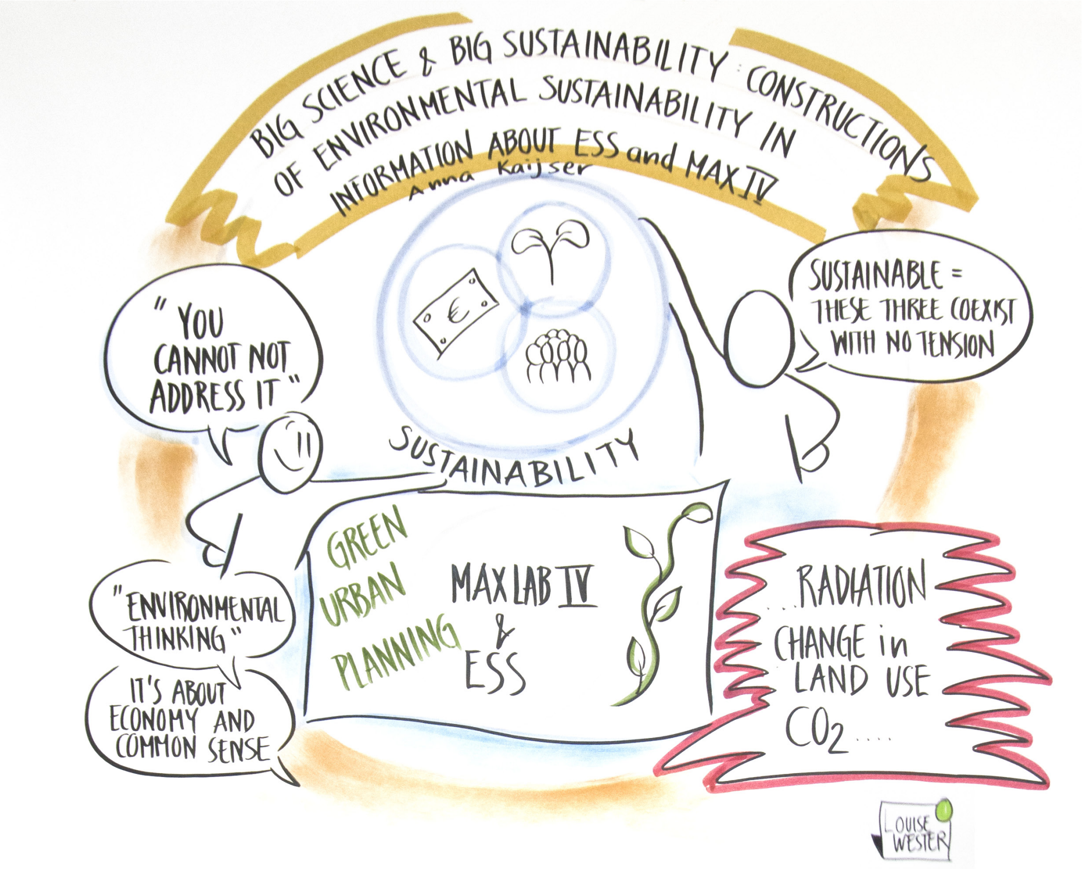
BIG SCIENCE & BIG SUSTAINABILITY: CONSTRUCTIONS OF ENVIRONMENTAL SUSTAINABILITY IN INFORMATION ABOUT ESS and MAX IV
Anna Kaijser
"YOU CANNOT NOT ADDRESS IT"
€
SUSTAINABILITY
SUSTAINABLE = THESE THREE COEXIST WITH NO TENSION
GREEN URBAN PLANNING
MAX LAB IV & ESS
"ENVIRONMENTAL THINKING"
IT'S ABOUT ECONOMY AND COMMON SENSE
...RADIATION
CHANGE in LAND USE
CO2 ....
LOUISE WESTER

4. Can big be made sustainable? Environmental contestations over the ESS and MAX IV

Anna Kaijser

Preface: a visit to the future

It is a Tuesday morning in May, and the weather is a bit changeable, which is only to be expected from spring in southern Sweden. We, a group of researchers from various disciplines, are guided by a representative from Lund Municipality on a 'future walk' through what is to become Brunnshög, a new urban area in north-eastern Lund. It is envisaged that in the near future Brunnshög will be home to the ESS and MAX IV facilities, the 'science village' linking them together and providing services to researchers and visitors, and a new residential neighbourhood (Lund Municipality 2012). In the planning documents of Lund Municipality, Brunnshög is pictured as a model of sustainable urban development:

> This will be the world's best environment for research and innovation. But it will also be a showcase for Swedish sustainable world-class urban planning: a neighbourhood where planning is permeated by wisdom and responsibility for coming generations. … North-east Lund/Brunnshög shows the way to a sustainable world. (Lund Municipality 2012, 4, my translation)

Our umbrellas are battered by the wind as we follow our guide through the landscape, climbing a hill created by years of landfill and overgrown with grass. From here, the view stretches across the fields of rapeseed about to burst in explosions of bright yellow, over buildings and construction sites on the other side of the noisy E22 motorway connecting Lund and Malmö with the eastern coast of Sweden. On the other side of the E22 is the construction site for MAX IV. The giant ring in which electrons will circulate looks like something from a sci-fi film: eerie, grandiose, and charged with the brightness of the future. The site of the ESS facility cannot be seen from here, but the promise of it is ever-present in the large-scale planning, visualized on the maps our guide has handed out.

We walk through a little copse of slender trees, newly planted on the former farmland to provide ecosystem services for the future neighbourhood. Here and there, orange poles mark the proposed route of the tram, which is planned to be in place in 2017. Along with improved cycle paths, it is part of the sustainability vision that aims to reduce private car use (Lund Municipality 2012). Where the trees end, the municipality has put in allotment gardens. Urban gardening has a prominent place in the envisioning of *Sustainable Brunnshög*, along with a number of other aspects. The buildings will be energy efficient and use recycled heat from MAX IV and the ESS (Lund Municipality 2012). The presence of the two research facilities is to be manifested in the urban design: the project leader hopes that the scientific findings may be displayed in physical form in the urban environment, and that Brunnshög might become a ‘test bed’ for innovations (Dalman 2015, personal interview; Lund Municipality 2012).

Exploring promises and concerns

The evident optimism in Lund Municipality's accounts of what the European Spallation Source (ESS) and MAX IV may bring, reflects the expectations placed on large-scale research facilities in general. In addition to scientific findings, it is anticipated that the ESS and MAX IV will attract jobs, famous researchers, international attention, and bring about innovations that may be displayed on the streets of Lund as signs of modernity and cutting-edge urban design. With the rising awareness of environmental issues in recent decades, another set of expectations have been placed on research facilities: the hope that they will generate knowledge and technology that will solve environmental problems and lead humanity onto more sustainable paths.

Sustainability is a widely celebrated and yet elusive concept. While its meaning is negotiated and shifts with the context, sustainability is hard to be against, and impossible for many actors to not address. The notion of environmental sustainability has become something that all kinds of projects, and especially those with the magnitude of large-scale research facilities, need to take into account. MAX IV and the ESS, being high-cost and high-profile projects, are subject to great expectations related to sustainability, but also to worries and concerns. While some stakeholders are hopeful about new innovations and sustainable technologies that may come out of the facilities, others are afraid of the potential negative environmental impact that they may have. In this essay, I explore in what ways such expectations and concerns play out, and how environmental sustainability is addressed in the development of the ESS and MAX IV. I look into the conceptualizations of sustainability that are expressed and mobilized in information about the two facilities, how sustainability ambitions are formulated and put into practice in planning and construction, and how promises for sustainability figure in the expectations on research outcomes. Furthermore, I look into how these processes evolve in dialogue and negotiation with other actors, particularly local environmental organizations. I argue that while the exact implications of the concerns and promises about sustainability related to MAX IV and the ESS are disputed, in order to appear sensible the various actors involved in these debates all need to adhere to ideas of modernity and scientific progress as inherently positive. This can be understood in the light of the ecological modernization or ecomodernization approach, which dominates environmental politics and debates in Lund as elsewhere in Sweden and internationally.

In this study of the construction and negotiation of sustainability at the new Lund facilities, I have used a variety of source material. Semi-structured interviews were conducted with staff members of the ESS who have insight into the organization's sustainability ambitions; with Lund University's project director for MAX IV; and with representatives of Lund Municipality and local environmental organizations. Field visits were made to the ESS offices, to the offices and construction site of MAX IV, and to the Brunnshög area, which will host the two facilities along with a brand new city district. Furthermore, a large body of written material was collated, including reports and information material about MAX IV and the ESS; planning and information documents from Lund Municipality; documents from the Environmental Court trial about the ESS; reports and comments submitted to the municipality and the Environmental Court by environmental organizations; and media coverage of the processes of realizing the ESS and MAX IV. The respondents were selected for their knowledge and experience of working with issues related to environmental sustainability—for example, energy, construction, urban planning, and radiation safety—in their respective organizations. I first contacted them through their organizations or, in some cases, by following up recommendations from other respondents. Everyone I contacted was positive about the study and willing to participate. All the interviews were carried out in Swedish—the material quoted here appears in my translations—and, having been transcribed, were, together with the text material, subject to a content analysis in which I identified the following salient themes: energy consumption, radiation safety, science as promise, and land use.

Environmental sustainability, an ecomodern boundary object

The concept of sustainability has been used in environmental debates since the 1970s, but gained wider popularity with the 1987 *Report of the World*

Commission on Environment and Development: Our Common Future (Lumley & Armstrong 2004). This UN-appointed commission, chaired by the former prime minister of Norway, Gro Harlem Brundtland, optimistically claimed that 'Humanity has the ability to make development sustainable to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs', thus providing a framework of sustainability that encompasses environmental, economic, and social dimensions, and suggesting that these dimensions can coexist (WCED 1987). This conceptualization of sustainability as bringing together environmental, economic, and social aspects became highly influential, and in the intervening decades since the report came out, sustainability has been embraced as a key concept in political debates, policy-making, and the private sector (Mebratu 1998; Davidson 2010; Lidskog & Elander 2012). It is nowadays nearly impossible for any larger project not to take sustainability into account, and very few would claim to be against it. In relation to the establishment of large-scale research facilities, as the head of the ESS's Energy Division pointed out, sustainability is something that you cannot *not* address (Parker 2015, personal interview). True, the exact definition of the concept remains vague and disputed (Mebratu 1998), but this vagueness might well be part of its success, for it can be charged with a variety of meanings according to context and interests. Sustainability may thus be regarded as a boundary object around which different actors can 'meet and find mutual interests' (Lidskog & Elander 2012, 412). Boundary objects, according to STS (science and technology) scholars Susan Leigh Star and James R. Griesemer, are

> objects which are both plastic enough to adapt to local needs and the constraints of the several parties employing them, yet robust enough to maintain a common identity across sites. … These objects may be abstract or concrete. They have different meanings in different social worlds but their structure is common enough to more than one world to make them recognizable. (Star & Griesemer 1989, 393)

The environmental scientists Fridolin Simon Brand and Kurt Jax maintain that sustainability as a boundary object has managed to provide common ground for various actors to meet and agree on an agenda. While being successful in reconciling different communities and interests, however, they warn that there is a risk that the boundary object of sustainability may 'hide conflicts and power relations when different persons agree on the need for sustainability when in fact meaning different things by it' (Brand & Jax 2007, 16).

The authors of *Our Common Future* acknowledged that human resource consumption puts pressure on the environment, but maintained that 'technology and social organization can be both managed and improved to make way for a new era of economic growth' (WCED 1987). This techno-optimistic and governance-oriented perspective marked a shift in the dominant view on environmental issues, towards an increasing belief in the possibility to reconcile environmental sustainability with economic growth through scientific knowledge, technology, and adequate governance. The worldwide embracing of sustainability since the 1980s has been paralleled by the increasing dominance of an approach in environmental debates and politics that is labelled ecological modernization or ecomodernization. A core feature of this approach is the notion that environmental problems can and should be solved within the existing economic and political system, through adjustments and technical fixes. The approach presupposes consensus and reform rather than political struggle and systemic change. No contradiction is seen between environmental protection and economic growth; rather, they are regarded as mutually reinforcing (Hajer 1995; Mol & Spaargaren 2000). Ecomodernization thus 'indicates the possibility of overcoming the environmental crisis without leaving the path of modernization' (Hannigan 1995, quoted in Bäckstrand 2004, 697). Ideas of modernity and progress take centre stage, and there is a strong belief in the ability of science and technology to provide innovations that will solve sustainability challenges. A recent manifestation of this perspective is the Ecomodernist Manifesto, released in April 2015 by a group of 'scholars, scientists, campaigners, and citizens' (Asafu-Adjaye et al. 2015). Acknowledging the severity of environmental destruction, the authors contend that there are no absolute limits to the expansion of human activity and economic growth: through new knowledge and technological development, human needs can be satisfied with much less environmental damage. ‘Humans should seek to liberate the environment from the economy’, it is argued (Asafu-Adjaye et al. 2015, 18).

When the ecomodernization approach was first articulated in the early 1980s, it challenged other approaches to the environment. In the 1960s and 1970s, many environmentalist theories and movements questioned ideals of development and growth, and proposed that deep societal transformations were needed to avoid massive environmental deterioration (Mol & Spaargaren 2000). Such perspectives reached wide audiences, for instance through the influential *Limits to Growth* report by the Club of Rome in 1972, and the UN Conference on the Human Environment that was held in Stockholm the same year (Gomez-Baggethun & Naredo 2015). Since the 1980s, however, the ecomodernization approach has gained the upper hand in environmental decision-making and public debate. As Arthur Mol and Gert Spaargaren, specialists on environmental policy, argue: ‘Especially since the Brundtland report that started the third wave of environmental concern, demodernization perspectives do no longer succeed in challenging the core features of Ecological Modernisation Theory’ (Mol & Spaargaren 2000, 21; see also Gomez-Baggethun & Naredo 2015).

However, ecomodernization has been criticized by a range of theorists who oppose the idea that environmental protection is compatible with the pursuit of economic growth, and point to the limited ability of market and governance mechanisms and technological fixes to solve ecological crises (York & Rosa 2003; Foster 2012). In a reaction to the Ecomodernist Manifesto, the STS scholar Bruno Latour remarks that ‘ “ecomodernism” seems to me another version of “having one’s cake and eating it too” ’ (2015), and questions what he perceives as a lack of explicit politics in the document—no friends or enemies are identified. Similarly, others have criticized the ecomodernist approach for contributing to a depoliticization of environmental issues, by overlooking power imbalances and differing interests (Bradley & Hedrén 2014). The geographer Eric Swyngedouw (2014) argues that from an ecomodernization perspective, environmental problems are framed as universally threatening humankind as a whole, and sustainability measures should be taken to ‘save’ existing, resource-intensive ways of life, rather than challenging them or questioning—or even acknowledging—the unequal distribution of resources and risks.

In environmental–political forums and debates, alternative perspectives challenge the ecomodernization paradigm. For instance, environmental policy researchers Karin Bäckstrand and Eva Lövbrand talk about a 'civic environmentalism', which calls for increased civil society involvement in decision-making or, in a more radical form, a fundamental change to the economic and political system (Bäckstrand & Lövbrand 2007). The political scientists John Dryzek and Hayley Stevenson introduce the label 'green radicalism' to describe a similar call for profound systemic changes as the only chance to avoid massive environmental destruction (Dryzek & Stevenson 2013; Stevenson 2014). However, such alternative approaches are largely marginalized in relation to the strong dominance of ecomodernization.

The making of sustainable research facilities

During a visit to the ESS's office in Lund in December 2014, our research team met two senior staff members, who presented their areas of work and answered our questions about the facility. Both acknowledged sustainability to be a key challenge facing the project. They accepted that building and operating the ESS will require a great deal of energy and other resources, but also asserted that the expected use of energy had been significantly reduced through an ambitious energy efficiency program, and that the entire design of the facility is guided by sustainability ideals and a Swedish environmental mindset. But the greatest environmental impact of the ESS, the staff members emphasized, will be the science that comes out of it, as it will contribute to finding solutions to sustainability problems.

Several sustainability issues related to large-scale research facilities were brought up in this meeting: the challenges of energy consumption, radiation safety, environmentally friendly construction and land use, and the promises of scientific results. These aspects, as I will show, kept on reappearing in my subsequent conversations with ESS and MAX IV staff members and information material about the facilities.

Energy consumption

In 2013, the ESS released its *Energy Design Report*, along with a summary presented in a more accessible form entitled *Proposal for a Sustainable Research Facility: the ESS Energy Concept Final Report*. These documents present the organization's commitment to making the ESS a sustainable facility, particularly in terms of energy consumption. The keywords 'responsible, renewable, recyclable and reliable' illustrate a commitment to energy efficiency, to the extent that the facility will supposedly be 'a net carbon sink, even when building materials and transportation are taken into account' (ESS 2013, 12). Efforts have been made to reduce the facility's energy consumption without compromising its operational capacity. There are plans to subcontract a company to construct a new wind power park, which will produce enough electricity to compensate for the still large amount of energy that will be required (ESS 2013; Parker 2013). There are also plans to recycle excess heat generated by the facility's operation. Conventionally, similar facilities use cooling towers to get rid of such excess heat, but the ESS has entered into joint venture with Lund Municipality and the energy companies E.ON and Kraftringen in order to recycle waste heat by using it in the district heating system (ESS 2013; Parker 2015, personal interview). In the ESS's *Proposal for a Sustainable Research Facility*, graphics illustrate how the facility will be integrated with the local energy and heating grids (ESS 2013:12), something that was also explained to me by respondents.

On the homepage of MAX IV, meanwhile, a specific section describes the lab as 'a sustainable facility' (MAX IV n.d. a). Under this heading, the efficient energy consumption of the buildings and the scientific instruments enabled by new technology is stressed. Similar to the ESS, the excess heat from MAX IV is to be recycled in the district heating system (MAX IV n.d. a). They have also made efforts to reduce the expected energy consumption, and will only use electricity from renewable sources (Lavesson 2015, personal interview). Some coordination is taking place here between the two facilities.

Greening research facilities

The homepage of MAX IV asserts that the facility will be a 'green building', and that the area around MAX IV will follow a 'high sustainability agenda', which means, for instance, that seed from a nearby nature conservation area will be planted to enhance biodiversity, while 'instead of using your ordinary, motorized lawn mower the slopes are planned to be grazed by sheep' (MAX IV n.d. a). Both the ESS and MAX IV are to work towards BREEAM certification, which is a method for the assessment and certification of sustainable buildings. For MAX IV, the office buildings and surrounding landscape will be certified according to BREEAM standards; the ESS aims to get the entire facility as well as its offices certified. In both cases, this will call for a major effort, involving the continuous monitoring of the entire building process, from the materials used to the on-site construction work (Lavesson 2015, personal interview; Åberg 2015, personal interview).

My respondents' contention that environmental sustainability is an issue that has to be addressed in projects of this magnitude seems valid when it comes to the ESS and MAX IV (see also Agrell 2012). The ESS *Proposal for a Sustainable Research Facility* has a foreword by Colin Carlile, the then CEO of the ESS, which indicates the importance of sustainability. Carlile describes how, over a lunch with another scientist six years earlier, he had discussed how a large research facility might be powered in an environmentally friendly manner. 'On a napkin, that I still have in my drawer, we wrote down the outline to what has now been refined and will make the ESS not only the world's leading research facility using neutrons, but also the first large-scale research facility that will be environmentally sustainable' (ESS 2013, 3). While the potential of such facilities for generating more sustainable technologies and materials was at that time already recognized, Carlile writes, the resource demands of the facilities themselves were not much considered (ibid.). His account illuminates several features that reoccurred in the material about the ESS and in my interviews with staff members. Primarily, it was the boldness and uniqueness of a large-scale research facility that incorporates sustainability ideals in its design that was often highlighted. It is something that Carlile, with his compelling story of how these ideas were first scribbled on a napkin, makes much of. He establishes a narrative of how sustainability concerns emerged within the ESS itself and were built into the project from its inception. Several of my respondents pointed to Carlile's key role in promoting sustainability ideals within the ESS, and suggested that these sustainability ambitions carried some weight in the decision to place the facility in Sweden, and Lund, as opposed to Spain or Hungary. An explicit commitment to environmental concerns may thus have worked as a comparative advantage in the selection process.

This ambition might also have played on a widespread image of Sweden as a front-runner in environmental sustainability (see Lidskog & Elander 2012). The idea of a Swedish environmental mindset, which a staff member referred to on our visit to the ESS, was also evoked by my respondents. Thomas Parker, head of the Energy Division at the ESS, pointed out that 'it was clearly the perception of Colin [Carlile] and others who came here from abroad, that if you are to do something in Sweden you are expected to have a sustainability profile. It is unthinkable to set up anything of this size without any such concept' (Parker 2015, personal interview). According to the staff members I interviewed, the ESS's sustainability ambitions have attracted interest from other, similar actors. Malin Åberg, who is a section leader at the Conventional Facilities Support at the ESS and thus has considerable insight into what it means to construct a green facility, said that 'our energy concept to some extent sets a standard. It might become a little embarrassing to construct a new research facility where environment and sustainability issues are not at all considered, since we have shown that it is totally doable' (Åberg 2015, personal interview).

Legal procedures and risk management

In Sweden, the processes for handling the environmental issues associated with major construction projects are highly institutionalized (see Stenborg & Klintman 2012). The ESS has been subject to a trial in the regional Environmental Court, according to Swedish law, which demands that all projects that produce ionizing radiation, handle certain chemicals, and/or involve water-related risks must obtain permission. Such permission was granted in June 2014 (Växjö Tingsrätt 2014). MAX IV has not been subject to a trial, since their activities do not demand particular attention by the Environmental Court. However, both the ESS and MAX IV will be continuously monitored by the Swedish Radiation Safety Authority (Strålskyddsmyndigheten, SSM), which handles issues of nuclear safety, radiation protection, and nuclear non-proliferation in the country (Jacobsson 2015, personal interview; Lavesson 2015, personal interview). The ESS has been very active in communicating to the public that while the spallation process causes ionizing radiation, it will not pose any danger to humans or the environment (ESS n.d. a n.d. b). In a brochure, the ESS ensure that levels of radiation from the facility will be so low 'that personnel do not require any protective clothing, even next to the target station's walls', and that the surrounding environment's exposure to radiation will only be about 'one hundredth of the natural background radiation' (ESS n.d. a, 8). Such public information may partly be intended to pre-empt potential criticism and fear of radiation (Agrell 2012).

Rationalizing sustainability

Economic reasoning and environmental concerns go hand in hand in the conceptualization of the sustainability of both MAX IV and the ESS: it is assumed that well-planned and well-designed construction and energy efficiency means saving money (see ESS 2013; Lavesson 2015, personal interview). The project director for MAX IV at Lund University, Lars Lavesson, has been a key figure in the planning of MAX IV as a sustainable facility. In my interview with Lavesson, he stated that his devotion to green building does not stem from ideological commitment or personal environmentalism. 'I think sometimes there is a too strong faith in the environment and so on—it is largely about common sense. It is not about woollen socks and beak boots, but very much about economy and common sense' (Lavesson 2015, personal interview). In his account, Lavesson dissociates himself from an image of 'ideological' environmentalists with their naïve ideas, or 'faith', recognizable from their particular clothing style. Instead he presents ideas of environmental sustainability as resource-efficient and economically rational, thus invoking an ecomodernization perspective.

Stable energy costs were stressed by respondents at the ESS as a factor in ensuring economic and environmental sustainability. Here too an ecomodernization approach can be discerned. The ESS's *Energy Design Report* presents both economic and environmental arguments as a rationale for the facility's ambitious plans for saving energy:

> The costs tend to be comparatively clear, whether they are capital expenditure, operating expenditure or in externalities such as environmental impact. It stands to reason that if these costs can be significantly reduced, or even in some cases turned to a benefit, this could help tilt the balance towards investment in research infrastructure and thereby form not one but two stepping stones towards a sustainable future based on knowledge creation. (Parker 2013, 9)

Thus, it is argued that costs saved through, for instance, energy efficiency, means that more resources can be allocated to the research infrastructure, and thus to research, which might in turn contribute to 'a sustainable future'.

This leads into a key aspect of the sustainability narratives of the two facilities: the expectation that scientific research conducted at the ESS and MAX IV will contribute to solving sustainability problems.

The promise of future sustainability

Information material from both MAX IV and the ESS, available on their respective websites and in printed brochures, promotes the projects as contributing to a more sustainable future, since the research to be carried out is expected to result in more resource-efficient and less polluting materials and technologies (Agrell 2012; ESS n.d. a; MAX IV n.d. b). My respondents at the ESS unanimously asserted that the most important sustainability issue of the facility is the research. Peter Jacobsson, head of the Safety, Health and Environment department, pointed to the expected sustainability innovations of future research as justifying the environmental risks involved in the project:

> This is in a way what motivates the construction of the whole facility. If you see the Environmental Court case you think, why use all this land for building this facility? And it has to be that the research that will be done contributes to a more environmentally friendly and more sustainable future society. There cannot be any other reason. (Jacobsson 2015, personal interview)

A brochure from the ESS maintains that 'new and more environmentally friendly solutions and entirely new technology' may be enabled through the research tools provided by the facility (ESS n.d. a, 9). These hopes are illustrated by pictures of clouds, a wet leaf, and a hand catching drops of water—images that clearly are intended to communicate a commitment to environmental sustainability. Thomas Parker of the ESS argued that much of the science that the facility enables has direct sustainability implications, including research on fuel cells, hydrogen storage, and superconducting materials (Parker 2015, personal interview). Similar remarks were made by Lars Lavesson, project director at MAX IV. Yet, as Malin Åberg pointed out, while instrument design choices affect what kinds of research can be done at the facility, the ESS can never control how the research results are used: it can contribute to more sustainable materials and products, but it may also be used to create new kinds of weapons, for instance (Åberg 2015, personal interview). This reflection is important, as it points to the obvious uncertainty of future scientific research: it is impossible to anticipate exactly what the results will be, and how, by whom, and for what purposes they will be used. However, this uncertainty is not much stressed in communications from the ESS and MAX IV. The interviews and the information material that I have studied generally convey a sense of technological optimism and a belief in innovating one's way to future sustainability.

Resistance from local environmental movements

I have shown that both the ESS and MAX IV make ambitious sustainability claims. As outlined at the outset of this essay, the projects are charged with positive expectations regarding future innovations associated with environmental sustainability, reflected in the visions of politicians and planners in Lund. However, environmental concerns have been expressed in relation to the projects, and especially the ESS has generated criticism. In particular, Lunds Naturskyddsförening (LNF) has persistently opposed and criticized the ESS facility (Stenborg & Klintman 2012; personal interviews with LNF members 2015), the LNF being the local branch of the Society for Nature Conservation (Naturskyddsföreningen), which was founded in 1909 by a group of academics and is now the oldest and largest environmental organization in Sweden.

Already in the first planning process of the facility, around 2002, a group dedicated to contesting the project was formed within LNF. This group has worked continuously over the last decade, mainly through formal decision-making processes: they have participated in stakeholder meetings and dialogues and submitted formal reports and consultation responses to the municipality and to the Environmental Court. They have also organized public events and drummed up media attention (*Skånska Dagbladet* 2010; *Sydsvenska Dagbladet* 2012; Anderberg 2015, personal interview). Local resistance has primarily been directed at the ESS, with very little opposition to MAX IV. This seems to be related to the fact that the ESS is the bigger facility, with greater demands for energy and land and causing greater ionizing radiation and using more chemicals. MAX IV was described by one respondent from LNF as the ‘little brother’ of the ESS. Furthermore, unlike the ESS, MAX IV has not been subject to Environmental Court testing, which may signal to the public that its environmental impact is not so worrying. My respondents also suggested that since many LNF members are affiliated with Lund University, the fact that MAX IV is Lund-based and connected to the university may be a reason why it has met less resistance. Margit Anderberg, who is part of the group within LNF working against the ESS, told me that she has talked with many people at the university who were sceptical about the ESS, while they had no concerns about MAX IV. She argued: ‘ESS is different in the sense that it is not primarily a research project, but a political project. MAX is a research project … the ESS is driven by politicians who want to generate employment opportunities, or increase the appeal of Lund. There are many such arguments behind it' (Anderberg, personal interview 2015).

While LNF has been responsible for the most consistent and high-profile critique, resistance to the ESS based on environmental concerns has been articulated also by other groups, including the Federation of Swedish Farmers and the Anti-nuclear Movement (Stenborg & Klintman 2012; Anderberg 2015, personal interview; Widstrand 2015, personal interview). The resistance to the issue of radiation safety by the Anti-nuclear Movement (Folkkampanjen mot Kärnkraft och Kärnvapen) deserves a special mention. This movement grew large and influential in the late seventies and early eighties, when the debate about nuclear energy peaked in Sweden. During the cold war, the fear of nuclear weapons added to the general nuclear scepticism. Since the end of the cold war and the coming of climate change to public attention, making greenhouse gas emissions seem a more urgent threat than ionizing radiation, the general interest in nuclear safety has faded. The Anti-nuclear Movement is still active, but quite small. In relation to the ESS they, like LNF, have mainly confined their criticism to stakeholder meetings and formal consultation responses, but they have also organized public seminars and gained some media attention (ESS 2012; *Sydsvenska Dagbladet* 2012). The Anti-nuclear Movement activists are generally concerned about ionizing radiation, and especially oppose the placement of the ESS in close proximity to people's homes. Their main worries are the risk of contamination of local drinking water, and explosions that may cause ionizing radiation to spread across populated areas (Widstrand 2015, personal interview). A respondent from LNF raised similar worries, arguing that

> the risk may be small, but the potential consequences are very serious, and therefore the ESS should not be placed so close to the city. An accident can cause radioactive leakage, and that risk itself should mean that the facility should be placed in a less densely populated area, even though that may have been less practical. (Anderberg 2015, personal interview)

In addition to concerns about ionizing radiation, other environmental issues have been raised by LNF. The organization's main criticisms of the ESS's siting are as follows: (*a*) the high energy requirements; (*b*) the risks associated with ionizing radiation and the use of chemicals and toxic materials; (*c*) the use of land, including landscape changes, threats to biodiversity and water, and loss of farmland; and (*d*) CO_2 emissions caused by the construction of the facility (LNF 2012a; LNF 2012b; LNF 2014; Anderberg 2015, personal interview). As shown in the previous section, all of these concerns are to some extent addressed by the ESS and MAX IV as part of their ambitions to create themselves as sustainable, both rhetorically and in practice.

Articulating resistance in Lund

Environmental organizations have historically played an important role in Swedish environmental politics and the shaping of environmental legislation, objectives, and decision-making processes. They continue to play a vital role as political advocates and watchdogs (Hedrén 2002; Jamison 2001). The Society for Nature Conservation, of which LNF is a local group, has a good reputation and legitimacy among politicians and the general public. However, my conclusion is that environmental organizations cannot diverge too far from mainstream environmental debates without losing legitimacy. The past decades have seen a trend of shifting ideological stances in environmental organizations. This reflects a general political shift from radical criticism of the socio-economic system to a stance more in line with ecomodernization, suggesting a reform of existing institutions rather than their dissolution (Mol 2000). Such a turn has been seen in the Society for Nature Conservation (Anshelm 2004). Emelie Stenborg and Mikael Klintman (2012) list a number of challenges that the local group LNF have faced in their resistance to the ESS. First, there has been a lack of active support from the Swedish Society for Nature Conservation at the national level, which LNF member Margit Anderberg (2015, personal interview) confirmed, attributing it to the fact that Lund is perceived as provincial and therefore unimportant by the Stockholm-based national organization. Secondly, LNF claims to have worked against a solid wall of established local and regional politicians and authorities, and a prevalent media and public perception that the placement of the ESS in Lund had already been settled long before it actually was (Hallonsten 2013), which created the impression that it was already a lost cause. Thirdly, working with negative messages, such as information about environmental risks, means there is a danger of being thought reactionary.

This third challenge is especially interesting for this study. Given the dominance of ecomodernization perspectives in environmental politics, public debates, and mainstream environmental organizations, it is difficult for environmental movements to criticize projects that are associated with development and progress and still be perceived as legitimate. As described above, the ESS has avowed ambitious sustainability ideals and has great hopes for scientific advances that will ensure future sustainability. This makes it very hard to criticize it without being dismissed as Luddites, especially in a university city like Lund, with a deeply rooted self-image of being at the cutting edge of science. Environmental movements need to navigate this faith in science as a key to environmental sustainability. While at first objecting to the facility being placed in Lund at all, once that was settled the environmental resistance groups moved on to focus on specific problems, such as radiation and electricity consumption. Their strategies have been largely in line with the formal processes of decision-making, where they have submitted comments and objections at every stage and to the various authorities in charge, from Lund Municipality to the Environmental Court. A respondent from LNF expressed concern about the institutional procedures for approving the ESS, arguing that they are scattered among several authorities with little coordination between them, and that the projects are approved in incremental steps, which makes them hard to overrule. Such processes require a strong civil society, she argued, but special-interest organizations have a difficult task: they are expected to act as watchdogs, yet they have very little resources to do so, and rely to a great extent on voluntary work, while an actor such as the ESS can afford to hire people to manage their public relations and contract one of Sweden's leading business law firms to work on their Environmental Court case.

The impacts of resistance

While the environmentalist opponents of the ESS have not been able to raise wider popular awareness or resistance, they have managed to impact specific aspects of the project. A prominent example is the use of mercury. Originally, the ESS considered selecting mercury as a target material in the spallation process. This was heavily criticized by local environmentalists, since mercury is highly toxic. One cubic meter, or 13 tonnes, of mercury would have been needed, and even if the risk of an accident was considered low, a release of that magnitude into the environment would cause great damage (Agrell 2012; Stenborg & Klintman 2012). Since 2009 there has been a general ban on mercury in Sweden. Special permission to use it may be given, and it is likely that the ESS would have obtained such a permission had it been requested (Stenborg & Klintman 2012). However, in 2011 the ESS decided to change the target material from mercury to tungsten. While the ESS, in its own material, claims to have independently found that tungsten is a better-suited material (see the ESS n.d. b), the local environmental movements attributed the change to their persistent lobbying (Stenborg & Klintman 2012; personal interviews with LNF members, 2015; Widstrand 2015, personal interview).

A respondent from LNF claimed that apart from this specific issue, the ambitious green profile of the ESS is itself a result of pressure from environmental movements. At the beginning of the planning process, she claimed, environmental sustainability did not feature on the agenda, but after the ESS had begun to take the criticism seriously it was incorporated into the organization, and is now taken for granted by the current staff, and, as addressed above, narrated as part of the collective memory. The respondent reflected that LNF and the other environmental movements may have indirectly contributed to the choice of Lund as host for the ESS, since environmental aspects are considered to have played some role in the process. However, she continued, the criticism posed by herself and others has meant that the facility is being constructed in a more sustainable manner than would otherwise have been the case. This does not mean that all the potential problems are solved, of course. Though it is now clear that the facility indeed will be constructed, LNF and other groups keep monitoring the project, acting as a watchdog keeping an eye on local, regional, and national authorities.

Conclusions

The main conclusion of my study is that the framing of environmental sustainability in relation to the ESS and MAX IV has taken place within a framework of ecomodernization. This perspective argues that existing economic systems and ways of life do not have to be abandoned—as more radical and system-critical green approaches would argue—but can be maintained through technical solutions and innovations for resource efficiency.

The hopes and fears about the environmental sustainability impacts of the ESS and MAX IV are legion. Environmentalist opponents have expressed concern, mainly regarding energy consumption, ionizing radiation, toxic materials, and land use. These aspects are also referred to as sustainability challenges in official communications from the ESS and MAX IV, and were raised in interviews with staff members of the two organizations. The message here was generally reassuring: both the ESS and MAX IV communicated an awareness of these potential problems, and a determination to manage them in the best possible way to minimize risks and negative environmental impacts.

While certain environmental issues have generated resistance and concern, a key idea about the sustainability impacts of the two facilities seems not to be negotiable: the positive outcomes that they will generate in the form of eco-friendly innovations and technologies. This was repeated in the official information material and in the interviews with staff members, who maintained that the facilities' demand for resources would be justified by their expected scientific contributions to increased sustainability. The high expectations of the facilities' ability to solve environmental problems are also evident in Lund Municipality's hopes for a more sustainable urban life. As illustrated by our visit to Brunnshög, MAX IV and the ESS are clearly integrated in the municipal planning and visions of the future. The *Sustainable Brunnshög* project embodies an ecomodern dream, where environmental sustainability is envisioned to be achieved through the input of the latest technology and knowledge, and inspired by the scientific innovations that come out of the research facilitates. When local environmental movements have been critical of the facilities, they have used existing channels, and have not sought to question the ideals of knowledge, modernization, and scientific progress.

I conclude that while the stakeholders have different interests in and understandings of sustainability, they cannot diverge too much from the ecomodernization perspective. The various actors that I have included in this study thus have all had to embrace a progress-oriented, knowledge-intensive, institutionalized vision of environmental sustainability if they were to be taken seriously, given the dominance of this perspective in local and national politics and public debate. Environmental sustainability in this ecomodern sense can be regarded as a boundary object: an ideal that everyone can agree on, despite their different interests and objectives.

Mobilizations and contestations of boundary objects such as environmental sustainability, which are vague enough to be charged with various and shifting meanings, need to be understood in their specific contexts. It has been noted elsewhere that ecomodernization is especially influential in Swedish environmental politics and public debates (Lidskog & Elander 2012). I would argue that the positive attitude towards innovation and scientific progress, which is part of an ecomodernist view, may well be especially strong in a university city such as Lund, with high average levels of income and education, and an established self-image as a hub for knowledge and research; the slogan of Lund Municipality is 'city of ideas'. A tradition of modernity prevails here that is difficult to oppose. The environmental debates and negotiations about the research facilities in Lund are thus situated within a very particular realm, characterized by trust in knowledge and scientific progress. The actors that I have studied may therefore not only have to relate to a Swedish environmental mindset, as suggested by at least one member of the ESS staff, but to Lund's particular sustainability mindset. Or, perhaps, the Lund mindset common to the predominately well-educated upper-middle-class individuals who are involved in municipal decision-making and planning, the development of the ESS and MAX IV, *and* the local environmental movements. In light of this, the statement from a respondent at LNF that the ESS is a politically motivated project, compared to the research project that is MAX IV, is interesting. This and similar remarks from local environmentalists suggest the ESS's delegitimization among its critics, based on the perception that it has less genuine research ambitions than MAX IV, in line with the strong belief in science as a path to increased sustainability. The ESS is here portrayed by environmentalist critics as the wrong kind of modern—a project steered not by a thirst for knowledge but by political interests, and therefore less trustworthy.

Several positive effects can be attributed to the attention to environmental sustainability among the actors considered in this study. Driven by the ecomodern ideals of sustainability popular among politicians, planners, and the general public in Lund, and indeed Sweden, both the ESS and MAX IV have exerted themselves to make their facilities as resource-efficient and environmentally friendly as possible, recognizing the challenges of energy consumption, radiation safety, and land use. Local environmental organizations have played an important role in this by putting pressure on the facilities. However, when the ESS and MAX IV set out to reduce energy consumption or environmental risk, they will not only build facilities that are arguably more sustainable than existing facilities built using conventional methods, but they also contribute to promoting a certain ecomodern notion of environmental sustainability, which holds that facilities such as these *can* be constructed and operated in a sustainable manner, if only the adequate technologies are used, and that they will have positive sustainability impacts through the scientific results they generate. Lund Municipality helps promoting the same ecomodern notion of environmental sustainability when they envision the ESS and MAX IV facilities within the logics of sustainable city planning. An ecomodernization perspective is inscribed in local policy- and decision-making processes and Swedish legislation. Local environmental organizations such as LNF have to articulate their claims in line with these principles if they are to be thought realistic and potentially have some impact. Thus, these environmental organizations—deliberately or reluctantly—ultimately contribute to the legitimization of an ecomodernist approach to sustainability.

Finally, environmental sustainability is not a neutral description, but a normative and politically charged concept. Due to its prevalence, the ecomodernist perspective on sustainability might appear unquestionable, the only logical and possible position. Yet, an ecomodern conceptualization of environmental sustainability is not coherent or stable, but in need of continuous reinforcement and reaffirmation, and subject to challenge. Recognizing the situated and contested nature of the notion of environmental sustainability is important in order to grasp the dissonances and shifts in meaning, and to trace the processes of sustainability-making as they play out in particular times and places.

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5. Looking at value-making: Cod and scientists swimming their own way

An interview with Kristin Asdal by Anna Kaijser

Kristin Asdal is professor at the Centre for Technology, Innovation and Culture at the University of Oslo. Coming from a background in economic history, she later moved on to science and technology studies (STS). In her work, Asdal has explored encounters between natural science and economics within politics and administration. She is particularly interested in the politics and performativity of methods, and has published extensively on empirical studies of 'nature'. She is currently managing the ERC grant 'Enacting the good economy—Biocapitalization and the little tools of valuation'.

During a visit to Lund in April 2015, Asdal gave a lecture based on her studies of practices of valuation. Valuation is a concept that has lately gained interest among STS scholars. In a recent publication, Asdal explores valuation practices by looking at innovation documents aimed at enabling a new blue economy and the farming of new species, such as Atlantic cod (Asdal 2015a). This so-called blue revolution, where fish are envisaged as being farmed rather than caught, Asdal argues, must be linked to wider economic processes, which involve the production of value from life in new, inventive ways. Importantly, Asdal points out, the emerging bio-economies are expected not only to produce straightforward economic value, or profit, but also contribute to other values, such as sustainability and welfare for humans and non-humans. Science is listed as a core asset in the bio-economy, as scientific knowledge is called upon—for instance, to provide knowledge about the life and habits of the Atlantic cod—in order to succeed in boosting the economy and producing new versions of value. Science is thus becoming closely entwined with policymaking and the economy. Studying these entanglements poses analytical as well as methodological challenges, Asdal argues. She not only suggests novel ways of conceptualizing and analytically describing value-making processes, but also suggests methodological tools and approaches. For instance, in her lecture she referred to her method as 'staying with the documents': as a methodological device, rather than looking too much into the external context in which the innovation documents are produced, she wants to tease out contexts from within the documents (Asdal 2012). She approaches the documents as lively valuation agents, and urges us to take an interest in what the documents 'do' as part of the machinery of value-making.

Asdal's research is relevant for the study of new big science in several ways. Like aquaculture projects, facilities such as the ESS and MAX IV are subject to a wide range of expectations regarding their ability to create value in the shape of scientific progress, job opportunities, and innovations for environmental sustainability, for example. A key theme in Asdal's work is the issue of time and timing: the timing of innovation and economic processes that become co-dependent on the times and rhythms of the scientists and the codfish. Similarly, the realization of the ESS and MAX IV involves the interweaving of several time logics: the times of site decisions, financing, and permission processes; dialogues with stakeholders; construction and the management of the physical facilities; the beamtimes assigned to researchers; the scientific procedures of project design, writing, peer review, and publication; the social scientists and humanists following the process; and so on. These all entail their own times and rhythms, which need to be adjusted and reconciled, sometimes awkwardly, in the processes of value-making.

As becomes evident in the essays of this volume, new big science involves and entangles a variety of actors, sectors, and logics, posing similar methodological challenges as those encountered by Asdal for us who seek to study them. In this interview, the primary focus is therefore on methods.

You work with the concepts 'values' and 'valuation'. Would you say something about how you understand them, and how you engage them in your analysis?

There is a proliferation in the concept of value. Value-making is everywhere. It appears in a variety of contexts, including policy documents, strategy plans, and innovation reports. Thus it should attract our interest as an empirical phenomenon. Very often, the value concept is being made to belong to the field of economics and economists, with a focus on economic value, profit and increased production, but there is a theoretical or analytical side to the concept that is worth exploring. It is therefore important for us in the social sciences and the humanities to take an interest in values. Valuation is analytically interesting because actually it has no defined or definite meaning. Is it a price? Something that we praise, or appreciate, or care for? What kind of value-making are we talking about? I and other STS scholars employ the concept of *valuation*, which goes back to John Dewey's work. We are interested in valuation as a practice. I study practices of valuation as they are being done by what I call 'little tools', which are material–semiotic entities.

So how do you go about tracing such practices of valuation? In the seminar here at Lund University in which you presented your work on valuation, you suggested that we may approach the documents that we analyse as our material as a field, and your methods as a version of ethnography. Can you elaborate on that?

I should be careful not to give methodological recipes. However, what I have done, for instance, is to approach innovation documents in this way. I trace how valuation practices are part of these documents, and suggest seeing these documents as what I call 'innovation devices' and 'value agents'. So, I try to read these documents as my fieldwork: paperwork as fieldwork, as a site for the study of practices. Innovation documents can be seen as a series of works that act upon the very issue in question. The specific set of documents that I refer to here are innovation documents that seek to enable new versions of the economy—a specific version of the bio-economy. More precisely, they seek to enable the farming of a new species, namely the Atlantic cod. There is more to this strategy than straightforward efforts at profit-making. A series of value questions need to be solved. For instance, how do consumers value the Atlantic cod in a farmed version? Is farming appreciated? How? To what extent? By way of these innovation documents, actors are drawn together around the innovation problem. For instance, particular forms of research are appreciated, such as coordinated action and close forms of cooperation between researchers and other actors.

Theoretically, I seek to bring together discourses on value that have been running alongside one another in the social sciences. These include economic sociology (the social construction of values), Foucauldism and Marxism (a concern with how bodies are inserted into the economy, and eye for the materiality of the object), and economics. I point to different traditions and to challenges in drawing them together. I suggest the notion *co-modification*—which is meant to address the fact that in valuation processes, like the ones I have studied, we need to grasp not only how values are socially constructed, worked upon, and modified, but also how the very living object is worked upon and modified as part of the valuation processes; how these interfere with its biological rhythms, reproduction cycles, and time. We as researches in the humanities and social sciences can fruitfully challenge established research practices and traditions by not only exploring *either* the social *or* the material, but seeking to study them simultaneously as practices of *co*-modification. Obviously, the notion is also a play on how entities are being made into commodities, hence made part of markets.

An interesting feature of the innovation documents is how history, or 'the past', is appreciated or valued. This has to do with appreciating—here, a rich history of fishing and fish farming. Norway is presented as a site with specific competence and resources, including a species that has been highly valued over the centuries, namely the wild Atlantic cod. What I draw from my analysis of the documents is that their mission is to promote Atlantic cod as a farmed species, but they end up promoting fresh Atlantic cod.

So in order to 'invent' farmed Atlantic cod they draw on the fresh cod, and add to its value?

Exactly, and, ironically you might say, this becomes part of the marketing strategy for farmed cod. Rather than marketing it as *farmed*, the wild and the farmed are drawn together under the label 'fresh cod'. Hence the wild and the farmed are made not to matter; instead, the 'fresh' is what matters. But the consequence, it seems, is that the consumer is not being informed about the fact that the Atlantic cod that you purchase might in fact be a farmed version of it.

I guess that doing this type of research requires you to be familiar with the context in which the documents are produced? I know that you deliberately don't talk about context, but still, in order to analyse it, you perhaps need to know what is there, what processes of valuation are there to (possibly) link up with?

Yes, that is in many ways right. You need to know a lot more than what you write. Just the matter of choosing which documents to trace and analyse, and not others, is a deliberate action that requires knowledge of their context, in the sense of where they came from, what their (normal) trajectories are, how they are linked up with other sites and other documents, and so on. But rather than approaching context as a kind of passive background, I suggest that we see how context and the very issues that we study go together, and how we as researchers, as well as the actors and events that we study, are involved in 'contexting work' [Asdal & Moser 2012]. Context can be approached as something that is actively being done and something we may seek to trace and follow. Hence, this is still in line with what I advocated above, about 'staying with the documents'.

Again, of course, this is not a recipe. You need to choose methods that you like and that make sense to you. But whichever methods we choose, we need to keep an eye open for the richness in the materials we trace; the richness and complexities of events; actions that take place within them—hence what they do; how they move the world and take part in modifying it, how they are taking part in modifying work [see Asdal 2015b for a more detailed presentation of what she terms modifying work].

Since you have already touched on it, I wanted to ask you about the role of the social sciences and humanities. Can we as researchers be of use in policy or strategy processes? Are there any reasons that we should or should not engage in such processes?

First of all, I think we need to acknowledge that we do not always know what ‘being useful’ is. Latour has addressed this, and pointed out how difficult it is even to be interesting. So maybe we should rather start out there, a little bit more modestly. Because being interesting, doing something interesting, analysing in an interesting way, that is already quite challenging. Part of being interesting is being good at describing. Also, being interesting requires being *interested*—that is, taking an interest in what is actually already there, in our material. This can imply, for instance, providing space for the liveliness of assumedly grey and boring documents. It can imply providing space for the detailed ‘modifying work’ that is investing in efforts to work on the living as part of the strategies to enable future versions of the bioeconomy. We can ask questions such as, Are these good ways? Could they be, or become, different? Whose welfare do these strategy documents work for and what is ‘well fare’ being made to be? We can stay alert, create alertness, to the strangeness and liveliness of grey technologies, grey little tools. There is an overflow, a huge flow of documents that work upon forms of life—our own and others’. Understanding, being alert to, how life and the living are intertwined with the economy and the nitty-gritty practices—the *little tools* that are involved—is a precondition for acting and intervening in these practices. It is also crucial in order to figure out how our own sense of value, what we appreciate and not, might come to matter. Perhaps it is not directly *applicable*, but still I do think it is valuable.

How can these efforts be made available to people outside our small community? How do we make ourselves understood and create curiosity?

We don’t need to *create* curiosity. I think there is a lot of curiosity out there! Moreover, we are often inclined to think that everything happens on the *real* outside, outside our academic communities. But our own research machineries are quite huge. We also need to talk to one another. It might be difficult to find time to talk to different publics at the same time, but there are many medias, platforms, and tools available to us now. And I think we should allow ourselves to experiment more than we do!

Yes, I think you are right: we can experiment more than we do. Perhaps my *question comes from the frustration of trying to frame ideas on specific requirements, which place a lot of focus on policy relevance, for instance.*

Kerstin [Sandell] said something, when she talked about the work of Hans-Jörg Rheinberger, about the quest- or question-making machinery. We can regard policy reports and research programmes as question-generating machineries. They allow us to articulate, while at the same time experimenting.

Yes, and I also think because of that it is important for us as social scientists and humanists to describe our methods carefully. Because we use methods that are very particular and thought through and often rigorous, and if we don't put words to them there is a risk that they are mystified, or simplified.

Yes, I think you are right that we need to capture and specify our methods, and that rather than providing frameworks or theories that should be simply 'applied'.

So, talking about another kind of science and scientists, how do you perceive the role of science and scientists in the innovation strategy processes that you are studying, and more generally in processes of co-modification and valuation? What is science mobilized to perform here?

In the paper on innovation strategies and cod-farming that we have been discussing, I very briefly refer to how the Atlantic cod may swim in its own direction: in directions that were not expected and which also escape or resist innovation strategies and scientific projects. In parallel ways, scientists also find ways, if not to escape, then to work in their, or our, own ways and directions. Scientists work on and modify situations, demands, and projects. They twist and tweak their own time, resources, and curiosity, and, at least sometimes, do things differently than what was expected of them.

So, the scientists are taking part in the co-modification?

Yes, you can say that.

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6. How new things come into being

An interview with Hans-Jörg Rheinberger
by Kerstin Sandell & Catherine Westfall

Hans-Jörg Rheinberger, director emeritus at the Max Planck Institute for the History of Science in Berlin, has written extensively on the epistemology of experimentation in the life sciences from a historical and philosophical perspective. His 1997 book *Toward a History of Epistemic Things* is a historical study and a philosophical assessment of biochemistry on its way towards molecular biology, concentrating on protein synthesis research in the period 1947–1961. In *An Epistemology of the Concrete* (2010) he brings together case studies and theoretical reflections on the history and epistemology of the life sciences more broadly.

Rheinberger has a degree in philosophy. In addition to this, in the 1980s he worked in molecular biology and obtained a Ph.D. and his habilitation in this field. Thus he has first-hand experience of the everyday work of the respondents in the present project, and a deep knowledge of the experiments themselves. In this interview we asked him about his concept of experimental system, based on our readings of his work and our own research on large-scale facilities.

Rheinberger's book *Toward a History of Epistemic Things* (1997), in which he elaborates on his concept of experimental system, came out at a time when studies of science were starting to take a more praxis-oriented approach. Earlier approaches to experimentation had been more philosophical, with an underlying understanding of the unity of science, and the role of experiments defined as confirming or falsifying theories. Rheinberger here stands for a more open approach, for in studying experimentation he also emphasizes the open-endedness of experiments. He draws on philosophers as Ludwik Fleck, Gaston Bachelard, and Georges Canguilhem to chart both the history of epistemology and the ways science is formed in specific collectives.

Experimental systems, according to Rheinberger, are the smallest integral working units of research in which the division of epistemic things and technical objects is relevant. *Epistemic things* are the material entities that are manipulated in experiments—things that scientists want to know from their research, in other words. They embody what scientists do not yet exactly know and emerge from the analysis of the experimental data as knowledge entities that often take the form of models. On the other hand, *technical objects* are defined as the technical conditions—the research technologies used to probe and shape the epistemic things. In the context of the ESS and MAX IV, the technical conditions can in the first instance be equated with the instruments. When epistemic things take form, the experiments used to know them become standard techniques, tools for mundane mapping as it were. This is because what has been learned is incorporated into the future development of technical conditions, into new or modified instruments. For example, the mechanism of protein synthesis, which Rheinberger writes about, started out as an enigmatic, essentially unknown epistemic entity. Once some of its aspects were delineated, they were soon turned into standard techniques in molecular biology, forming the basis of new experimental systems, and at the same time opening the way for researchers to pose new questions.

Can you tell us a little about what led you to develop the concept of the experimental system?

Experimentation has always been the subject that interested me most, because it is so deeply rooted in the sciences to find out new things, and experimenting is the way to do so. I have always been much more interested in the opening of new research horizons than in processes of closure. I grew into the history of science at a time when a considerable part of the community was working on processes of closure, for example metrological standardization, or the social settlement of controversies that cannot be solved scientifically. You may think in this respect of the work of Harry Collins in the middle of the 1980s, and of Peter Galison's *How Experiments End*.[10] I was interested in the other side: how experiments start, how experiments develop, and what kind of openings experiments can produce. I soon realized this is not something happening in a flash. If you are interested in experiments, you have to look at how an experimental process extends over time. In all events, experiments are not singular feats; they rather form chains that relate to one another. They are usually recursively bound to one another. So each step forward, if it is of importance within this particular experimental context, retroacts on the whole arrangement, and becomes integrated into it in one way or the other. Or it leads to the exclusion of a particular instrument that looked promising, but turns out not to be so.

When I try to delineate what an experimental system is, as the smallest possible integral working unit of the empirical sciences, I also understand it as the unit that produces what scientists call 'results'—the currency of the experimental sciences, the primary products of research. If you go to a conference, scientists usually talk about their 'findings', their recent 'results'. These are the immediate products of experimental work within the units that I call experimental systems.

It appears to me that this way of looking at research opens the possibility of bringing together different factors or aspects of scientific work—besides the epistemic and the technical ones—such as social factors, how people work together, or the spatial architecture within which a particular experimental process is initiated and then carried on. Of course, the material environment is very important. We are not just dealing here with what is only in people's minds, but really the materials and the material environment they are working with. They are part and parcel of the process, and must be taken seriously.

For example to make them actors?

It is not necessary to turn them into agents like living beings, but they

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[10] See Galison 1987; Collins 1985.

have a particular presence that one has to take into account, I think—as the material environment, as the social environment, as the cultural setting. All these aspects go into shaping an experimental system. It seemed to me that with that unit of analysis [the experimental system], one could deal with the sciences, including the perspectives of the philosophy of science, the history of science, and the sociology of science, without having to confess to belonging to one discipline or another. The experimental systems perspective contains all of them. That way you can situate yourself beyond these disciplinary boundaries, and, most importantly, it allows you to do this without having to appeal to 'interdisciplinarity' or 'transdisciplinarity'. This is a vocabulary that presupposes the disciplines, which is a problem if you do not feel it is meaningful. That made the concept of the experimental system attractive to me, I would say.

Are experimental systems predetermined?

It appears to me—we are talking here about paradigmatic cases of a research process in which something new happens along a trajectory—that we cannot talk about predetermination in this context. When discussing this topic, what comes to mind is the way Thomas Kuhn thought about the sciences towards the end of his career, when he said that, taken as a whole or in parts, they are not defined in a teleological manner.[11] The sciences are not processes oriented *towards* something, something out there that you can define and then approach. On the contrary, what we can do as scientists is to *move away* from a given state of knowledge, on to something that cannot be anticipated. So, experimental systems are neither predetermined in terms of an origin nor predetermined in terms of an endpoint.

Have experimental systems always existed historically?

No. Experimental systems were not always simply there. They did not exist in the early modern period. You could not use the category of experimental system to do a meaningful and pertinent analysis of the work of, say, Galileo Galilei on falling bodies or his observations of the moon.

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[11] Kuhn 1992.

Experimental systems are a more recent development. But looking back over the past two centuries, it is fair to say that experimental systems are working structures that obviously have proved useful for practising the art of empirically exploring the unknown; otherwise they would not have come into existence in the course of the development of the modern sciences.

If we look back to the second half of the eighteenth century we see that *avant la lettre* biologists *did* talk extensively about systems. But they did not mean experimental systems, they rather meant systems of nature—for example, the *Systema naturae* of Linnaeus, or the protogenetic 'system of germs', be it of 'sperm' or of 'eggs', meaning that people thought of life as being preformed *in toto* in what they perceived as spermatic animals, or else in the eggs. All these ideas about nature were built on the notion of system. But they were systems of thought. Into these systems of assumptions, experiments or observations were sporadically inserted, for the sake of supporting the argument. But the experiments whose results were inserted into these systems of thought were not a driving force for the establishment or for the change of these systems.

Two hundred years later, it is the other way around: experimental systems are the material structures that constitute a historical trajectory. In my book on *in vitro* protein synthesis research, I have shown one of these trajectories in detail, and also laid out what kinds of theorems eventually had a chance of being inserted into them. So it appears that the relationship between theory and experiment has been turned upside down. No longer theory first; instead, experiment first.

As far as I can see, the research structures that I call experimental systems have been the moving forces in the development of the sciences in the twentieth century. As a consequence, in the first half of the century, there was a profound shift in disciplinary boundaries, including the hybridization of disciplines, and more recently the result of their dynamic potential has been a destabilization of the boundaries of scientific disciplines altogether. Disciplines were the superstructures within which the exploration of the unknown in the form of experimental systems could emerge. Disciplines largely dominated the sciences in the nineteenth and early twentieth centuries. In the second half of the twentieth century, the products of these disciplines—experimental systems—appear to have more and more eroded these superstructures from within. What took their place are much more mobile assemblages of experimental systems, or cultures of experimentation. Experimental systems do not exist as isolated from one another; they come in bundles, they come in assembalges that are addressed appropriately, I think, with a term such as *experimental culture*.

Originally, I picked up the concept of experimental systems as it was used in the research literature, more or less in a colloquial fashion. Scientists talk about systems when they talk about their work, sometimes only systems, sometimes more explicitly experimental systems, at times also model systems. Scientists use these terms quite naturally. What fascinated me was the historiographical potential of such a notion. It could be picked up, taken out of the context in which it was used as an actor's category. It could be used as a category for doing the *history* of science. It could help to assess these environments in which experimental research processes are going on.

Can you tell us a little more about how you draw the boundary between epistemic objects and technical things, and about the significance of this boundary?

Yes, this is a distinction that has occupied me for quite some time. An important aspect of it concerns the interface between a particular research technology, or a number of such technologies, and the scientific object that they engage with. It is quite interesting to see that not everything can become an object of investigation for a particular technology. Scientific object and technology clash at an interface; they need to be adapted mutually. On the one hand, what need to be taken into account are the physical conditions of the instrument. These conditions are usually malleable only to a certain extent. On the other hand, there are the conditions of the objects that one would like to bring into interaction with the instrument and find something out about them. So, these points of intersection are absolutely crucial. They decide whether this instrument can be used as a research tool in this particular instance or not. They are of paramount importance if one is interested in a microscopic perspective on what is going on in an experimental system. Take X-ray crystallography. For X-ray crystallography to be used for doing biological studies, the absolute requirement is that the biological object of interest can be crystalized. Otherwise the technology cannot be used. Various questions arise from this. Which conditions to create? What kind of distortions do they introduce into the object of investigation? And how far can one go without ending up with artefacts? All this forms a package that sits there at the very interface between the object of investigation and the instrument. I think one should write the history of research technologies as a history of this boundary and its manipulation.

What do you think about the extension of this process over time? What kind of trajectory do experimental systems have?

If you look at these processes in terms of a historical trajectory, you have to take into account not only what happens at a particular point in time, but also what kind of changes it produces over time. The example of protein synthesis has always been very telling for me in this respect. It started with a medical—more precisely, an oncological—question. Then it moved on to the identification of a biochemical substance that the world of chemistry had never thought could exist. It was a hybrid between a nucleic acid and a protein. Proteins were known as polymers of amino acids, nucleic acids were known as polymers of nucleotides. But that there could be a hybrid molecule that consisted of building blocks of both these classes of macromolecules came as an absolute surprise. In turn, this hybrid molecule revealed itself to be the Rosetta stone for deciphering the genetic code. All these massive reorientations happened along the trajectory of one and the same experimental system that, of course, was refined and got more and more sophisticated over time. But the overall configuration remained stable for over twenty years and several generations of postdoctoral students joined the endeavour. So, there is no linearity built into an experimental system, although it confines what you can do within it. What is more important, it makes these unexpected moves possible that, however, without such a confinement, would be impossible.

We would like to explore with you how experimental systems could be used to understand instruments in large-scale facilities. One division that reoccurs in Kerstin's interviews is the one between experienced users, often physicists who know the instruments intimately, and users who use the instruments more as tools, wanting to be able to put in their samples and get readable data out. What would be your thoughts on that division?

Of course, my perspective is dependent on the area with which I am familiar, which is more the life sciences and less the physical sciences. It is certainly possible to divide people into these two categories, but it is also a somewhat dangerous categorization. Let me rephrase your question in the following terms. In scientific research, you have people who are doing what can be called problem-driven research. They are always looking for tools that they hope could help them find aspects of the solution to the problem they are working on. They are problem-fixated, not instrument-fixated. The other category could be called technology-driven people. They stick to an instrument and try to do everything that can be done with this instrument, and, of course, improve it along this line. The point, however, is that both categories of scientists are experienced people. It depends on the perspective. One group wants to use a research technology as black-boxed as possible in the context of a particular experimental system. The other group turns a particular instrument, or research technology, itself into an experimental system.

I think that the notion of experimental system helps to deal with both of these groups. The important thing is—and this leads us to the core of such a system—the dialectics between epistemicity and technicity, as it were; that is, the interplay between epistemic things and technical things or technical conditions. I find this particularly interesting because, as a rule, when engaging in a research process, people don't do this or that for a couple of weeks and then move on to do something else. For many it is the job of a lifetime. Thus they really engage with the problems at hand. It is their epistemic *Einsatz*, as we would say in German. In the process, bits and pieces of such an epistemic thing can be sharpened; they can gain contours, to the extent that they become transformed into technical entities. As such, they can typically become a more or less unproblematic piece of equipment of the on-going research process. This kind of recursivity is the driving force of the experimental process as a whole. It is not only that it eventually leads to results that make their way into the world; it also leads to results that are retroactively integrated into the experimental process itself. In turn, this can open new vistas, new avenues, to the extent that one engages in a different direction. Autopoiesis is probably not a very good word, but it indicates that in research, we have to do with a process that is creating its own dynamics.

Many of my colleagues use the term technoscience for the contemporary mode of doing science. I have always been a little bit critical about this conflation. Nevertheless, I think that there is a deeply entrenched internal relationship between epistemicity and technicity in the way our modern sciences work and function. But precisely because of this dialectical relationship one should not confuse the terms. This relationship is in operation regardless whether you work on the characteristics of a particular macromolecule or on an aspect of a particular research technology.

Let me briefly come back to the 'experienced user' you mentioned in your question. Jacques Lacan, in one of his seminars, used the notion of 'extimacy' for this kind of experienced-ness.[12] It is a particular relationship that people acquire when they are working for years, in an exploratory context, with the same materials. Intimacy would be the wrong word here. Because this kind of nearness to the material one is working with actually does not result in one being able to manipulate it at will, but that you let it go; you let it expose its own potentialities. So what you have is an attachment and a detachment at the same time, in such a way that your machine plays out its own forces and does not obey your command. So that's what I mean by experienced-ness, in a slightly counterintuitive way.

Have you also seen examples were knowing intimately can create closure rather than opportunities?

The danger is absolutely there. This is exactly the reason why I like and prefer the notion of extimacy over that of intimacy. Extimacy includes not only the necessity of being familiar with the process and material one is dealing with, but also the possibility of detachment. If you lose the option of detachment, you can easily get closure. Then everything starts to turn

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[12] Lacan 1997.

around itself and you won't be able to get out anything new any more. One of the founders of molecular biology, the physicist and geneticist Max Delbrück, formulated this requirement in a slightly different and in a much more colloquial way, when he talked about what makes a good experimenter. A good experimenter, he claimed, works under conditions of limited sloppiness.[13] You have to be precise enough and close to the matter to keep the experiment running, but you also have to keep your experiment loose enough so that eventually phenomena that were not in the focus of your initial attention can sneak in. If your own actual focus becomes dominant, you won't see the side paths anymore. In yet another guise, you can also find a treatment of this idea in the writings of Michael Polanyi. He distinguishes between focal attention, when you glare at and firmly fix on a particular thing, and subsidiary, liminal attention, when you are not really looking straight at it, but rather glossing over.[14] Both kinds of awareness are needed in experimentation; finding the right trade-off is the art of the experimenter. One needs to be precise enough so that the experiment does not dissipate, but you also need to build into your experiments certain little holes through which things that you couldn't have imagined can come to show themselves.

Finally, we would like to ask you what your double literacies—that is, being trained in more than one scientific field—has meant for your work?

Of course my double literacy has been very important for the way I have come to practice history of science. I was first trained in philosophy. Having completed this first cycle of academic education, I started all over again to study biology and chemistry. Towards the end of my philosophy studies, I had become interested in the philosophy of science, and it appeared to me that having one's own experience of science would help when judging the writings of then much-discussed scholars such as Ludwik Fleck, Karl Popper, Thomas Kuhn, or Paul Feyerabend. But then I stayed much longer in the field of molecular biology, doing laboratory work myself, than I had anticipated. I became a molecular biologist and practised

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[13] Hayes 1982.

[14] Polanyi 1965.

the trade for about fifteen years. This experience has been a major resource for my subsequent work as a historian of science. The second resource is the sort of reflexivity that philosophy brings with it for working at the conceptual level. I think this usually doesn't come packaged with a training in the sciences, so here my background in the humanities has been crucially important, including my engagement with French philosophy and history of science. For me, this became a productive combination. Generally, I think this is how new things come into being in the process of generating knowledge, that you bring things and competences that exist apart from one another into vicinity and thus into interaction with one another. Novelty is usually not a creation out of nothing—something new happens at these points of interaction. This holds for empirical *and* for theoretical work.

Can you also find double literacies in experimental systems, and what role do they play?

In respect of the people whose work I have been investigating as a historian of science, dual literacies were generally not present in one and the same person, but different literacies were embodied by different people who were working closely with each other. The protein synthesis research group I studied worked in a lab where people with different educational backgrounds were interacting every day: medical doctors, biochemists, biologists, technicians. So the diffusion was probably of a similar kind. This in itself would be an interesting topic to study—what multiple literacies do for the advancement of science, and whether they possibly can also turn into obstacles. A brief look at the history of molecular biology tells you that many of its pioneers were coming out of chemistry or out of physics, either acquiring themselves a second literacy in biology, or teaming up with one another and thus combining different knowledges. Out of such combination most, if not all, of the major breakthroughs in molecular biology happened. If you look at the research literature from 1945–1965, research papers usually had two to three people as authors, always combining different expertise. And most of them were also international collaborations. Not only did the authors come from different areas of expertise, but also from different cultural backgrounds.

You talk about instruments, but very little about social institutions. Can you see institutions promoting changes and trends, for example medical companies? And how do you view the interaction between social institutions and instruments?

This is an important point, you are completely right. In my work I do not usually emphasize this. This tendency is probably an artefact of my own opposition to doing history of science in a disciplinary framework. There was a time when historians of science were very much inclined to consider the history of disciplines and the kind of institutions that came with the establishment of these disciplines. In contrast, for me it was important to pay more attention to the scientific practices, and these practices are inseparable from their respective instruments, or research technologies.

But you are completely right. If you look at the wider context within which scientific research is situated and developed, institutions necessarily come into play. The sciences are a social, a cultural undertaking. This has to be understood in a double sense. They are an integral part of our culture; they are part and parcel of our social reality like probably few other things in our lives. But scientific practice is in itself also a cultural, a social phenomenon. The social does not just come added to the sciences in the form of institutions. Experimental systems themselves are social, cultural phenomena, as I said at the beginning. The only question is what to concentrate on. When doing history of science, or doing science and technology studies for that matter, I think we encounter a problem that is rather similar to the cases we are investigating. We are also enclosing ourselves in something like an experimental system. We also organize our work into such niches. The point is that we have to be aware of this, that we try to remain able to interconnect with one another, so that in the end, history, philosophy, and social studies of science do not fall apart completely. In that sense your question is very much to the point. Consider our interview as an effort in this direction.

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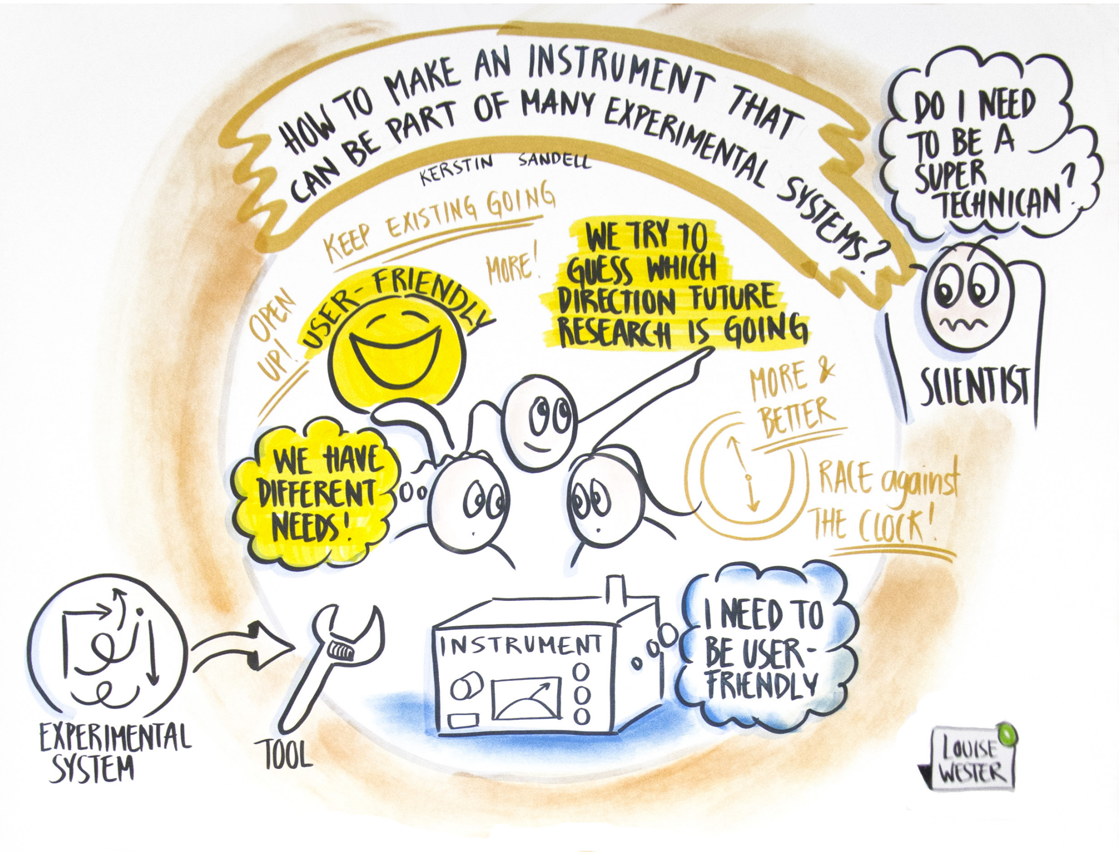
HOW TO MAKE AN INSTRUMENT THAT CAN BE PART OF MANY EXPERIMENTAL SYSTEMS?
KERSTIN SANDELL
KEEP EXISTING GOING
MORE!
OPEN UP!
USER-FRIENDLY
WE TRY TO GUESS WHICH DIRECTION FUTURE RESEARCH IS GOING
DO I NEED TO BE A SUPER TECHNICAN?
SCIENTIST
MORE & BETTER
RACE against THE CLOCK!
WE HAVE DIFFERENT NEEDS!
EXPERIMENTAL SYSTEM
TOOL
INSTRUMENT
I NEED TO BE USER-FRIENDLY
LOUISE WESTER

7. How to design a question-generating machine for the future: Instruments as part of experimental systems at MAX IV

Kerstin Sandell

Experimental science of the kind that will be done at the ESS and MAX IV relies heavily on advanced and costly instruments; unique ones built in specific places to which scientists travel to do their experiments. I am currently studying the process of designing and realizing some of these instruments at MAX IV, the synchrotron facility under construction in Lund. One important aim for MAX IV is to be world leader in its field, that is to be better than all existing facilities. In this it also looks to the future, to provide instruments that are capable of performing tomorrow's experiments, answering the questions scientists will want to ask in the future. Designing instruments for large-scale facilities such as MAX IV is thus to push today's limits while trying to guess which directions future research will take. In this essay, I will inquire into this process of making better instruments, instruments for the future, using the concept of experimental system coined by Hans-Jörg Rheinberger. Empirically, I draw on interviews with scientists involved in developing instruments for MAX IV.

The concept of an experimental system is part of a wider shift in the understanding of experiments in the philosophy of science. For a long time, the purpose of experiments was seen as confirming or falsifying theories. This meant that the way of working was initiated by a hypothesis to be tested in experiments, after which it was found to be supported or it was discarded. Thus experiments were theory-driven (Hacking 1983). Rheinberger's book *Toward a History of Epistemic Things* (1997) came out at a time when science and technology studies were shifting towards practice and an exploration of how facts are made. That meant being interested in the everyday practices of science, but with a focus on closure: Rheinberger, drawing on philosophers such as Ludwik Fleck, Gaston Bachelard, and Georges Canguilhem, is interested in how things are kept open. His reason is that experiments are by and large done to increase the sum of knowledge. In order to be able to discover new things, experiments have to be undetermined: there has to be an aspect of embarking on something that is not fully known. At the same time, experiments and instruments alike build on what is known at the time of construction. As Tim Lenoir writes in the introduction to Rheinberger's *An Epistemology of the Concrete*, 'the instrument represents the material existence of a body of knowledge' (Rheinberger 2010, xiii). It is with this tension in mind between building existing knowledge into the instruments and keeping things open that I approach my interviewees with questions about the design process of the instruments they are responsible for.

As a new facility, MAX IV carries the promise of doing better than earlier facilities, in whatever ways that is measured. The way to gauge this is for me to use a theory of science perspective, put into an ethnographic methodology. I am interested in the pervasive desire in science to see into matter a way of knowing more, discovering, unveiling, and in this the explicit and implicit link between seeing more and knowing more (Haraway 1991; Pomian 1998). Knowing more in itself carries promises—the dream is that this knowledge could be used to provide technological and scientific solutions, which will result in innovations, economic growth, and prosperity. Thus a great many hopes are bound up with these facilities and their instruments, and the kinds of new things they aim to make knowable. I am fascinated by how 'knowing more' relies on the construction and use of more powerful sources/accelerators, advanced and unique scientific instrumentation, data processing, and visualization. To put it crudely, and in sociological terms, I am interested in studying the operationalization of the desire to see and know more.

To help me out analytically, I rely on the concept of experimental system launched by Hans-Jörg Rheinberger (1997). As is evident in the interview with him in this volume, he is interested in the openness and indeterminacy of experimentation, and of how to capture this process theoretically. For this he has coined the concept of experimental system, as the smallest integral unit of experimentation. In these systems, he draws an analytical distinction between epistemic objects (or epistemic things) and technical objects (Rheinberger also uses the concepts of technical things and technical conditions interchangeably). Epistemic objects are the part under investigation, being what one does not yet know. He argues that the epistemic objects

> represent themselves in a characteristic, irreducible vagueness. This vagueness is inevitable because, paradoxically, epistemic things embody what one does not yet know. Scientific objects have the precarious status of being absent in their experimental presence. (Rheinberger 1997, 28)

The epistemic object has to be made possible to probe in the experiment, which means that the epistemic object is contained in or is otherwise characteristic of the sample in some way.

The technical conditions can roughly be equated with the instruments. It has to be possible to manipulate them, since they are to interact with the epistemic objects with some degree of openness or vagueness, yet sufficiently precisely to get at what one wants to know, at what one does not yet know. Thus technical conditions or technical objects provide the context for experimentation.

> It is through them [the technical objects] that the objects of investigation become entrenched and articulate themselves in a wider field of epistemic practices and material cultures. (Rheinberger 1997, 29)

When an epistemic object has become known, to Rheinberger's mind, it ceases to be an epistemic object. Instead, it turns into a model. The new knowledge, the model, can be incorporated into the technical conditions, that is the instruments. When a model is built as a finished instrument, the instrument becomes, in the language of Rheinberger, a tool. This means that the instrument can perform standard routines or measurements of an already known phenomenon. As such, new knowledge, transformed into instruments-as-tools, can be used as subroutines for new or emerging experimental systems. But the instrument is then *not* used to explore the unknown, or as Rheinberger puts it, it is not a question-generating machine. An experimental system can also turn into a tool if it becomes too rigid. In both cases, Rheinberger claims the research system 'turn into devices for testing'.

> They lose their function as machines for making the future. (Rheinberger 1997, 80)

This aspect—that instruments also can be tools—will be important for my analysis, as it is here a tension emerges. Tools are stable, predictable, and provide measurements of something that is known. As Rheinberger writes, 'A technical product, as everybody expects, has to fulfill the purpose implemented in its construction. It is first and foremost an answering machine' (1997, 32). Yet an experimental system also 'has to be kept at the borderline of its breakdown' (Rheinberger 1997, 80) in order to stay sufficiently open and vague. I would argue that the instruments at MAX IV are very much shaped by this tension. On the one hand, they are made to be part of experimental systems not only now, but also in the future: they are intended to play a part in answering what we will be able to ask in the future, and this since experimental systems work as 'vehicles for materializing questions' (Rheinberger 1997, 28). On the other hand, they are made to be measuring devices for things already known, since these measurements provide data on specific samples.

The instruments that I equate with technical objects in this essay will be made to cater for diverse user communities. I take this to mean that they are made to be part of many different experimental systems, probing many different epistemic objects. The questions that have guided the analysis of the interviews for this essay are how the instruments are made into technical objects to enable them to be part of experimental systems, and how they are made to be able to interact with what is not known—that is, the epistemic object. But I also consider whether the instruments also are made to function as tools, able to perform subroutines and providing reliable measurements. I will discuss this in terms of three themes: the issue of scale; the stability and robustness of the instruments; and the communication of familiarity.

The interviews

During the spring of 2015, I conducted ten interviews with scientists involved in the development of the instruments at MAX IV. At this point MAX IV had been built, the accelerator was tested, and the first instruments were being set up on site. The design process, and with that the process of selecting instruments for construction, had started back in 2004, when the plans of MAX IV took shape. My starting point in terms of data was the application for funding for ten instruments that MAX IV sent in to the Knut and Alice Wallenberg Foundation (KAW) in 2010. The response to this application by KAW was that MAX IV had to prioritize among the ten. In 2011, an extended and prioritized application was sent in for seven instruments, which was granted.

I interviewed scientists working on these first seven instruments, as well as those working on the three others that had not made it past that first funding round (one of which now has funding, one is still waiting to be funded, and the third has been turned into a mobile endstation that can be used on several of the instruments under construction). Some of the respondents are involved as senior experimenters, mainly responsible for the underlying science and the dialogue with the users; some are more directly involved in the realization, working with project management, design, and procurement. The interviews were each about two hours long, and were recorded and transcribed. The interviewees have read and had the opportunity to comment on the resultant essay.

The instruments

The beams of X-rays are taken out of the synchrotron ring at different places, making it possible to have many instruments, or beamlines, on the same ring. Each instrument manipulates the beam of X-rays in different ways to shape its characteristics. The components used to manipulate it are commonly mirrors (shifting the direction of the beam and/or focusing the beam), monochromators (selecting specific wavelengths of the beam), and apertures (openings that restrict the size of the beam). The instrument finishes with an endstation where the experimenter mounts the sample, and where there is equipment to have the sample under different conditions—pressure, temperature, magnetic fields, and so on. Lastly we find the detectors, placed to capture the energies and directions of the beam after it has interacted with the sample.

Scale—more and better

Scale is the most obvious factor mentioned in the interviews as making it possible to see new things. It is one of the main reasons for building a world-leading new facility, and indeed is the primary thing the facility has to deliver. It is given by the accelerator, the synchrotron ring, or, to put in in colloquial language, the machine. It is quite simply stronger X-rays beams or more photons, but it also involves the quality or characteristics of the photon/X-ray beam. These are the conditions under which the instruments start out.

One of the scientists recounts a televised round-table discussion among Nobel laureates from 1981 that had stayed in his mind. This was when Kai Siegbahn from Uppsala got the Nobel prize in Physics for developing electron spectroscopy. The respondent remembered:

> Then they [the Nobel laureates] were asked the question—how does science progress? And you expect a very profound answer, Roger Sperry was there also, him of the split-brain, so some really deep ones. And he [Kai Siegbahn] just says—'science progresses by building larger machines, because with them you see more'. Period. Simple as that. Then you think this is embarrassing, kind of simple-minded. But now I am almost there myself—terrible, if you think about it.

Even if new synchrotrons are not always bigger, in terms of greater power to the accelerator and higher energy in the storage ring, scale is still the most important factor in making the instruments better—in this case, the machine produces more photons per unit time. What MAX IV further offers is a beam that is better by being more parallel and coherent. This means that some new things can be done that is on the order of scale—for example focusing the beam on a smaller, indeed very tiny, target. This means there will be more photons on that tiny spot.

The scale improvement for each instrument is transformed into what the designers want it to be best at, perhaps even the best in the world. From this comes the requirements for how the beam is to be shaped, and thus the demands to be placed on the components. Every decision about how to shape the beam has its trade-offs, and being good at one thing can compromise or limit the possibilities of being good at others. The demands on the beam are said to come mainly from the Swedish user community, and more specifically from the MAX IV laboratory itself in terms of instrument scientists, senior scientific management, and the scientific advisory committee. Thus to some extent what is realized is something the Swedish community needs, can imagine, and will be able and willing to use.

The drive towards improvements of scale is always there, as the wish for more. It is a potential, an indication of the future. It is in a way self-evident, in that at least some experiments done today push the limits of what the current instruments can deliver. There is always a need for more photons. It is also self-evident since the understanding is that technology can always improve, can always be done better. Before calling to mind the Nobel Prize discussion of 1981, the instrument scientist had been thinking about techniques:

> So now there is kind of boom in this technique, a technique that up until now has been fairly marginal [at synchrotrons].
>
> Kerstin: Why has it been marginal?
>
> Because we have not had the strong light sources that you need.
>
> Kerstin: So this is linked to the new generation of light sources?
>
> Yes, it's because then you can refine it so you can really accomplish what the technique has promised it could do all these years.

And then:

> At least for some systems,[15] this [the instrument] will provide unique information. In principle we've always been able to do it, but the resolution has been so bad that you could not really see much.[16] You could get some structures in the spectra [output data], but actually there are a lot of fine structures that we now will be able to see. Finally! [Cheerfully] What we have hoped for is here. … we had seen structures that we have had to guess what they are about. Perhaps that's good for your imagination. But sometimes it fails to correspond completely, and with this new [instrument] we can see all these things.

If the optimism about being able to see more is not fully realized by MAX IV, the quest for even better resolution, and thus stronger light, in order to see better will continue. And even if with MAX IV 'we can see all these things', the scientists might be able to see even finer structures that today they do not know of, because they cannot be seen. Again, imagination is all. And the longing for stronger, more, and better—in other words, improvements in scale—will continue.

Using improvements in scale also paradoxically means losing photons at times, and thus you still only have (almost too) few photons for your measurements. Here, calculations and simulations play a central role in judging whether the push in what could be reached will actually produce some usable data. Even with these calculations, there is still a measure of risk-taking involved.

> When you build larger instruments [in this case a spectrometer] they also become more inefficient, you capture less of the light that comes in. But you have to dare to push the limits, even if it might not be enough. Of course, you estimate what signal you're getting out, but sometimes it fail to correspond. But this other group [at another facility] already had the nerve to make the jump to the larger spectrometers.

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[15] Here the respondent uses the concept of a system—an echo of the colloquialism that Rheinberger had picked up.

[16] With more photons per time unit, the resolution improves.

At some point, however, it can be that scale alone does not give further improvements for particular questions, for some epistemic objects, for some techniques. Perhaps there is a point where more photons will not show more. Perhaps the epistemic things will be completely seen, and thus known, whereupon the instrument showing them will become a tool, a measuring device. Being a person who likes to develop methods, one instrument scientist reflects:

> I think it's kind of natural that if everyone is using a method, then you have seen [everything], and you know in principle what it usually looks like and you can be pretty sure about what you're seeing methodologically. The maturity that we have reached is a goal in itself, but maybe not so fun or challenging for me. If the method is mature—that is, you know what answers you will get—then you can use it to create better solar cells or batteries. But methodologically it's over. That's the goal, even if I will be out of job.

To use Rheinberger's vocabulary, this is where the instrument might no longer be part of an experimental system for this scientist. Instead it will function as a tool, able to perform asked-for measurements to optimize, say, fuel cells, but no longer used to ask new questions. Still, when asked again about the future, the instrument scientist starts to think about future possibilities. Perhaps new aspects can be added, or what about time-resolved measurements to see dynamics? Again, the ability to see new things comes to mind, even though the more and the better that the instrument is required to deliver has shifted to other aspects that have not been in focus until now.

However, it is not enough that the machine produces more photons: the photons produced have to be taken care of, and that can also involve orders of scale. Some mentioned detectors as a limitation. If all the photons that interact with the sample cannot be registered, counted, measured, then improvements in scale, in the number of photons, are for now still waiting.

> Right now the development of detectors happens really very fast. They have a life span of three to four years. That's a little scary. So I talked to a colleague and we just shook our heads. But at the same time you know, if you have a leading beamline but not the best detector, you loose out.

There is a constant race to improve that permeates all practices in large-scale facilities. There is almost always room for upgrades and additions, or at least plans for them, in a field that is constantly moving, and where everything could potentially be done better. The goal is to be the best, but also to beat the clock doing it. New facilities are being built, existing ones are upgrading, and new components for existing instruments are continuously being developed and installed:

> So when MAX IV comes online we will be the best for some three to four years.
>
> Kerstin: That's a fairly short time.
>
> Well yes, we do not have long. It [the development] has moved fast.

There is something about wanting to be best that is enticing, yet it is still always negotiable, fallible, or just a victim of a reality principle that says that everything moves and improves. This ambition figures large in the interviews from the very beginning of the preliminary ideas for MAX IV, motivating respondents to engage in this huge project that will move the MAX IV laboratory from being a small national facility to a facility with the eyes of the world on it.

Improvements in scale and stronger X-rays/more photons can be used to see more things in greater detail. Improvements can keep existing experimental systems going, invigorating them, and lifting them out of current guesses and vagueness. Scale thus promises the chance to get at epistemic things that still elude knowing, visibility, and measurability. More and better might also open up for doing new things, or more things, as in a new sample environment. Just what that new might be is still unknown, and is unpredictable. The predominant notion is that something can always be done with improvements in scale: it holds much of the promise of future experimental systems. To be the facility with the instruments that are part of a new, exiting experimental system is to race against the clock, or against other facilities—new facilities and instruments are being built as I write; somewhere there is always an upgraded instrument or component being installed. And thus the demands for resources at each and every facility will never cease—a new detector, a new better mirror—in the pursuit of improvements in scale.

Simple and robust

Doing better, and exploiting the possibilities that improvements in scale offer, invites the scientists to push the new instruments to the uttermost, both in the performance of the components and the daringness of the design. However, in the interviews this was counterbalanced by experiences of how hard it can be to get an instrument running and the harmful effects on the user community if the instrument is not running smoothly enough. Most of the instrument scientists that I interviewed had been at MAX-lab for a long time and had earlier developed and built new instruments or upgraded existing ones. This was expressed in terms of simplicity and robustness.

> It's very, very important to us—it has to be a simple and robust beamline that works. At the same time we have MAX IV, which is a very fine source. So it will actually turn out an excellent beamline thanks to that. But we haven't done anything really extra, just tried to make it as simple as possible with the few optical components we have. Well, it is not anything special, but still it will be fine. And it is very important to the users that come that it is a beamline that works and does not mess up. Because if you open too early or if you open with something that does not really function, then you will get a very bad reputation. And that's bad. So it's better to go for something really stable. Then the users will be happy because the will come home with good data and we get a good reputation.

The beamline scientist here very strongly advocates simplicity and robustness, while relying on the machine itself to make the instrument excellent—meaning that it functions well, especially in terms of getting 'good data' out. The importance of robustness, meaning the ability to keep the instrument running more or less continuously, was also linked in the interviews with the time pressure on the users. When they are at the facility, they have a time slot in which they can do their experiments. Thus they are dependent on the instruments working during that time slot.

> Especially on a synchrotron it is always important to look at user friendliness. Maybe the users have a week, maybe only half a week. So they have to get the results out; everything simply has to be right on the day.

The machine has to be up and running, the instrument operating smoothly (for an in-depth discussion, see Doing 2009). Time is allotted in a peer-review system where users apply for time for their planned experiments. If the experiment cannot be carried out as planned, the user might have to wait months for the next round of applications for beam-time.

Robustness was given different meanings in the interviews. One was that of mechanical stability. This meant that no vibrations from moving parts should propagate through the instrument, or that moving components do not mean having to realign the beam or shift other components. Robustness was also talked about in terms of simplicity—as if robustness is in part created by simplicity. Here moving components were again mentioned, as making an instrument simpler in design could mean limiting the number of components that could be moved in and out of the instrument and how they are moved. At times, simplicity was also articulated as the basic shaping of the beam with mirrors and monochromators—a fairly straightforward affair in terms of how to choose the outline and placement of components. Another aspect of simplicity was designing an instrument to do too many things, largely because that too usually involved moving and/or readjusting parts.

> I would say the guiding principle is not to make an instrument that can do everything. Make a simple beamline that is more limited, but is bloody good at it. Anything complicated that can be made simpler with a compromise, then I choose the simpler option. Because it costs so much more to get those instruments operating than anyone wants to imagine

> from the beginning. They're optimists, they think we'll be up and running fast, that it'll be fine. Maybe that's the push that gives you energy to do it, but, well.

Simplicity of design is also mentioned as a quality in itself, as a thing of beauty that equates to functionality. Several respondents talk about simplifications made in the development of the design, as an art in itself.

Another way of ensuring robustness was to choose commercially available components. The understanding was that these have been around for a while, they are tried and tested, and the problems that the first generation of a component often carries have been solved. The price in terms of performance was mentioned in the order of tens of per cent compared with the newest stuff. When set in relation to the orders of scale the new machine provides (times 10 is one order of scale, times 100 is two orders) this was not considered a high price to pay to have an instrument that runs smoothly. As the instrument scientist mentioned in the earlier quote, even with a conventional design, commercially available components, while not advancing the design of the instrument, will still mean the instrument can be a fine one.

Learning from others was fundamental to instrument development, if only in order not to make the same mistakes. All instrument scientists had travelled to see and work with similar instruments at other facilities. They had presented their designs at the yearly user meetings at the MAX IV laboratory and at conferences solely in order to get feedback. And, crucially, these review processes are on-going. The community is wholly reliant on cross-reviewing. Most instruments have an advisory board that discusses the design at different stages. For the KAW application of 2011, each instrument was reviewed by two people, and the reviews were amended. When I asked, respondents talked of a culture of openness, a frank discussion of what worked and what failed. It was also said that it is extremely difficult to hide how an instrument works, or does not work: users get a very close-up experience of the instrument, they talk, and they vote with their feet.

The stress on robustness I have identified in the interviews chimes with what Tim Lenoir writes about instrumentation in the introduction to Rheinberger's book *An Epistemology of the Concrete*:

> The name of the game is constructing a robust experimental arrangement of instruments, chemical processes, psychical structures, and biological materials capable of generating a network of experiments. (Lenoir in Rheinberger 2010, xiii).

A central development for Rheinberger comes when epistemic things are becoming known, whereupon they turn into models, and this knowledge is incorporated into the instruments. What I want to highlight here is that a large variety of other forms of knowledge go into building the instruments; knowledge that might not necessarily aim at opening up, or for that matter closing down, so much as to making it work. Rheinberger's point that experimental systems are kept on the verge of breakdown might be counterbalanced by the demands for workability that permeate the interviews. Breaking down is not really an option when scientists are lining up to perform their experiments in a limited amount of time. Or when vast resources have been invested and stakeholders expect to see a result. The fine line between pushing the design towards new possibilities and keeping it from breaking down is one trodden by experienced people who work to realize the instruments, with at their backs a community of scientists and their crisscrossing exchange of experiences and knowledge.

Even though this stress on robustness and stability was not directly talked about as hampering the potential to do new experiments, this was indeed the case. Pushing the performance of components and the instrument as a whole was at times understood as making the instrument more focused on experimentation. In talking about robustness, the instrument scientist concluded by saying,

> Then the users will be happy because they'll go home with good data and we get a good reputation. But also, if you say you have a beamline that's a little more experimental and it has some problems, then they can live with that.

An acceptable degree of trouble is set against creating an instrument that is 'a little more experimental' in the words of the instrument scientists, more of an experimental system in the words of Rheinberger. Pushing the instrument a little further, beyond what would be optimal for stability and robustness, can be done, but when it is, users should be warned in advance, as the instrument scientist said. While stability and robustness were fundamental requirements—otherwise the instruments would not be able to do experiments—trouble might, just possibly turn out to pay off in even better experiments. This is not a consistent line, of course, even when the robustness of the performance is emphasized, for the instrument scientists claim that the instruments will be good in international terms because of the performance of the machine, which is often highlighted as the core strength of MAX IV. What I have shown is that adding to this strength is the long experience of designing and optimizing instruments that is essential to both instrument scientists and core users alike.

Communicating familiarity

From reading Rheinberger, I was focused on the instrument, the choice of components, the development of the design over time. However, through the interviews I discovered that there is also a lot of thinking involved about how the instruments are going to be used when they are up and running. During experiments, the instruments have to be handled. In order to do this, the scientist needs to know how the instrument works. For now I will call this knowledge familiarity, but it is a preliminary naming. Others have used tacit knowledge, or intimacy. In the interview in this anthology, Rheinberger talked about it as extimacy, a concept he has taken from Lacan. He argues that this knowing/extimacy expresses an experience, 'familiar to every working scientist', that 'the more he or she learns to handle his or her own experimental system, the more it plays out its own intrinsic capacities' (Rheinberger 1997, 24). I will therefore explore how this familiarity is learned, taught, and communicated, and by whom, in order to chart its implications for experimental systems of the kind being built in Lund.

In the interviews, knowledge of the instruments is described as being shared with visiting scientists when the instrument scientists work alongside them, largely by being on call and stepping in when problems arise.

> You show them [the users] how it works, the whole procedure, how to measure their samples and guide them through doing data analysis. It [learning to handle the instrument] is a process you have to go though. And it is very rewarding actually [for the instrument scientist] to meet a lot of different people, make contacts, and learn more about the technique. And also to learn more about how the beamline actually works, which components are needed to create a specific light, how to make it stable to make measurements possible.

The instrument scientist here talks about mutual learning as an important factor in running a successful instrument. His/her teaching and assistance is what makes it possible for users to perform their experiments; however, in attending to the user, the instrument scientists get to know not only the instrument itself in far greater detail, but what the users want to do, what kind of science they are engaged in, what questions they want to answer. Then there is the challenge of translating the user's interest into something the instrument can achieve. This involves helping users adapt their questions so the instrument is able to answer them. This may lead the instrument scientist to test the limits of what the instrument can do, exploring whether the instrument really can answer the questions that the users want to pose, either now or with possible future upgrades. This sort of openness is said to be essential to the successful development of the instrument, although one of the instrument scientists acknowledged that it can be easier to just turn down proposals that fall outside what the instrument usually does.

When users return—and many do—they add to their own familiarity with the instrument and can work it unaided. This acquired handling knowledge, the interviewees told me, is one reason why users return. Returning users are more sure they will get what they expect, or they arrive prepared to play and experiment more, trying out, exploring—in other words, using the instrument as an experimental system. Added to this, they can be left to their own devices, giving the instrument scientists space to do other things, even though they are in the vicinity or on call.

One respondent made much of the importance of organizing courses for future users, with beamtime included. I asked why this mattered so much, and the answer was that without the beamtime 'It's like learning to swim without water.' Both the future users and the staff at the facility tend to dismiss such courses as too time-consuming, but the respondent was emphatic that there is an uncanny difference in experimental skills between those who have attended a course with beamtime and those who have not: beamtime is always made available to the user, whether it is well used or not, the subtext being that the better trained the user, the better the use of resources. Even though it is already necessary for users to learn how to use the beamline, a full introductory course with beamtime was worth the extra effort for all concerned. The same respondent had suggested that MAX IV calculate the running costs for a day's experiments, just to make them visible and impress on users the true cost of their 'free' use of beamtime and the support they get while they are there.

One question left begging in the interviews was whether (and if so, how much) this familiarity should be left to the staff at MAX IV. This partly comes from working with inexperienced users who need a lot of 'babysitting'. In scaling up, as MAX IV is doing, one element in the success of the facility will be attracting new users, including ones who are new to synchrotron research—and some of them cannot realistically be expected to learn to operate the instrument, since they come from very different disciplinary backgrounds and are there to use the instrument more as a measuring device or a tool. Such users do not want or need to know much about the instrument:

> We can see among our users, the ones that only want to run the experiment. They are not interested in how the synchrotron works. On our instrument it is more, how to put it, the users take a sample but don't do an experiment or anything. They take data and don't experiment with the equipment or the instrumentation. They come with their samples and take the data, and that's it. And this is a change, getting users who are not in physics. They want to see the data, but not the other parts.

The users talked about here are non-physisists, few of whom are going to attempt an experiment in the sense that the interviewee describes it, not having enough in-depth grasp of the physics behind the workings of the instrument. The composition of the user community is plainly going to change: consider only the ethnography of *Velvet Revolution at the Synchrotron* by Park Doing (2009). Naturally, this does not mean that non-physicists cannot learn these things, or that they will never do full experiments in the way envisaged by the respondent here, because of course the principles of how the instrument and the analysis work can be learned. After all, even physicists have to learn it when going into synchrotron research.

Users who are not familiar with the instrument and who are there to use it as a tool are often mentioned by respondents in conjunction with fast though-put, standard measurements, especially in protein crystallography (see Doing 2009). Very fast measurements from a large number of samples are increasingly done through remote access. I asked if this will be the case for the instruments in MAX IV.

> Yes, because as I said before, our experiments are very standardized. Sometimes the user has to go through a hundred samples. And actively choose the right ones. This is very much just—check, check, check, this one, check, this one, check, check. It's very automated. The time for collecting data is very short. Thus it makes no sense for a group to come all the way from Umeå to collect data for two hours, for example. If it only takes two hours, it might be better if they do it from home.

The instrument scientist mentions an instrument at another world-leading facility, where 75 per cent of the experiments on a similar instrument are remote access; this is the direction they are heading in also in Lund. One argument for remote access is that the experiments would be done better, since they will be done by experienced beamline scientists. But then again, the experiment as an interface for meetings, dialogue, and questioning will vanish.

> Well, it is a source of information that's disappearing. You listen to the users and hear what they like and what they think should be changed. It could be a problem for us if this source of information from us to them and from them to us disappears. Then we'll also need more staff.

What I have done in this section is to factor in the scientist, and especially the instrument scientist, into the experimental system using the theme of familiarity with the instruments. It is something that Rheinberger brings up, but does not pay that much attention to, finding it self-evident—as in the quote I started this section with, it is 'an experience familiar to every scientist'. What I want to suggest is that at these large-scale facilities, the instrument scientist should be seen as a vital part of the experimental system. Without him or her, the necessary familiarity with the instrument cannot be communicated, or not in any depth. The embodied knowledge implicit in familiarity with the instruments, often with layers of experience from having designed, built, and worked with generations of the same kind of instrument, is fundamental to getting the instrument to work. The tension I have identified by applying Rheinberger's concepts to the issue is between using an instrument for tool-like measurements and using it for more explorative experiments; between users who are not interested in learning about the instrument, and the ones that are. With the first group, the instrument scientists fear that they might end up as assistants, deprived of their mutually educational interaction with users. This might well push the instrument into becoming even more of a tool, a measuring device. On the other hand, the user who wants to learn demands a great deal of staff time, and even after the first couple of rounds might still not be a very good experimenter. This is where continuity becomes useful, as repeat users are far more likely to approach the instrument as part of an experimental system, making the most of its intrinsic capabilities.

Concluding reflections

With the use of Rheinberger's concept of experimental systems, I have aimed at capturing some of the process of designing and building instruments at MAX IV. In this concluding section I would like to share some preliminary thoughts on what has proved significant for instruments at large-scale facilities. Having analysed interviews with instrument scientists who are working on ten very different instruments, it is now time to lift my sights to the more general issues involved.

Rheinberger makes an analytical distinction between epistemic objects—that which is not known—and technical conditions—that which is used to probe the epistemic things, embodying the current state of knowledge. Things epistemic are always vague and elusive, and to guess about future epistemic things becomes an almost impossible task, as I have discussed in relation to designing instruments for the ESS (Sandell 2013). Scale is thus an important improvement that in itself promises enhanced seeing and new questions. In a facility catering to many different instruments, this becomes a common denominator that the instrument scientists have to rely on in order to design better instruments. This opens up for questions about which instruments are selected for construction, and how these instruments cope with improvements—things I would like to explore further. Added to this is a constant striving for scale, for more, for better, something that strikes outsiders particularly. People at these facilities always have ideas, at least at the backs of their minds, about new facilities, new instruments, and upgrades to existing ones.

A finding that I would argue has the potential to advance the discussion about experimental systems is the way knowledge—possessed not only by the instrument scientists, but also by the whole community of instrument scientists and core users—is built into the instrument. Thus not only are epistemic things that have become known, and have been turned into models, built into the instruments, but so too is a vast body of knowledge about how to make instruments work. This knowledge is central to the instrument scientist, both in the design process and when an instrument is up and running. I think it would be fruitful to view the instrument scientist as *part* of the experimental system, especially at large-scale facilities, perhaps conceptualized as 'bodies of knowledge' to stress the importance of location. Since these facilities house very specialized instruments, which users only have limited access to with clear time constraints, while the instrument scientists are the ones continuously present at the location, it would be interesting to see how the role of the instrument scientist in the overall operation of the facility and the instrument creates or blocks opportunities for the instrument to be used as an experimental system. In my analysis, for example, remote access is posited as a possible change that might leave instruments as tools only, because of the diminished interaction between users, instruments, and instrument scientists.

Something that has come out of my analysis is that the tool aspect of the instruments is important. At first I read the distinction between tools and experimental systems as meaning that the one was no longer part of the other, and thus uninteresting to users. While that might still be true, I now think that it can still be a *part* of an experimental system. The instrument scientists are manifestly conscious of the importance of incorporating this tool/measuring aspect into their designs, for it has to be possible to use most instruments a tool-like way. The distinction, articulated as the difference between measuring and experimenting, figured prominently in the interviews—and, interestingly, coupled to the idea that problems with the instrument can be acceptable at times. Where there is a concerted effort to use an instrument as an experimental system, disruptions and instability are tolerated. This is not without its risks, however—one might fail to notice new questions as they go by; the instrument might not function properly when needed by users, or might prove inadequate to its new task; new solutions and components might take time to get up and running, or they might not actually work at all—yet equally, it might turn out to be a roaring success. Either way, it would be of great interest to follow the instruments as they are built and rebuilt, to see how their use changes over time within the analytical framework of experimental systems.

Finally, I want to say a few words about time and the future. One point that needs to be made is that the design process itself is future-oriented—each design is a plan for an instrument that is on its way to being realized, but is still yet not ready to be used. This adds a further layer to Rheinberger's point that the design process exists to plan instruments that will be 'machines for making the future' (Rheinberger 1997, 28), in the future. Further, the timeline for large-scale facilities is generally far longer than it is for the molecular biology that Rheinberger investigates, a field with much smaller and more malleable technological conditions, where the turning of known epistemic objects into subroutines as the system develops is a fairly fast process. The interplay and recombination of methods elapses over a much longer timescale for new big science. Years can pass between the instruments being outlined and then finally being built and put into service. Resources were secured for the first seven instruments for MAX IV in 2011, and that was preceded by at least a year of conceptual design work, yet the first of them will only start up in the summer of 2016. Even if some of the components of those first seven instruments had not been bought at the time of the interviews, even if there are still meetings being held to prioritize, review, and decide, much is now fixed. And even if upgrades are already being discussed, they lie years ahead in the future.

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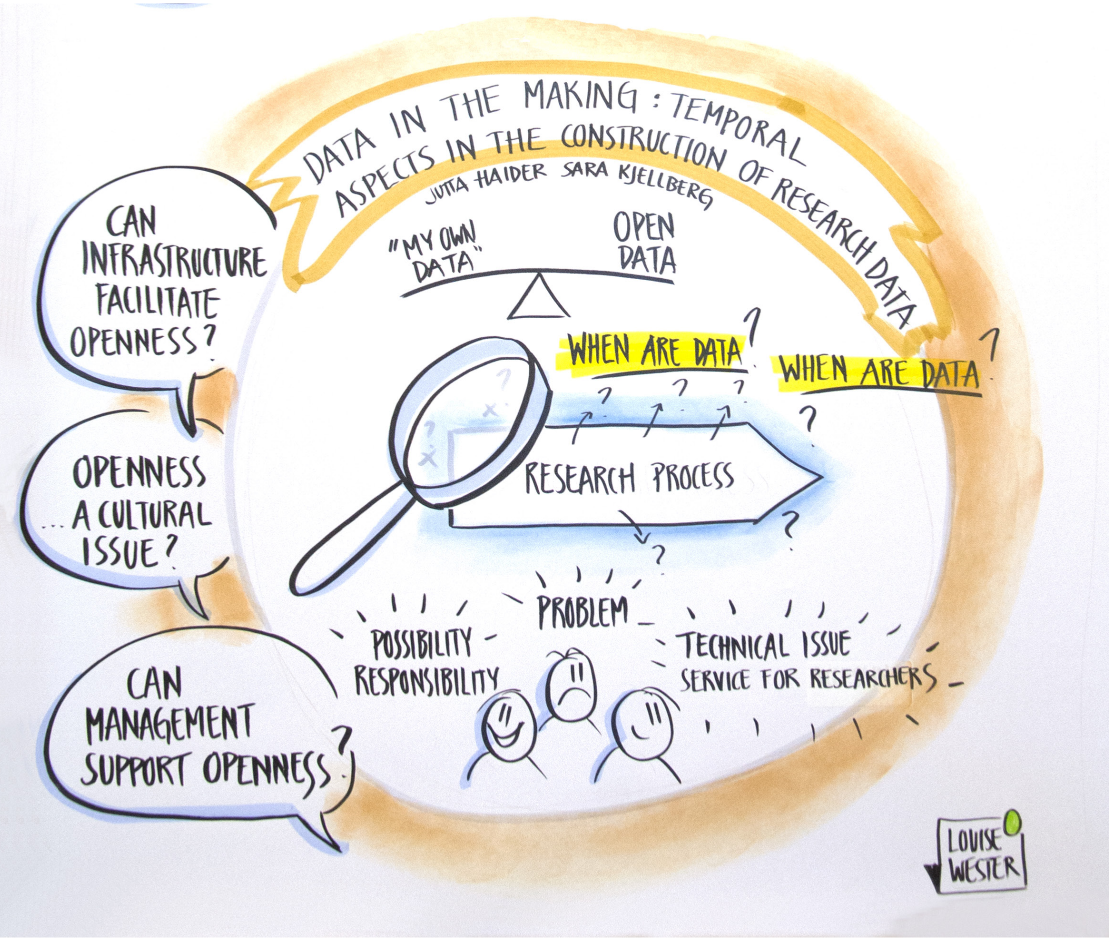
DATA IN THE MAKING: TEMPORAL ASPECTS IN THE CONSTRUCTION OF RESEARCH DATA
JUTTA HAIDER SARA KJELLBERG
"MY OWN DATA"
OPEN DATA
WHEN ARE DATA?
WHEN ARE DATA?
RESEARCH PROCESS
CAN INFRASTRUCTURE FACILITATE OPENNESS?
OPENNESS ... A CULTURAL ISSUE?
CAN MANAGEMENT SUPPORT OPENNESS?
POSSIBILITY - RESPONSIBILITY
PROBLEM
TECHNICAL ISSUE
SERVICE FOR RESEARCHERS
LOUISE WESTER

8. Data in the making: Temporal aspects in the construction of research data

Jutta Haider & Sara Kjellberg

Increasingly the material research deals with is cast as data, and more and more as digital data, a seemingly unproblematic concept with which to describe the matter of research at all stages of the research process, from the object of investigation to the output. The aim of this essay is to complicate this framing by investigating the ways in which notions of data emerge in the construction of new big science facilities, in order to explore some of the implications for how and when knowledge production is thought to occur. We study data and the making of data during the design and construction of two large-scale research facilities in southern Sweden, the ESS and MAX IV, and specifically of the necessary infrastructure for dealing with various aspects of research data management. The making of data does not refer here solely to the data produced during an experiment or an observation, but rather to how they are made possible by setting up and planning for the production, storage, and use of data, and even the limitations, strategic roles, and other effects.

'Rarely can a magic moment be established when things become data' writes Christine Borgman (2015, 62), and as she develops at length, the question commonly asked—What are data?—and which occupies policy makers, lawyers, university administrators, data service staff, and archivists, might not be the most interesting or even the most relevant. Rather, considering the various ways in which data always exist in a specific moment and in relation to particular conditions, a more adequate and indeed more productive question, she suggests, is when are data? We take inspiration from Borgman (2015) and let this question guide our exploration. Hence, our intention is not to compare different understandings of data, even less to judge which is preferable, but to a gain a diverse and faceted understanding of the meaning of research data in the process of building a research facility, and of the temporal aspects to how these meanings are shaped.

'One of the founding myths of scientific practice is that science is carried out in an eternal present. From it all external influence has been banished', writes Geoffrey Bowker (2005, 32–33) in his book on memory practices in the sciences. Of course, the archive is one of the most central functions for science as an institution. As an organized collection of the records of past science, it introduces a temporal axis to scientific knowledge and knowledge production that is equally foundational. The archive, as a memory institution, articulates a specific relationship between the objects and the records of science. Bowker (2005, 36) further reminds us 'all things on earth can be seen as at once objects and archives'. As institutions, archives are involved in turning things into documents, which can then be stored, described, organized, accessed, and put into new contexts (see Briet 1951). However, with the increasing significance of computers and information and communications technology (ICT) for knowledge production in the sciences (Hine 2006), the process of documenting objects has been fundamentally complicated. The question of what it actually *is* that is turned into documents is getting increasingly difficult to answer, at the same time as the need to store data for longer periods and as openly accessible has grown exponentially. Furthermore, as the number of stakeholders involved in the process of documenting in the sciences increases, it has become more and more obvious that the relationship between object and memory institution—archive, library—has to be recast (see Hansson 2015). Our focus is on the apparatus, including the work, functions, and policies, that enable data collection and processing before the actual research can be carried out. As Borgman (2015, xviii) reminds us, 'data rarely are things at all. They are not natural objects with an essence of their own'. Data are records of something, and in this way they are born as documents. At the same time they are also the very objects that need to be turned into documents to be added to the archive. This essay is intended to better the understanding of how this happens, and when.

Research data management: Between data-driven science and open data

At time of writing, two new big science facilities are being built just outside the city of Lund, the multinational ESS and the national MAX IV laboratory, located next to each other with a planned science village alongside. While MAX IV is a new facility that developed from an existing centre for synchrotron research at Lund University, the other facility, a neutron source, is an international effort spanning several European Union countries. In addition, both the ESS and MAX IV are multidisciplinary, with research covering physics, chemistry, geology, biology, and medicine, and are primarily intended to serve researchers from a wide community, including industry and different disciplines, and to develop an infrastructure to support the users as temporary visitors when performing experiments. The ESS will have a dedicated data management and software centre to handle, analyse, and possibly store research data emanating from the experiments. Interestingly, this centre is located in Copenhagen, Denmark, on the other side of the Öresund.

The digital aspects of doing research and its implications for handling data as part of the research process are important for all fields today, and interest in the role of computers in knowledge production in the sciences has grown in step with the emergence of concepts such as eScience, data-intensive research, and also big data analytics (see Borgman 2007, 2015; Hine 2006; Meyer & Schroeder 2015;). Data-intensive research can be described as being based on data sets that are analysed using computers, algorithms, and statistical methods. There have been attempts to distinguish between eScience, eResearch, data-driven research, and computational research (see Griffin 2013; Ray 2014), but without much success. Even though there can be differences in these categories of research, the main discussion turns on how changes of methodology and approach might shape contemporary scholarship or research (Borgman 2007, 2015; Ekbia et al. 2014; Frické 2015). Dealing with huge data sets and large amounts of data is part of this development, and thus is linked to the phenomenon of big data (Borgman 2007, 2014; Boyd & Crawford 2012). Big data is debated in relation to with the epistemics of knowledge production and data-driven science, and put in opposition to problem-or theory-driven science (Frické 2015; Ekbia et al. 2014; Leonelli 2014).

The production and use of digital data and the challenges this poses on research also call for new knowledge in order to handle the data successfully (Ray 2014). Research data management involves more than the individual researcher's work in managing, describing, sharing, archiving, and preserving research data; as has been pointed out, a multitude of supporting roles are required to cover all the different aspects of managing the complex of research data (Verbaan & Cox 2014). Studies show that new support services are being developed (Antell et al. 2014; Cox et al. 2012; Cox et al. 2014; Griffin 2013; Mayernik 2015; Ray 2014; Verbaan & Cox 2014). Research data management is part of a whole chain of research documentation both before, during, and after a project takes place. The organisation of documentation includes descriptions to discover the data and metadata about the data-sets, and also how data have been managed to make them trustworthy in order to prevent data loss and possible file corruption (Ray 2014).

Moreover, it is research data management that lies behind the idea of making data open—available and accessible—and of sharing data. The assumption is that making data freely available for others to use will benefit society and promote new ways of using the data and cross-connecting with other data sets. Over decade ago, Arzberger et al. (2004) explained the principle as follows: 'publicly funded research data should be openly available to the maximum extent possible'. This is now also spelled out in the policies of the National Science Foundation (NSF) in the US, the EU in its open access strategy, and various other national and international funding bodies and research councils. Increasingly, funders demand that data management plans be included in grant applications (see Arzberger et al. 2004; Tenopir et al. 2011).

Additionally, governments encourage researchers to share their data, and periodicals have begun to include requirements for uploaded data sets when submitting manuscripts for publication (Borgman 2015, 8). To make data open you need not only a technical infrastructure, but also routines, which depend on organizational capacity (Meyer & Schroeder 2015, 184). At the same time several studies have made it clear that there are also challenges (see Axelsson & Schroeder 2009), given that there are no uniform practices for data-sharing (Beaulieu 2003; Hine 2006; Tenopir et al. 2011). Even within the same discipline, different approaches can be found (Mayernik 2015). The attitudes of researchers and the social shaping of research communities also have an effect on making data open, as do possible developments in both official policy and the technology as such (Meyer & Schroeder 2015, 186).

Material and analysis

Our aim is to understand the ways in which notions of data emerge in the construction of big science facilities, and specifically of the infrastructure for research data management. This is shaped by the expansion of data-driven science and the paradigm of making data freely available. Thus we chose to interview people working in the support and administrative organization at the new facilities in Lund and to collect and analyse documentation available from the facilities' websites. Our source material also included the slides for a presentation that one of our respondents shared with us. In addition we took part in a group meeting with several representatives from the ESS, where we heard various presentations and were able to ask questions. This helped us to identify possible interviewees and relevant organizational groups and to draw up the interview guide.

The potential number of interviewees was limited by the type of expertise relevant to our study. We began by contacting and interviewing people working at the ESS. During those interviews we found that, in order to better understand our preliminary analysis, we needed a more diverse material. Hence we decided to include an interview with someone in a similar position at MAX IV. This proved fruitful as it showed that data management at MAX IV is facing the same challenges, as the very similar views expressed in the interview would seem to indicate.

In total we conducted five interviews with seven respondents. The interviewees worked in support functions—legal, communications, and curation/data management—and we chose to focus on the latter group. Our questions concerned their understanding of data and their views on research data as part of the development and construction of the facilities. The interviews were semi-structured, with a set of questions designed to elicit responses about the following three themes: disciplines and user groups; data and metadata; and sharing data. The questions were then slightly adapted in order to accommodate each interviewee's field of expertise.

The interviews lasted approximately one hour each. We recorded all but one interview, and subsequently listened to them repeatedly, took notes, and transcribed the relevant parts. The transcriptions and notes, together with the documents, formed the basis for our analysis. We constructed themes by repeatedly going back and forth in the material to identify commonalities and differences that emerged during the analysis. In what follows, we bring together the salient points from the interviews, before interrogating the material using our guiding question, 'When are data?'

Some emergent meanings, or, what are data?

Most of our interview material is derived from interviews with staff in leading roles at the ESS and MAX IV, who work with different aspects of systems development to enable research data management. While their views also dominate our analysis and provide the greatest detail, a study of research data from legal and public relations perspectives using other documentation can contribute to an understanding of the full range of demands and requirements that determine how data are envisioned and systems to handle them are built.

Below we present the most tangible understandings of research data as they emerged in the interviews, which also serve to set out our general findings and the ways in which different notions of research data are conceptualized (and in relation to what, where, and whom). The focus when talking about research data was largely determined by who the interviewees were. This is not to say that our interviewees were unaware of other meanings; on the contrary, their roles as mediators between different groups in many ways demands a high degree of awareness, and in fact all our interviewees expressed concern at the way communication between groups and systems worked, and all reflected on their roles in this.

Data as a technical issue

The interviewees who work with research data management and software issues all had leading roles in developing the computer-based, technical infrastructure. All had a scientific background, and all had used similar facilities as researchers before going over to working with research data management. Their understanding of research data was shaped by seeing data as part of interlinked processes and other data such as metadata gathered using the instruments. In this perspective, data become a technical issue and are treated as such. Here, data never just are—they are always being dealt with, changed, reduced, moved, sent, or described, and always in relation to technology of some kind, whether a database, reduction program, metadata registry, analysis tool, storage device, fibre cable, or visualizing software and the like.

A lot of thought and effort has gone into preparing the facilities' user services. This chimes well with how the ESS describe its handling of software and data, for example—'The ESS is putting special emphasis on creating and using first-class software for instrument control, data processing, analysis, and visualisation' (ESS n.d. 'The unique')—and is also reflected in the design of MAX IV (MAX IV 2010). Here too data are presented as a technical issue, and dealing with them is seen as a service for researchers. As the MAX IV website explains, 'Companies wishing to solve their research needs at the MAX IV Laboratory can be offered initial discussions with expert laboratory scientists, sample preparation, assistance during measurements and help with data analysis and interpretation' (MAX IV n.d.). Both facilities will cater to academic researchers with different disciplinary backgrounds and users from industry. They are assumed to have different requirements regarding data management and processing, not least interface design and visualization. 'Everyone has the challenge of making it straightforward and giving the user community the kind of analysis and the tools required to actually get the scientific information and impact out of the data, which traditionally has been the work of a Ph.D.' (Int. 2). Things are meant to be kept simple, 'otherwise they'll just get confused, because these are people who do biology. They are not neutron scatterists', said one respondent, and continued, 'the time when you could make a career out of just neutron scattering … those days are gone, it's more multidisciplinary, so you have to cater for a broader range of scientific disciplines … and provide them the tools they can reasonably access.' Later he added, 'The same goes for the data. That needs to be presented in a way that they understand what that is, rather than, well I mean obviously, rather than giving them neutron events, but also...' (Int. 2). Clearly, the expectation that there will be a growing and more diverse user base has implications for how software development and research data management are tackled. These expectations shape what future users will experience, see, measure, and interpret when they finally get to encounter 'their' data on a screen.

Data as a problem

From a legal perspective, data are mostly approached in terms of a problem to be dealt with. How to define data is a pressing issue, as is awareness of different interests that need to be accommodated, different user groups who have to be served, and laws and policies adhered to. The most important goal was said to be serving the so-called science community, a community that was terminologically cast as the legal department's most important client. However, it is less clear who exactly makes up that science community, as it features as a vaguely homogenous bloc. Specifically, the role of different disciplinary cultures or the relations between industrial research and university research seemed unclear or remained unexpressed. Attempts to circumscribe data in relation to this nominal client, as to laws, regulations, and policies, were felt by the legal team to be something of a challenge, with data being neither immaterial nor material, neither object nor archive—or both at the same time—and so escaping the existing legal terminology. While free and open access to research publications is quite unproblematic, at least in the sense that there is a widely shared understanding of what a publication is and what we should encounter when we access one, what exactly should be regulated when data are freely available is a lot more opaque (see Wennersten & Maunsbach, in this volume). The conflation of data and intellectual property is common, and one of the thorniest issues is the role research facilities will have in opening up access to research data, which implies control of the data in the first place.

Data as a possibility and responsibility

From a public relations and communications perspective, research data was framed as both a possibility and a responsibility. As one interviewee put it, 'The data that we produce at this facility is our raw material. We have to help our users or create processes ourselves if we want to get the most of our raw material' (Int. 4). Research data are connected to a vision of science that highlights science's potential to solve societal problems and to advance knowledge for the common good. Industry and EU funding frameworks, which require industrial partnerships, function as categories that help describe research as useful. However, when it comes to research data, open data—which is thought of as something that might be problematic for the demands of industry—is seen as a means to make visible how the facility does what it is supposed to do, namely produce science. This is documented in the form of research data made available for others to see and reuse. This way, research data is inscribed into a double narrative of future opportunity and evaluatory control.

Managing the flow, or, when are data?

One of our respondents opened the interview by claiming that it was premature to talk about data. In hindsight, this introduced a number of complexities to the topic that we had not appreciated at the outset, for what it expresses is not so much the way in which people in different positions perceived the issue as more or less urgent, but rather the transient character of research data. If data can be premature, when are they mature? we have to ask. The transience of research data that we encountered is expressed in the various temporally structured descriptions employed, and also in the way in which the digital materiality of data in use is constantly changing. Put bluntly, data are never in and of themselves, but exist only in relation to other data, software, and instruments, to people, measurements, interfaces, computers, or various other tools. We will sketch out some of the most tangible ways in which the temporality of research data emerged in our material, in relation to the processes of doing research, to ideas of an archive, to policy demands, and, probably most of all, to understandings of the future. We use these themes as pragmatic categories to outline the various ways in which data are imagined as having been configured over time. In that sense, they are neither mutually exclusive nor do we ascribe values intrinsic to these themes nor to the institutions they refer to.

Data are what researchers will take back with them or access remotely after they have done an experiment using one of the instruments at the ESS or a beamline at MAX IV. Everything that is being built, installed, and programmed as the instruments and data centres are installed is meant to lead up to this. Yet the data that will be stored on a hard drive and taken back on a plane or accessed over a network will have undergone a series of reductions, translations, and contextualizations since the neutron or X-ray beam has met the sample. They will undergo numerous further treatments in order to be calculable, publishable, storable, describable, and accessible—or to be overwritten and deleted. Yet, there is one magic moment, to use Borgman's words, when researchers first encounter their data, when they see the data coming in from the instrument and displayed on a computer screen, or as one respondent envisaged it, 'so, we publish the data frame by frame on our computers. The people who are doing the experiment, they are sitting at a terminal' (Int. 1). He went on to describe it as 'a publish–subscribe system (it's like Netflix) … it's streaming. Multiple subscribers can subscribe to the same film' (Int. 1). There are two interrelated questions here. Firstly, what do researchers see when they look at data, as it was put repeatedly in our interviews, and how did this data get to be data at that very moment? In order for data to be something that can be looked at as it moves past on a screen like a film, as our respondents described it, entire series of translations must have occurred. At some point there must have been a decision on how to visualize the way in which, say, neutrons hit a sample in meaningful way—as a graph, a scatterplot, a 3D image—and, indeed, how to deal with that data from that point on, not least when moving on from processing to putting records in a file for storage.

Data are anything but static in the accounts we were given. They do not arrive on the researcher's computer desktop ready and waiting to be handled. Interviewees likened data to a film that happens on a screen, and that has a clear temporal dimension to it, as its series of moving images elapse over time. This is also the way it is presented in an organizational chart entitled 'Data Acquisition, Reduction & Control' that one of our respondents showed us. Here we get a picture of how data are meant to be processed from the instrument to the screen. Numerous lines and arrows connect boxes with names of software, metadata standards, illustrations of instruments and storage devices, all illustrating a flow of data from the experiment via a series of automated data aggregation and reduction steps, involving time-stamping and metadata descriptions, to the instrument control room. This too is included: a little box showing a person sitting at a desk in front of a screen with colourful dots, seemingly watching a data visualization as if it was a film. Clearly, a great deal happens to the data before they are even encountered *as* data by the researchers. And none of this is forgotten, because the process is added to the archive and attached as metadata. As one respondent put it, 'the data framework used for data reduction keeps a history of reduction itself of everything that was done to the data' (Int. 2). Yet, while processes are kept as records, it is also a priority to reduce visible complexity and to speed things up. This can be connected to the question of how researchers are constructed as users, with research data management seen as a service for those users who need to be presented with a simple interface (see. Hine 2006).

Yet, time is important here in a different way—'Not in real-time, but we are pushing for it', and 'you can get it after a few minutes' (Int. 3), as one of the interviewees puts it. The issue here is the time that elapses between the experiment taking place in the instrument and the data becoming visible to the researchers, and thus is as much a matter of efficiency as speed in carrying out research, something which our interviewee touched on in different ways. Immediacy is positioned as the ideal. This, of course, would allow for beamlines or instruments to be used more efficiently, which is financially beneficial. Yet the research process itself has a part to play here. Researchers, we learned from our respondents, might want to tweak samples and adjust the set-up of their experiments in direct response to the data, as they are visualized on screen. In a way this also aspires to immediacy, where the elapse between neutrons hitting the sample and the data being visible on a computer screen would ideally shrink to almost nothing, making the computer and software—after an enabling series of translations that are as rapid and invisible as possible—something to see through rather than see with. 'Absolutely at the top of the wish list, and what we are trying to get to work right now, is to get some type of integration. I have seen so many individual solutions that do not fit together in their context; it is at the very top of my list, and it is the thing which no one will see, it will just work' (Int. 3), said one interviewee, underlining the significance of the often invisible infrastructure. The ideal of offering a 'real-time' as well as a 'ready-to-use' interface for the data film, supported by an increasingly invisible technical infrastructure, ultimately also depends on immediacy, intended to maximize the impression of control for users.

Policies and regulations

Policies on open and free access to scholarly publications have become commonplace throughout the world, and many of the world's largest funders now demand open access to publications that result from research funded by them. Increasingly, this has also been extended to encompass open access to the original data too, usually labelled open data policies. Regulatory moves have been made to circumscribe and regulate research data and institutional responsibilities are being negotiated (Borgman 2015, 42–5).

Policies, regulations, guidelines, and data management plans all impact on the research facilities we studied, and on many levels. All relate to data, but it remains an elusive concept which, while clearly significant and laden with values, expectations, and even capital, is very hard to pin down as a policy category—and this despite the fact that it, like the all-important issue of time and timing, has implications for how data management services and processes are prepared. Local guidelines are drafted to reflect the policies researchers have with them from their home institutions or funders, while industry users are considered to need specific regulations and possibly exceptions. Legal requirements, rights, regulation, and the question of ownership all play an important role, as do notions of how researchers treat and create value from their data—and when they do it (see Arzberger 2004).

As one of our interviewees said of research data, 'As a researcher, you own it in within the embargo period. It's your data for a period of time … Generally this is set by the data policy of the facility … after that it somehow becomes open access?' (Int. 2). Embargo periods, during which individual researchers have exclusive rights to their data, are common in most fields of research, and will likely also feature in the type of research carried out at MAX IV and the ESS. Data change meaning in relation to variously negotiated periods of the research process, defined by who has access to the data; however, with periods that can vary significantly between disciplines in both length and scope, it is unclear how they might tally with the requirements of access policies and funder demands, which are a lot more uniform. Equally unclear is the role of research facilities in negotiating what these timings should be, and how best to express the agreed times in their research data management plans.

Before data are even collected, there has to be a moment when they are described, however cursorily, in a research application, and more and more frequently in a data management plan too, as they are increasingly demanded by funders (see Mullins 2014). One interviewee used past experience to illustrate the problems with these plans: 'We had this in the US, because the NSF were asking people to hand in a data management plan, and, yes, users came rushing to the facilities and said, well, if you keep the data forever can we call that our data management plan' (Int. 1). Clearly, funders' requirements shape the demand for data management plans, and the focus is almost entirely on long-term preservation. Thus, by virtue of their mere existence, data management plans project data into a future, where they are primarily meant to be stored. Sure enough, each discipline's specific research culture works with the scholarly publishing system to shape how data are thought of, and here too time is a key reference point. ‘Research is an incremental process, essentially’, as one interviewee said, continuing, ‘So if you have more steps—and access to more data *will* give you more steps—you’ll have a better stab at making some reasonable new understanding of [inaudible], which is the point of the literature. Literature only gives you one side of the story. It gives you published data after some period of distillation within their group … it doesn’t give you everything else that they did.’ His colleague added, ‘Then journals require you to submit raw data … and when you’re going to high-impact journals, there’s “supplementary information”, and people just put lots of stuff in supplementary information’ (Int. 2). Here the idea of the scientific literature as continuously advancing, with each publication building on the ones before, means that research data are thought to take on different guises, depending on when in the publication process they feature. Raw data, published data, supplementary information, ‘stepping stone’ data—all make their appearance here, and all are conceptualized in terms of doing science as a linear process that plays out over a period of time, from the data from previous research, to raw data, to research data, to distilled and eventually published data, to supplementary information, and so on.

From data in use to data in waiting

From the framing of data as a technical concern and a service for researchers, it is a short step to accessibility and use, and from there to short- and long-term preservation. These are often constructed in relation to archiving as a question of disk space, with reference to vague temporal factors, the designation of different uses, and, importantly, the non-use of data.

The website of one of the Lund facilities offers this description of its computing centre: ‘The primary activity is the operation of the high performance computing cluster, which is used by scientists who rely on computer modelling in order to support the design of the ESS facility and consists of two main parts: a high performance scientific computing cluster and a high performance storage and backup system’ (ESS n.d. ‘Computing’). Research processes and data storage are disconnected from each other, not only in time, but also in regard to the digital infrastructure (Leonelli 2014).

‘We would keep the data … we have planned to sort of keep the data for ever’ (Int. 1) said one of our interviewees:

> We are still some years out. I talked about the data being copied to multiple locations, the stream going to Copenhagen, going to Lund, also still being on the instrument in multiple copies, in case something went wrong. What I imagine is that we would also automatically copy this to one of the archive facilities, either something like EUDAT or possibly CERN. (Int. 1)

Data are seen to exist in multiple copies and on devices in different physical locations, with back-ups needed on the instrument as a safeguard. Interestingly, ‘the instrument’ is used as a stand-in for all the data processing and computing connected to the experiment. A long-term archive copy is more of a possibility than a certainty, and it is clear that the interviewees partly reflected on this because we posed questions about it; archiving, and specifically long-term archiving, was not an issue that came to the fore otherwise.

Archiving is mostly framed as a question of storage, not unlike an analogue archive, which is identified with its physical space: ‘What determines how long we can save the data is how much money we have. We must have more disk space, that is what the question is about’ (Int. 3). Another interviewee saw the costs as less of a problem, as ‘storage is cheap’ (Int. 1), yet here too archiving was predominantly described in terms of storage, and not so much a question of access or maintenance. Maintaining software or other means to access old file formats were thought less relevant, to the point of being almost speculative: ‘[Our] hope would be that the file format is still valid for the software in the future’ (Int. 2). This also has to do with a vision of what constitutes long-term archiving for different purposes. In the public discourse, as in various official policies, archiving is presented as being synonymous with long-term preservation. With no time limits defined, the default appears to be ‘forever’—indefinite preservation (see Kimpton & Minton Morris 2014). Routines for deletion, as a form of sanctioned and controlled forgetting, are not part of this framing of the archive or data’s function in it. Yet, this long-term view is absent from the planning of research data management at the Lund facilities, where data are described in terms of time frames that are more directly instrumental. One interviewee talks of mere months:

> Would it now be, now we are looking in the crystal ball, say that we would have a greater responsibility when it comes to open access and long term storage then we have basically the infrastructure to … we do not store, as we have said now we save data for 3 months in order to be able to bring home your data … (Int. 3)

Regarding a longer-term perspective, he continued, 'We must not rebuild the system to store it longer or to make it available for longer; at least as far as I know, there is nothing more going to happen to the data after 6 years than there is after 20 years' (Int. 3). Here, data are seen to have a 'use-by date', after which they become inactive and are irrelevant for the planning of the data processing necessary for future experiments. At the same time, this is also problematized, for as another respondent reasoned, 'it is not fair to compare the uselessness of 10-year-old data today for how it will be in the future … better metadata might make today's data more useful in the future' (Int. 2).

The way in which the archive is framed reflects the conflict inherent in an instrumental view of data's place in the research process, and when data are inactive and have passed their use-by date. Access and use are relevant during the initial period, but afterwards data are put on hold and reduced to a question of disk space and storage, where they are at best held in waiting, but generally are defunct. Yet, that said, the same data can also hold a different future, a future when they might be found useful, and this is framed in terms of an opportunity, an expression of hope—'what if' or 'just in case'. That hope that data might have a life in a near or distant future also emerged in our material, yet here again this was vague and contradictory at times.

Timewise, research is done on tight margins. Lack of time necessarily factors in when discarding certain questions or not following certain paths. By saving data, the assumption is that researchers can go back to it later, when they have more time to follow up on interesting points noted at the time: such future data serves to delay the present, offsetting some of the pressures of delivering fast results while wanting to be thorough. Future data can 'provide opportunities to do things' (Int. 3) in new contexts, or 'in twenty years' time you might be interested in different effects or you could store the intended effect with the data. So you could replay the visualization' (Int. 2). Quite apart from this being good PR for the facility, it is exactly the point of open data policies that advocate long-term or perpetual preservation (see Arzberger 2014; Meyer & Schroeder 2015, 175–6). The hope is that technology will advance knowledge, almost by itself: 'You can imagine the future: that by the time by we get to 2020, 2022, that kind of time, that maybe you'll already have the algorithms available to have machine-learning tools that could help to qualify that data' (Int. 4). The hope, the possibility, that technology could be the driving force in the advancement of science in the long term, stands in contrast to the few months quoted above for the time data would be of real use to researchers. Similarly, data-mining was described as a far-off prospect—'I think it's far in the future. I've not seen anyone in this business who's looked into it' (Int. 3). The role of human researchers, close to their material and their sample, the physical artefact to be studied using the instrument or the beamline, was much more present. Interestingly, the sample is seen to be central for how it is imagined data will be useful outside their context of creation: 'If you don't have an understanding of the sample, it's a different story' (Int. 1) said one interviewee, highlighting the difficulty of making data meaningful through a succession of decontextualizations and recontextualizations.

Concluding remarks

We started from the question 'When are data?' in order to interrogate our material and pinpoint how data are made into objects of research and into documents in the archive of science (Bowker 2005). How data are created in the actual research process, as it is commonly imagined, is not our focus here; rather, all that surrounds and supports these processes. By bringing together the temporal and contextual notions of data, a richer, more diverse, but also more complicated, understanding of research data emerges. We find that research data are not only different things for different disciplines and in relation to different functions or even policies, but also that they have different meanings depending on when in the research process they are approached, and that the research process starts long before individual researchers start work and extends long after they have finished.

We have investigated how the ESS and MAX IV, two large-scale research facilities, work with data and metadata standards, the software tools with which to handle data, and policy tools and communication strategies. The challenges of data curation, handling, and description are immense, and increasingly big science is discursively associated with big data. Notions of data—what it is, how it should be handled, stored, and accessed, and why—inevitably vary, but all relate to the idea that data are a fundamental, component in the processes that stabilize science. From having been seen as stepping stones in the production of scientific results, data are increasingly positioned as results in themselves (Leonelli, 2014). This shift was also seen in our material. Often the justification given for data preservation and openness is that they might be of some use for new discoveries in the future, although what this means in exact terms is put differently by different groups. Research data engage a multitude of stakeholders, tools, and policies, and so forth in its management, transforming them from an ephemeral procedural element into stable components of scientific research to be handled, stored, and passed on. Clearly, what data are anticipated as doing in different futures plays a role in how data are framed today. Yet, when exactly this future will occur is a lot less clear. The accounts we were given shifted between vague hopes for a time ahead when technology will drive knowledge production and old data will be useful in ways impossible to fathom today, and more cautious, down-to-earth descriptions of technical issues, researchers, the requirements of different disciplines, and actual samples, and issues such as backing-up, file transfers, metadata, and processing, for which the future is just around the corner. Data is framed as occurring in the present, but in passing and on various temporal axes: streamed past the researcher, data go through various processes of enhancement, description, visualization, or recalculation, always on-going, always in the making.

Concerning the handling of research data, the interviewees' focus was often on the perceived needs of users, and the various translation processes required to enable communication between groups of people, but also between computer systems and software tools. Language metaphors were often employed to conceptualize the mediation of meaning or technical standards. Talk often turned to users—either individual researchers and groups, or industry as a more abstract category—with as many different ideas of who these users would be and what they might want to do. Those who had a background in the sciences imagined their users, and their data management goals and requirements, in greatly more diverse terms; they were alert to disciplinary cultures, policy or funder demands, users' computing skills, and publication or career demands. Across the board, users were portrayed as largely competent in expressing their demands, even when they lacked advanced computing skills. This is in contrast to what others have found elsewhere. Among our respondents from MAX IV and ESS, users were not described as a problem, existing only to disrupt an otherwise well-functioning system—a common way for users to be viewed by technical or other support staff in e-research and elsewhere (see Meyer & Schroeder 2015, 37). On the other hand, they are still seen to require a simplification of complex processes in order to be able to act at the level their qualifications and disciplinary background would indicate.

Our findings make it plain that data are not fixed and never can be. Data exist only by way of mediation, through their descriptions and the various digital tools that make them 'happen'. We explored some of the ways in which this is thought to occur, depending on when in the research process data are assigned a role. Data need to be rendered and related to other sets of data every time they are made manifest. They are emergent, relational, and shaped by their use—and use includes the preparation for data collection as much as archiving. The intricate relationship between data as object and data as archive is complicated further by the data being constantly relocated and redescribed in new contexts in order to function as research data in the first place. This way the archive is continuously delayed as new data objects emerge each time data are processed and made to exist. This brings us back to the question of how objects are made into documents, the central concern of the documentalist movement in the twentieth century (Bowker 2005; Hansson 2015). To conclude, thinking of research data as emergent not only through its entanglement with different user needs and data-processing tools, but also through the various temporal factors and across time-scales, can enrich our understanding of data as an object of research, an object of memory, and a cultural object of a continuously suspended future.

Interviews

(Int. 1) Interview, 27 January 2015. (RDM)
(Int. 2) Interview with 2 people, 17 February 2015. (RDM)
(Int. 3) Interview, 10 February 2015. (RDM)
(Int. 4) Interview, 20 March 2015. (PR)
(Int. 5) Interview with 2 people, 27 January 2015, not recorded. (Legal)

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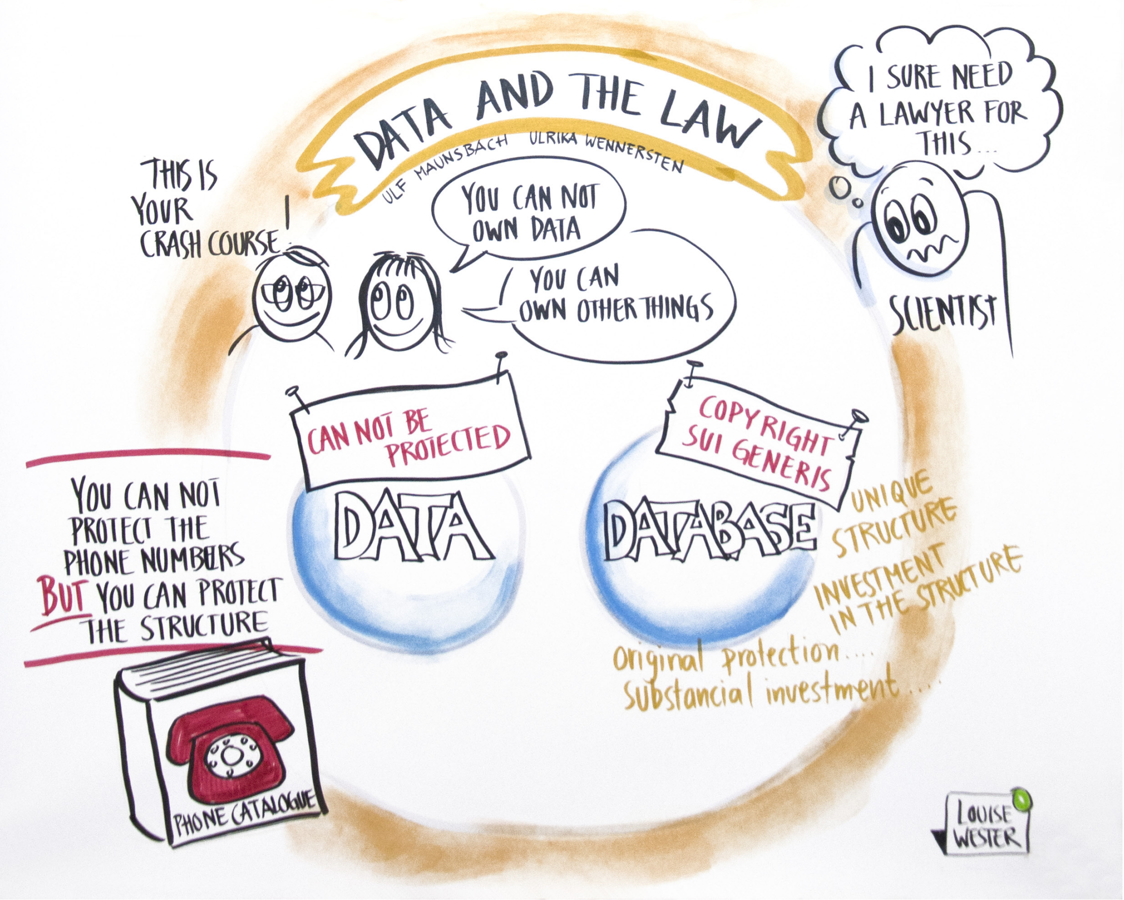
DATA AND THE LAW
ULF MAUNSBACH ULRIKA WENNERSTEN
THIS IS YOUR CRASH COURSE!
YOU CAN NOT OWN DATA
YOU CAN OWN OTHER THINGS
I SURE NEED A LAWYER FOR THIS...
SCIENTIST
CAN NOT BE PROTECTED
DATA
COPYRIGHT SUI GENERIS
DATABASE
UNIQUE STRUCTURE
INVESTMENT IN THE STRUCTURE
original protection....
substancial investment....
YOU CAN NOT PROTECT THE PHONE NUMBERS BUT YOU CAN PROTECT THE STRUCTURE
PHONE CATALOGUE
LOUISE WESTER

9. Data and the law

Ulf Maunsbach & Ulrika Wennersten

The notion of new big science involves the idea that scientific instruments are 'the heart of the empirical science' (Kaiserfeld & O'Dell 2013, 10–11). The instruments are becoming larger, more powerful, and more sophisticated in order to produce quantity, quality, and larger amount of data. As the flood of data is increasing, one of the pertinent issues is how to handle it. Especially since data has a commercial value of increasing importance. Thus the purpose of this essay is to initiate a study of the legal protection of data, and in particular the protection afforded to databases, both in the form of copyright and the specific (*sui generis*) protection. The investigation will be focused on two specific aspects: the prerequisites for the legal protection of data; and the question of accessing and using data even though there may be proprietary rights attached to it. Considering the limited remit of the investigation, a second purpose is to pinpoint areas for further research. For reasons that will be explained later, we have chosen not to cover patent and trade secret law, and we will not go in detail into the opportunity to control data by way of contracts.

The development of MAX IV and the ESS in Lund is an illustrative case. The experiments that will be conducted at these facilities will create data, and such data is of course valuable. However, despite its potential value, data is an illusory concept—immaterial, volatile, omnipresent, and vague. In contrast, legal rules are optimized to apply to physical and separable objects, as explained by Murray (2013, 2–14), so they are better fitted to apply to 'atoms' than to 'bits'. Of course, it could be argued that data in its original form, irrespective of value, has no obvious legal protection (disregarding the possibility of handling data under specific contracts), and that by default it cannot be owned, and consequently is, by nature, free. The purpose of this essay, in other words, is to explore the truth of this, and we will thus analyse whether there are indeed property rights to data. To do so, we will focus our attention on such protection as is afforded by copyright and database law, looking at the extent to which rules on copyright and database protection that were framed to apply to 'atoms' might also be applicable to 'bits'. As MAX IV is a public authority, any data produced by experiments conducted at the facility might be public sector information (PSI). We will therefore also explore the potential conflict between copyright protection and the right to access PSI according to *offentlighetsprincipen*, the principle of public access to official records.

Before exploring the possible forms of legal protection for big data, one should be aware that there are growing, and well-argued, concerns that data should be freely available, a line of thinking that has resulted in the growing open data movement, for example. What open data actually means has not yet been legally defined in statute or case law (De Filippi & Maurel 2015, 2), although there is an Open Knowledge Foundation (2015) definition, which was inspired by the open source definition. Then there is the open access movement, which has led to a number of open access initiatives. One of the most influential is the Berlin Declaration (2015), a short statement that presents two general principles that apply to open access. However, in the discourse of open access and open source, there has been little concern with the categorization issue—how we should define data, and above all how data should be categorized from a legal point of view. Open access initiatives, perhaps for obvious reasons, are of greatest interest for scientific publications. The Berlin Declaration explains that an open access contribution requires 'the active commitment of each and every individual producer of scientific knowledge and holder of cultural heritage' (2015). Thus it would seem it holds some kind of human creative involvement a prerequisite, although it is not overly specific on this point. In fact, across the board the Berlin Declaration's definition of open access is extremely wide:

> Open Access contributions include original scientific research results, raw data and metadata, source materials, digital representations of pictorial and graphical materials and scholarly multimedia material. (Berlin Declaration 2015)

The close association with publication is also found in a number of other policy documents. One example is the ISIS policy on publications and open access, which primarily deals with scientific publications, and in turn refers to Research Councils UK's policy on open access (ISIS 2015a). Open source and open access is also mentioned in the ESS's intellectual property rights policy (ESS 2015c), which declares open access to be one of three fundamental principles for ESS facility users, defining it as the publication of research results and access to research data.

Even though it may be necessary to frame open access in general terms in policy documents, where being excessively specific would risk omitting important aspects, broad definitions are problematic from a legal point of view. It seems that there is a general belief that the law imposes boundaries that prevent access to research (meaning research data and information derived from such data), and therefore it is necessary to adhere to open initiatives of various kinds. There may definitely be such a need, but, as we will see, it is not the law that prevents access.

According to legal principles, the general answer to the question of how data should be treated is simple. In order to claim a right to an object, that object must be possible to be possessed with property rights (ownership). Consequently, data is within the realm of the law if there are property rights attached to it. The question then becomes whether or not there are property rights to data—a question that makes a perfect starting point for this essay. We are well aware of the wide scope of the topic and its multifaceted nature, and we cannot claim to present any absolute answers, but what we can offer is an exploration of specific issues for further research.

In doing so, we will not seek to define data per se; instead, we investigate the legal framework that can be used to protect data (for example, rules on copyright and database protection), and then the question of data access, and particularly where data can be accessed as public sector information according to the principles of public access to official records. We will also look at the prospects of using contractual limitations to hinder access to protected databases and to expand protection to unprotected databases. Contract law apart, we do not consider the opportunities presented by the creation of property rights by agreement, although we acknowledge that it is important that this possibility exists. Neither do we cover patent law and/or trade secret laws, for they primarily offer protection to developed knowledge (patentable inventions and know-how), not data as such. Instead, in this essay we focus on data protection through copyright and the *sui generis* right, and, importantly, only for the data as an object in itself, and not for authorship in relation to written publications. Similarly, we do not look at the question of personality rights (personal data) in the situations where data could be regarded as personal and where the use of such data falls under privacy rules.

As to intellectual property protection in general, including copyright and database protection, an important cornerstone is the fact that intellectual property rights are limited in effect to the territory in which they have been granted (Kur & Dreier 2013, 12 ff., 243–4). Thus the final limitation to our essay is that we will concentrate on Swedish law, primarily because we have used the production of data at the ESS and MAX IV in Lund as illustrations. However, because copyright and *sui generis* rights to databases are harmonized areas of law (to a large extent within the EU and to a lesser extent globally), it is likely that our findings will be of more general relevance.

The legal framework

In looking at whether or not there is legal protection for data in the existing copyright and *sui generis* rights that apply to databases, we focus on the protection available in Sweden. We have chosen the legal dogmatic method, meaning that we study acknowledged sources of law in order to gauge the legal protection that presently exists in Sweden. However, the task is complicated by the fact that this is an area of law that is increasingly influenced by EU and international law. As a consequence, international sources (cases from non-Swedish courts and doctrinal writing) may be needed in order to understand the law as it stands in Sweden. In particular, the development of EU law in this area has to be taken into account. Crucial parts of the Swedish legislation on copyright and databases are implementations of EU directives, and the Court of Justice of the European Union (CJEU), in its role as the interpreter of EU law, is thus a driving force in legal developments in Sweden too.

It is within the realm of intellectual property law, which covers a wide variety of different intellectual achievements (inventions, design, and creative works in general), that we focus on copyright and the *sui generis* right that is provided for databases. It should be noted that copyright is manifestly influenced by the InfoSoc Directive and that the database protection is a direct implementation of the Database Directive.[17] Both directives have been implemented in the Swedish Copyright Act.[18]

It bears repeating that we have not looked at the traditional aspects of copyright, for example the protection afforded to creators of literary and artistic works; our interest is the potential protection for data, and as such we are mainly concerned with data and databases. For databases, being a compilation of data and materials, there is a specific (*sui generis*) protection that is framed as an investment protection, derived from the Database Directive. Copyright, however, is not a protection for investments, but a protection for the creative effort that is inherent in the production of (traditionally) literary and artistic works, and not ‘simple’ (although potentially expensive) creations such as databases. It may appear strange, then, that copyright is still on our agenda. The reason is that a database can, in addition to being an investment, also be a creative achievement, which in rare circumstances can be the object of copyright protection (Lloyd 2014, 372 ff.; Murray 2013, 296 ff.; Reed & Angel 2007, 397 ff.). In the present study, the question of copyright is raised in order to analyse the possibility of protecting a database as a copyright-protected work.

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[17] Directive 2001/29/EC of the European Parliament and of the Council of 22 May 2001 on the harmonisation of certain aspects of copyright and related rights in the information society [2001] OJ L167/44 (InfoSoc Directive); Directive 96/9/EC of the European Parliament and of the Council of 11 March 1996 on the legal protection of databases [1996] OJ L77/39 (Database Directive).

[18] Lag 1960:729 om upphovsrätt till litterära och konstnärliga verk [Swedish Copyright Act].

Data and databases

In our analysis, we thus look at the different forms of protection available for databases, which may appear obtuse given that our overall purpose is to investigate the protection for data. The logic behind this seemingly contradictory approach is that database protection, we find, is the only possible area where intellectual property rights to data as such exist. It is thus relevant to address the relationship between data and databases before considering the extent to which laws on copyright and databases can provide protection for data.

Both of the new large-scale research facilities in Lund, the EES and MAX IV, will produce data that will be stored in databases. This will be handled using different kind of software (for example, control software, data reduction software, data analysis software, and user office software) (ESS 2015a). Here it should be noted that the Database Directive may protect the compilation of data in a database, but it does not protect 'computer programs used in the making or operation of databases accessible by electronic means' (Art 1(3)). Instead, possible protection for computer programs is found in copyright law (in this case through the implementation of the Software Directive in the Swedish Copyright Act).[19] It has been argued, however, that that material for the operation and consultation of the database can be protected by the *sui generis* right that exists for databases (Derclaye 2014, 304). The Database Directive protects a compilation of data, of course, but not necessarily the data as such: in Article 1(2), a database is defined as 'a collection of independent works, data, or other materials, arranged in a systematic or methodical way and individually accessible by electronic or other means'.

The CJEU decided in the Apis-Hristovich case that the Database Directive gives the concept of a database a wide scope (C-545/07 [69]). The fact that the definition is wide does not preclude the definition comprising several problematic elements, which require further elaboration if one is

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[19] Directive 2009/24/EC of the European Parliament and of the Council of 23 April 2009 on the legal protection of computer programs [2009] OJ L111/16 (Software Directive).

to understand the complex relationship between the compilation (the database) and its components (the data stored). What is a collection, what are independent works, data, and other materials, and what is a systematic arrangement?

In looking at the relationship between data and databases, it should be borne in mind that a *collection* does not mean that the database has to consist of a large quantity of data—it can be sufficient to have just two elements (C-444/02 [24]; Derclaye 2014, 300–301)—but it is as an absolute requirement that it consist of independent works, data, or other materials. The Database Directive does not define *independent*, but CJEU has stated that what it means by independent is 'materials which are separable from one another without their informative, literary, artistic, musical or other value being affected' (C-444/02 [29]). The database must thus consist of a collection of data separable from one another without the value of their contents being affected. It should be possible to remove an element from the database or add an element to the database (Derclaye 2008, 62–3).

The contents of a database should thus be independent works, data, or other materials, but there are no definitions of these terms in the Database Directive. It is reasonable to conclude, however, that the term *works* means copyright protected works (Davison 2003, 73). As to the closer meaning of the terms *data* and *other materials*, the situation is more complicated, and different views exist in the literature and case law. Furthermore, there have been a number of attempts to define data in the data policies adopted by different research organizations.

Regarding the conceptual meaning of *data* and *materials*, Bygrave has found that data has a different meaning in different contexts. In the social and biological sciences, it is often used in relation to facts, quantities, or conditions that are derived from systematic observation or experimentation; in informatics, meanwhile, data is usually distinguished from information (Bygrave 2013, 27). The International Organization for Standardization defines data as a 'reinterpretable representation of information in a formalized manner suitable for communication, interpretation, or processing, interpretation or processing by human beings or by automatic means' (ISO 2015), or, as Bygrave remarks,

> this definition indicates that data has a representational function; thus data will ordinarily be distinct from the entity it is supposed to signify. In terms of human involvement, the definition indicates that data is structured, directly or indirectly, by humans so that it can communicate information; thus data is essentially artificial. (Bygrave 2013, 27)

In US case law, raw data is described as 'wholly factual information not accompanied by any original written expression' (*Feist Publications v Rural Telephone Service*, 499 US 340 (1991) at 345). In the ISIS data management policy, data is presented, with the use of the terms 'raw data', 'metadata', and 'results' (ISIS 2015b). For example, it defines *raw data* as 'data collected from experiments performed on ISIS instruments. This definition includes data that are created automatically or manually by Facility-specific software and/or ISIS staff expertise in order to facilitate subsequent analysis of the experimental data, unless otherwise agreed' (ibid.). *Metadata* is defined as 'information pertaining to data collected from experiments performed on ISIS instruments, including (but not limited to) the context of the experiment, the experimental team (in accordance with the Data Protection Act), experimental conditions and other logistical information' (ibid.), whereas *result* is defined as 'data, intellectual property, and outcomes arising from the analysis of raw data' (ibid.).

According to Bygrave, is it not clear whether the Database Directive uses the term *data* 'in the ISO's sense (or an equivalent informatics-based sense) or as simply a synonym for information (or a class of information)' (2013, 27). Derclaye states that data 'must mean information, i.e. data that is understandable to humans' and that 'the nature of the data is irrelevant' (2014, 302.). Masson points out that data comes from the word datum in Latin and refers to something given. To her mind, it is 'something received which can only be accepted and not modified' (Masson 2006, 206).

What constitutes data in the legal sense is not clear-cut, in other words. The term *materials*, meanwhile, 'does not include tangible objects unless they are works' (Derclaye 2014, 302). According to the CJEU it is 'irrelevant whether the collection is made up of materials from a source or sources other than the person who constitutes that collection, materials created by that person himself or materials falling within both those categories' (C-444/02 [25]).

From the fact that the collection must be arranged in a systematic or methodical way, it may be concluded that this prerequisite relates to database protection rather than data per se, as will be discussed later. Here it suffices to say that it is not necessary for the arrangement to be physically stored. According to the CJEU, the collection should 'be contained in a fixed base, of some sort, and include technical means such as electronic, electromagnetic or electro-optical processes, … or other means, such as an index, a table of contents, or a particular plan or method of classification, to allow the retrieval of any independent material contained within it' (C-444/02 [30]). It may thus be concluded that a database is:

> any collection of works, data or other materials, separable from one another without the value of their contents being affected, including a method or system of some sort for the retrieval of each of its constituent materials. (C-444/02 [32])

It seems reasonable to conclude from this that it is possible to have a comparatively clear perception of what a database is without a clear perception of data.

Copyright protection

One fundamental pillar of copyright law is that it does not protect ideas, facts, or data; copyright protects literary and artistic works (TRIPS article 9.2;[20] Cornish et al. 2013, 435). The CJEU has stated that the criterion for qualifying for copyright protection is originality—in the sense that it is its author's own intellectual creation (C-5/08 [37]). An intellectual creation is the author's own if it reflects the author's personality and 'that is the case if the author was able to express his creative abilities in the production of the work by making free and creative choices' (C-145/10 [89]). The fact that copyright protection is limited to 'works' means that ideas can only be protected in the form in which they are expressed (with a spark of

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[20] WTO, Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS), 1994.

originality). Thus data per se cannot be protected, but it can be protected if it is expressed in a literary or artistic work. If so, it is the creator, the one who stands for the work's 'expression', who will be the proprietor of the copyright.

Databases can be protected under a specific database right; however, they may also be protected, like many other creative works, under copyright law, but only when they can be regarded as original creations. Copyright protection 'provided for databases by the directive concerns the "structure" of the database, and not it's "contents" nor, therefore, the elements constituting its contents' (C-604/10 [30]). In other words, copyright only protects the structure of the database and not the data it contains. The CJEU has clarified how the concept of originality should be applied to databases in a case, stating that they were to be 'protected by copyright if, by reason of the selection or arrangement of their contents, they constitute the author's own intellectual creation' (C-604/10 [29]). The CJEU also stated in the same case that "by contrast, the criterion of originality is not satisfied when the setting up of the database is dictated by technical considerations, rules, or constraints which leave no room for creative freedom" (C-604/10 [39]).

If the database is protected by copyright, the author of the database is the natural person or the group of natural persons who created the database. The proprietor/s of the copyright will be granted a set of exclusive economic and moral rights to the database. The economic rights can be transferred to a legal person or another natural person by contract. The opposite situation applies for moral rights, which cannot be transferred, but the proprietor may, with binding effect, waive the moral rights to uses that are limited as to character and scope (Swedish Copyright Act, Art 1, 3.3 & 27).

The economic rights include an exclusive right to control the work by reproducing it and by making it available to the public, be it in the original or in an altered form, in translation or adaptation, in another literary or artistic form, or by other technical means (Swedish Copyright Act, Art 2). Derclaye (2014, 313) notes that by analogy the CJEU Case C-5/08 is probably applicable, with the result that parts of the *expression* of the database can be protected 'provided that they contain elements which are the expression of the intellectual creation of the author of the work' (C-5/08 [39]).

Digital databases do not often qualify for copyright protection, since neither the selection of data they contain nor the method of arrangement show sufficient originality (Cornish et al. 2013, 847; Garrigues 1997, 3). Mere economic investment and intellectual effort are generally insufficient for copyright protection. In some EU countries is it also possible to protect databases from unauthorized misappropriation under a theory of protection against unfair competition or similar torts, but such protection is not available in Sweden (Kur & Dreier 2013, 266).

The upshot is that there is little scope for copyright protection of databases and data, unless there is an element of originality, some human creative effort. However, in the rare circumstances when a database *is* granted copyright protection, it gives the creator a strong position as regards both economic and moral rights. A copyright affords the proprietor the chance to prevent others from using the creation that the copyright protects—with the proviso, of course, that ideas, data, or facts are not covered by copyright protection, only the unique expressions that may be a result of an original selection or arrangement of the content. When it comes to the potential copyright protection of a database, it is not relevant if there is originality in creating the data (Derclaye 2014, 309).

Database protection

Even in situations when a database does not fulfil the prerequisites for copyright protection—the likely scenario for an overwhelming majority of databases—it may be granted protection under the *sui generis* right that exists within the EU for databases, thanks to the Database Directive (Murray 2013, 297 ff.). In Sweden, the Database Directive has been implemented in the Swedish Copyright Act, hence the principal rule established in Article 49, which states:

> Anyone who has produced a catalogue, a table or another similar product in which a large number of information items have been compiled or which is the result of a significant investment, has an exclusive right to make copies of the product and to make it available to the public. (Swedish Copyright Act 2005)

Article 49 also states that 'contractual stipulations that extend the rights of the producer pursuant to the first paragraph, are null and void.' Plainly Sweden offers protection for non-creative compilations under this 'catalogue rule', and it may even be argued that the protection afforded by Article 49, covering other forms of compilations, is more extensive than the level of protection suggested by the Database Directive. Henceforth, however, we will focus our attention on the protection that is implemented through the Database Directive and we will not develop potential differences that are related to the 'catalogue rule'.

According to the Database Directive, then, a database has to be a collection of independent works, data, or other materials, with the items it contains accessible on an individual basis, while according to the CJEU it is 'any collection of works, data, or other materials, separable from one another without the value of their contents being affected, including a method or system … for the retrieval of each of its constituent material' (C-444/02 [32])—a definition which, clear as it may be, pays little attention to content, for example the data that is included in the database. In other words, data is not a crucial aspect of the protection. Instead, a core aspect of the construction of database protection is the fact that the data needs to be arranged in a systematic or methodical way. Putting random information and items together will therefore not create a database, and the database right would never protect the data under those circumstances (Derclaye 2002, 465–6). If the software in the database organizes information which has been randomly fed into the system, the collection may meet the requirement (Stamatoudi 2004, 93); indeed, the criterion of a *systematic or methodical way* is relatively easy to meet as 'alphabetical, chronological or subject arrangement should suffice' (Aplin 2005, 206). The technical way in which this is achieved seems to be irrelevant (C-202/12).

The database right only protects databases that have been created after a qualitatively and/or quantitatively substantial investment in obtaining, verifying, or presenting their contents (C-203/02 [29]). Qualitatively and/or quantitatively investment is not defined in the Database Directive. The CJEU has stated that 'the quantitative assessment refers to quantifiable resources and the qualitative assessment to efforts which cannot be quantified, such as intellectual effort or energy, according to the 7th, 39th and 40th recitals of the preamble to the directive' (C-338/02 [28]; C-46/02 [38]; C-444/02 [43]). The investment can be made in financial, human, or technical resources. A substantial investment has to be evident in the obtaining, verifying, or presenting of the contents of the database (Bently & Sherman 2014, 351); in other words, a substantial investment refers to the investment in the creation of that database as such (C-203/02 [30]).

Both the courts and legal scholars have considered so-called spin-off databases, meaning spin-offs from a producer's activities such as scientific data resulting from research or experiments, and whether or not they are covered by the *sui generis* right, since the production of a database is not the primary purpose of these activities (Derclaye 2004, 402). From this, nuancing our understanding of the scope of the protection for a database, comes the spin-off doctrine, which holds that collections of data that are by-products ('spin-offs') of the main activity of the producer fall *outside* any database protection (ibid.)

Derclaye has classified data into four groups and investigated whether the spin-off doctrine applies to data in each of the groups. The fourth group she identified was 'data actually collected in nature by instruments of measure and recorded in intelligible form' (Derclaye 2004, 411). In theory, anyone could record this data as it pre-exists in nature, but the instruments are so expensive and advanced that very few entities can actually collect the information. Her point is that if the main activity is to present the data, then the substantial investment was in the collecting and presenting of the data for their own use, and the spin-off doctrine would then not apply, with the result that the database would be protected. If instead the main purpose was 'to understand the functioning of nature, be it the universe or living beings, then it can be said that the data generated are a by-product of this main activity. In this case, the spin-off theory would apply. As has been seen, the theory should not apply indiscriminately, since there can be a substantial investment in presentation' (Derclaye 2004, 411). To conclude, databases that are spin-off databases are only protected by the *sui generis* right if there is proof of separate, substantial investment in gathering the created data. This is often difficult when it comes to single-source databases (for example, a database that is produced by the same single entity as has produced the data) and therefore these kinds of databases will rarely be protected (Derclaye 2014, 322–3).

Adding further to the understanding of *sui generis* databases, it should be noted that the CJEU has clarified the scope of protection by introducing a distinction between the 'creation' and 'obtaining' of data. The CJEU stated that 'the expression 'investment in … the obtaining … of the contents' of a database in Article 7(1) of the Database Directive must be understood to refer to the resources used to seek out existing independent materials and collect them in the database. It does not cover the resources used for the creation of materials which make up the contents of a database' (C-203/02 [42]). The court's reasoning here was a development of previous case law, in which the CJEU had stated that:

> The purpose of the protection by the *sui generis* right provided for by the directive is to promote the establishment of storage and processing systems for existing information and not the creation of materials capable of being collected subsequently in a database. (C-46/02 [34])

The CJEU, in other words, refused to count any investment before or at the time of the 'creation' of the data as constituting a substantial investment in the database itself (Davison & Hugenholtz 2005, 118). As pointed out in the first evaluation of Directive 96/9/EC on the legal protection of databases, 'ECJ's differentiation between the "creation" of data and its *obtaining* demonstrate, the "*sui generis*" right comes precariously close to protecting basic information' (EC 2005, 24). As Borghi and Karapapa conclude, this seems to be in line with the principle that copyright should not cover basic information or 'raw' data, 'especially when these are made available from a single source only' (Borghi & Karapapa 2015, 505; Davison & Hugenholtz 2005, 113).

The maker of a database has to show a substantial investment (qualitatively and/or quantitatively) in obtaining, verifying, or presenting the content. The CJEU has defined the terms *verification* and *presentation* as follows:

> The expression 'investment in … the … verification … of the contents' of a database must be understood to refer to the resources used, with a view to ensuring the reliability of the information contained in that database,

> to monitor the accuracy of the materials collected when the database was created and during its operation. The expression 'investment in … the … presentation of the contents' of the database concerns, for its part, the resources used for the purpose of giving the database its function of processing information, that is to say those used for the systematic or methodical arrangement of the materials contained in that database and the organisation of their individual accessibility (C-338/02 [27]).

The database right is vested in the investor who produced the database (the maker of the database). This owner has the right to object to the extraction or reutilization of all, or a substantial part, of the contents of the database. According to the Database Directive (Art 7(2) a–b), *extraction* means the permanent or temporary transfer of all or a substantial part of the contents of a database to another medium by any means or in any form, and *reutilization* means any form of making available to the public all or a substantial part of the contents of a database by the distribution of copies, renting, online, or other forms of transmission. The repeated and systematic extraction or reutilization of insubstantial parts of the contents is also an infringement (Kur & Dreier 2013, 268). A typical example of another type of infringement is the extraction of a substantial part of the contents of the database and then reorganizing it by computer into a prima facie different database (C-203/02 [61]).

In one case, the CJEU found that the concept of *extraction* must be understood as referring to any unauthorized act of appropriation of the whole or a part of the contents of a database, and the concept is not dependent on the nature and form of the mode of operation used. The important criterion is an 'act of "transfer" of all or part of the contents of the database concerned to another medium, whether of the same nature as the medium of that database or of a different nature. Such a transfer implies that all or part of the contents of a database are to be found in a medium other than that of the original database' (C-304/07 [34–6]). In the same case, the CJEU also stated that

> transfer of material from a protected database to another database following an on-screen consultation of the first database and an individual assessment

> of the material contained in that first database is capable of constituting an 'extraction', within the meaning of Article 7 of Directive 96/9, to the extent that—which it is for the referring court to ascertain—that operation amounts to the transfer of a substantial part, evaluated qualitatively or quantitatively, of the contents of the protected database, or to transfers of insubstantial parts which, by their repeated or systematic nature, would have resulted in the reconstruction of a substantial part of those contents. (C-304/07 [60])

It may be concluded that there is no originality requirement for specific database protection, and that this *sui generis* right is better fitted than copyright to protecting a collection of data that may be part of the output of big science experiments, even if it is difficult to protect spin-off databases.

Contractual limitations

Although contracts are outside of the scope of this essay, it is important to underline that it is not possible, by way of a contract, to exclude the permitted lawful use of a database which is protected under the Database Directive. According to Article 15 of the Database Directive, a contract that overrides the rules in the directive regarding 'lawful use' (Art 6(1) & 8) will be declared null and void. Article 15 applies equally to sole-source databases and multiple-source databases (Derclaye 2014, 352).

A perhaps surprising contradiction is that Article 15 of the Database Directive, according to the CJEU (C-30/14), does not apply those databases which, even though that they fall under the definition of a database given in Article 1(2), are not protected by copyright or the *sui generis* right. That means that the Database Directive does not preclude the author of such a database from laying down contractual limitations on its use by third parties, without prejudice to the applicable national law (C-30/14 [44–45]). In other words, if a database is not protected either by copyright or by the *sui generis* right, the owner has full contractual freedom. According to Borghi, the consequences of this are that 'unprotected databases can benefit from stronger contractual protection than databases covered by copyright or the *sui generis* right' (Borghi & Karapapa 2015, 505).

Access to data

Thus far the discussion has focused on the question of whether or not data may be protected, with proprietary rights to data that give the proprietor the possibility to deny access to the protected data. Having thus investigated the ways of protecting data and databases, we now turn to the other side of the coin, the possible means of access.

One important starting point is the fact that the intellectual property rules that protect data cannot prevent Swedish citizens from exercising their right to access public sector information according to the principle of public access to official records. The principle states that:

> To encourage the free exchange of opinion and availability of comprehensive information, every Swedish citizen shall be entitled to have free access to official documents. (Swedish Freedom of the Press Act, c 2, Art 1)

A document is an object that contains information (Lenberg et al. 2015). For a document to be regarded as official it has to fulfil certain criteria, namely that it should be held by a public authority, having been submitted to it or has been drawn up by it. A document counts as drawn up when it is dispatched, or when the matter to which it relates has been settled or checked and approved by the authority, or has otherwise received its final form. In the case of records and comparable memoranda held by a public authority, the document has been finalized once it has been checked and approved by the authority or has otherwise received its final form (Swedish Freedom of the Press Act, c 2, Art 7).

The only exemption from the right to access public sector information is if the documents are protected under a rule in the Swedish Public Access to Information and Secrecy Act of 2009.[21] According to the Act:

> secrecy applies in relation to information in a work protected by copyright concerning which it cannot be assumed that it lacks commercial interest, if it is not obvious that the information item can be disclosed without harm to the right-owner and there are special reasons to assume that the

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[21] Offentlighets- och sekretesslag (2009:400).

> work has not earlier been made public in the sense of the Act (1960:729) on Copyright in Literary and Artistic Works, there are special reasons to assume that the work has been filed with the public authority without the consent of the rights owner, and a disclosure of the information item would constitute an exploitation in the copyright sense.
>
> For the purpose of the application of the first Paragraph, a work that has been made available under Chapter 2 of the Freedom of the Press Act or has been transmitted from one public authority to another shall not thereby be deemed to have been made public. (Swedish Public Access to Information and Secrecy Act, c 31, s 23)

This is an exemption, of course, and the standard rule is free access to official documents, but even if there is a possibility for a citizen to access official documents, that person has to comply with intellectual property rights that may exist for that official document (for example, there may be pictorial illustrations in official documents that are protected by copyright).

The right to reuse public sector information is regulated by the PSI Directive and was implemented in Sweden in the Re-use of Public Sector Information Act.[22] The directive establishes a minimum set of rules governing the reuse of existing documents held by public sector bodies. The term *document*, according to Article 2.3, means 'any content whatever its medium (written on paper or stored in electronic form or as a sound, visual or audio-visual recording)', or 'any part of such content'—plainly a very broad definition that thus also covers data. In the government Bill (Prop. 2014/15:79, 14) that preceded the Act, it is also stated that the definition of the term document it uses is the same as in the Swedish Freedom of the Press Act. MAX IV is a public sector body, but because the MAX IV laboratory is a national laboratory hosted by Lund University, it falls outside of the scope of the PSI Directive, as its cover does not extend to documents held by educational and research establishments, including organizations established for the transfer of research results, including

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[22] Directive 2003/98/EC of the European Parliament and of the Council of 17 November 2003 on the re-use of public sector information [2003] OJ L345/46, as amended Directive 2013/37/EU [2013] OJ L175/1 (PSI Directive).

schools and universities. The same is true of documents in which a third party holds intellectual property rights. The PSI Directive is applicable to university libraries, however.

In discussing access to data, it is essential to differentiate between situations in which data is produced in the public sector and when it is produced in the private sector. This distinction is highly relevant given the on-going developments in Lund, for whereas MAX IV is a part of Lund University, and thus part of a public authority, the ESS is a European Research Infrastructure Consortium (ERIC), which is to be regarded as an international organization.[23] The transition from ESS AB to ESS ERIC was due for completion by 1 October 2015 (ESS 2015b). The principle of public access to information applies only to central government and municipal authorities, which includes MAX IV, but not to international organizations, which is what the ESS will be when transformed into an ERIC.

The general principles of public access to information are one important aspect of 'open access', but in practice it is the possibility to handle access by way of contracts that is crucial. Contractual aspects, while not a primary focus in this essay, are nevertheless impossible to disregard completely. Bearing in mind the limited prospects for protecting data as such—for as we have seen, it is not the data, but rather the 'human involvement' in the refinement of data that is protected by copyright and/or database law—contracts provide a chance to create a protection that the law does not provide. In this sense, both copyright and database law offer considerable room for manoeuvre, with more or less unlimited room for agreements on access to data, even though the majority of such contracts exist to ensure strengthened protection rather than a limitation of existing legal protection. With a protection provided by law or, more likely, by contracts, it is possible (and very common) for proprietors to provide access to protected data by way of a licence agreement.

Traditional licence agreements are often not suitable for use in governing access to big data. The reason is that big data often consists of unstructured

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[23] Prop. 2012/13:190, p. 6, art. 7.3; Council Regulation (EC) 723/2009 of 25 June 2009 on the Community legal framework for a European Research Infrastructure Consortium (ERIC) [2009] OJ L206/1.

data, and the licensees often want to exploit the data in various ways, whether performing unique analytics, combining the data with other databases or using the data in ways not foreseen when the data was produced or collected (Tantlett 2015). This leads to other considerations when drafting licence agreements that concern big data.

Conclusion—the road ahead

The purpose of this essay has been twofold: to initiate an analysis of how data may be protected by copyright and database law; and to pinpoint areas for further research. As to the pinpointing, we can begin with the obvious. The areas that have been set aside in this essay will need to be addressed, for example the contractual aspects, patent law, and the protection of trade secrets. Of special use would be a further analysis of the specifics of drafting licence agreements for big data. Within the limits of our own study, we can also conclude that there is a need to establish how copyright and database law may be applied in relation to data. Our findings bear out much of the initial statement that data should be free and unprotected, but, true or not, this statement can nevertheless be questioned, and the question of the appropriate level of protection is still open.

As to our general conclusions regarding data protection, copyright law can very well protect the structure of a database, and database protection may provide a *sui generis* right to the use or extraction of the database content. For both, human involvement is the key element when the level of legal protection is to be assessed. In one sense, data, irrespective of how 'qualified' it is, can never be protected as such by copyright and/or database law. Rather, it is the human involvement that is protected; the original creative effort that is needed for an expression to be protected by copyright law, and for the investment that is embedded in a database to be protected by the *sui generis* right that exists for databases. Consequently, data per se can never be protected, whether by copyright or database law.

A perhaps unexpected conclusion is that the makers of databases that are not protected by copyright or the *sui generis* right are not subject to any obligation to ensure that lawful users can access the content. The makers, by way of their contractual freedom, thus benefit from a de facto unrestrained protection. Evidently, there is a longstanding consensus that potential protection should not prevent users from accessing information, facts, and raw data, especially when they are made available from a single source only.

Ultimately, our study shows that protection and access to data are surrounded by a complex system of multilayered rules, whether copyright for original databases, *sui generis* rights for non-original databases, intellectual property rights policies, and the right of Swedish citizens to access public sector information. It cannot be overemphasized that the consequence of this multifaceted environment is that all parties involved have almost limitless opportunities to clarify and simplify, simply by drafting well-thought-through agreements.

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10. Institutional change in science activities: The case of human spare parts in Finland

An interview with Markku Sotarauta
by Josephine V. Rekers

Markku Sotarauta is Professor of Policymaking Theories and Practices (Local and Regional Development) at the School of Management at the University of Tampere, Finland. His research focuses on leadership, innovation systems, and institutional entrepreneurship in city and regional development. In recent years, Sotarauta has contributed to a growing body of work in the field of economic geography, and the social sciences more generally, that takes the concept of institutions as its central object. Institutions can be defined as 'socially constructed rule systems, norms, and/or institutionalized practices and belief systems that produce routine-like behaviour' (Sotarauta & Mustikkamäki 2015, 343), and which thereby structure social interactions. Using a case study of the growth of the new scientific field of regenerative medicine in Tampere, Sotarauta investigates how institutions change in order to match an evolving economy. Institutional change poses an intriguing puzzle for investigation as they 'by definition, imply permanence and stability. Institutions are resistant to change by nature' (Sotarauta & Mustikkamäki 2015, 343). The key contribution of his work revolves around the concept of institutional entrepreneurship, which specifically aims to view the individual actor through the lens of institutional change for regional development (Sotarauta & Pulkkinen 2011).

You came to talk to us about institutions as enablers and obstacles to establishing new scientific fields—in your case, establishing research activities in regenerative medicine in Tampere, Finland. Could you tell us a little more about these obstacles and how they were overcome?

If I think about the early phases of regenerative medicine in Tampere, the biggest obstacles were related to cultural–cognitive institutions. People simply didn't know what this kind of science was, what were the potential commercialization products or businesses—regenerative medicine simply didn't exist in Tampere, and that was a big obstacle. There was a need to make people see beyond their own specialization areas. There were not so many obstacles in the legislation or anything like that; it was more that people didn't see the opportunity, and the two professors who introduced the idea, and pushed it forward, weren't able to explain it very well as the vocabulary was still not well developed, and as they didn't know well by themselves where it all might lead. The question was more about a scientific hunch than anything else. Thus, it was very difficult for university leaders to understand what scientists were talking about, and that was the biggest obstacle at first.

In making the scientific hunch more concrete, the Centre of Expertise programme played an important role. It facilitated a collective discussion; is there something with potential here or not? When they were able to launch a collective conversation about all this, some cracks in the wall began to show, cracks in the thinking; so to speak. More people began to see that there indeed might be something. It was a local economic development team, including scientists and clinicians, which set this collective conversation in motion, even if the key actors did not know exactly what they were aiming at. But they were positive people who wanted to find new employment, new businesses, and new opportunities.

There is a life cycle to institutional change. Different kinds of institutions change at different points in time and are dependent on one another in that sense. Sometimes we see obstacles that are not there, and when our collective thinking starts to change and we start to believe in something, we come to see that they are not obstacles at all. For instance, at first I thought that there was a lot of red tape in regenerative medicine. But the people involved proved my conviction wrong: 'No, there are no obstacles, it's a quality assurance system. We have to be on the safe side, we have to do scientifically sound research, and they are helping us, they are not against us'. And if there is something that is not regulated or if they don't know what some regulations mean, they pick up the phone and call them. So the regulation was co-evolving with the science.

In a way, one of the biggest obstacles for the human spare parts industry in Tampere was, and still is, that even though there is a lot of demand for these kinds of treatments, there are people who could be cured using the new technology, but, in practice there is no demand, as the treatments are not yet an elemental part of the healthcare system. Thus they are invisible to most of us. Broadly speaking, there was, and is, a strong societal demand or belief that this will change the healthcare system and we can cure incurable diseases in the future, but there are no services yet. So a new industry is emerging, but the supply and demand don't match yet.

So the belief in the opportunity and promise held by this new technology is now shared more amongst the different stakeholders, and it's about making those beliefs into concrete things?

Yes, the two universities have institutionalized biomedical research in this area in collaboration. Various funding bodies have been generous towards developments in Tampere, and BioMediTech, the institute with 250 scientists, has a favourable position both locally and nationally. Moreover, there indeed are individual people who might have lost a jaw or something in the facial area and who could be cured in Tampere. They may well call the university or the university hospital, but the answer is 'No, we can't do it. We don't have a service for you.' There is a science system for regenerative medicine, but there is no system in place to cure patients yet. They don't have enough clinical evidence yet for the healthcare system, and that's the biggest obstacle at the moment. In addition, the new technology is again facing so-called cognitive institutions—as the university hospital's leadership say, 'this is interesting, we have heard about this, but we'll see.' The university hospital is curious, but not strategic. That is quite natural, as it's facing financial difficulties, and its mission is not to push the frontiers. So, the hospital is not willing to do anything strategic about it yet, but it allows individual clinicians to experiment with new technology.

Generally speaking, many in the hospital are aware of what is said in the scientific papers and newspapers and media in general, they believe in the field, but they also believe that it may take 10 or 20 years to actually put these new technologies into everyday practice. That's the thing; they don't know where we are at the moment, and thus they wait and don't take a proactive stance. There also is a tricky balance between hype and reality. The media, TV, and newspapers describe the new treatments fairly regularly. They are mostly factual, but, of course, there are also some less factual stories in circulation. Not much, though, I would say. Scientists seem to be a bit worried about the hype and short-term expectations, but at the same time, many of them know that publicity is good for funding. And that's the tricky balance. Managing expectations is something that has not been done consciously in this case and I would say that in the near future, it may turn out to be harmful for the whole thing. If the hype is going its own way and the real science is going more slowly somewhere else, oversized expectations may burst like a balloon on the first of May.

You have written that institutional entrepreneurs are actors who have an interest in changing particular institutional arrangements, and who mobilize resources, competences, and power to create new institutions or transform existing ones. Can you say a little bit more about their role in the process of institutional change? On the one hand you describe this as a collective, on-going, multi-actor process, but on the other you suggest that institutional entrepreneurship is often unplanned, highly personal, an intuitive form of agency. What is the relationship between structures and agencies in the process of the emergence and launch of a new field?

If I go back to the early phases of the emergence of regenerative medicine in Tampere: those two professors who launched it, to put it really simply, they said, 'My research and other fields related to it are important, and they could be even more important, as there is something that is called tissue engineering emerging,' and that was the intuitive part of institutional entrepreneurship here. They didn't know exactly in what ways it could be beneficial, but they somehow believed that it would be, and they launched the process. But they didn't know if it would happen or not and in what ways it should be put in practice. In that way, it was intuitive and very personal. As the university was not keen on pushing it forward, the Centre of Expertise programme and some other local and regional development practitioners launched a collective conversation about what the opportunities were, and what could be done locally. They started to make a business plan and an infrastructure around the ideas. They believed in the idea, yes, but also in the reputation of those professors. They believed that if the professors are saying it's important, there must be something to it. But those guys at the local economic development team could not have done it by themselves. They got help from the university, but also outside the university system, and then later it became much more planned. What was important is that a collective belief emerged, and more and more core actors began to see what it was all about. Also the leadership of the University of Tampere saw that there was indeed something that should be taken seriously. Then in a fairly short time a tissue bank and an ultra-clean laboratory were established—that was a fairly big investment. Tampere University of Technology, Tampere University of Applied Sciences, and the University Hospital participated in these efforts with the University of Tampere, and soon the Regea Institute for Regenerative Medicine was established. Today, it is part of BioMediTech. Strengthening regenerative medicine became part of the university strategy, and it was not such a personal and intuitive effort any more. It had become part of the institutional strategy, and in 2014 all this received so called 'profile funding' from the Academy of Finland. Fifteen years ago regenerative medicine was a scientific hunch; today, with other fields of biomaterial research, it's a fundamental part of the officially recognized research profiles of two universities.

When the Institute for Regenerative Medicine was established, one important decision was to have a director who was very application-oriented, commercially oriented. There is always that question 'Should the director be a scientist or more focused on exploitation?', and the director who came to lead the institute was a scientist and a medical doctor, but really business-oriented. The director put her entire personality in the place. She was always ten years ahead of everyone else, including her researchers and the whole institute and the whole university. She made it in a way intuitive again. The first treatments doctors and scientists carried out at the institute were very experimental; I have been wondering how they had the courage to do it so early. They simply did it: if the patient says yes, if there is a medical doctor who is willing to carry out the surgery, and if the scientists say that the technology is good enough, OK let's do it. In practice, they were able to exploit the so-called hospital exemption that allows these kinds of treatments. The director knew the surgeons in various hospitals personally, she found people who were willing to do the surgery because they knew the scientific research that led to these treatments and trusted her. Actually, it was great, they simply jumped out in the unknown as the first in the world, and succeeded. And that's why it's institutional entrepreneurship, that the director was willing to push the boundaries of the whole system.

When studies look at the role of leadership and the role of individuals in this process of organizational and institutional change, are they not risking falling into the trap of hero-worshipping? How do you avoid this?

I don't like using the word 'hero', but in a way they are heroes at a certain point of time. They either exploit the existing structure or change it somehow, and take big risks and are able to mobilize people, their competences, and funding. But looking at it more broadly, if we look at the whole process, what happened to the two professors who launched the field of regenerative medicine in Tampere? One retired, the other one is teaching and doing research again, as far as I know. The same goes for the institute [Regea]: it doesn't exist any more in the form in which it was established, and the first director is with the University of Helsinki now. Leaders come and go, it is a kind of leadership relay, mostly unconscious, but in this case it was effective. I would say that many people played heroic roles at certain points in time. They are needed at a particular time. What is funny but human, I guess, is that the new heroes usually downplay the old heroes. They don't see the leadership relay, but only themselves.

You have been studying a subject that is scientifically very complex, as we have in our project on new big science in Lund. What is there to gain from studying a science-intensive case from a social science perspective? What is the opportunity of studying emerging fields in real time?

First of all, it's really interesting, because you do something that no one really knows if it will, or how it will, play out over time, and it's quite rare to be able to be close to these kinds of processes, witness them as they happen. You rarely get to see how a whole industry is emerging. That's really interesting. For us, it's useful to learn more about the scientific process—how the scientists think, what they do, how they work. It's also useful because it's so high on the agenda in Tampere and Finland at the moment. Being non-scientists, we are also a bit strange in that field, and that's a good combination. Being strange means that we can provide scientists as well as policymakers with added value; we think differently and they are very keen on us. We organize a policy briefing session every six months, where we invite 20–30 persons from ministries, city government, the chamber of commerce—dedicated people who are interested in this industry at the moment, economic development, etc. We present what we have been doing, what we have found, and then we spend something like 3–4 hours discussing this with them. There are usually really good questions and discussions after that. What's in it for them? Usually they say that they have never thought about it like that: the one who is responsible for regulations only sees regulations. And the one who is responsible for quality only sees the quality assurance system, and so on. We haven't published our conclusions and policy recommendations yet, but I can already see how BioMediTech is adjusting its commercialization strategy, and how the continuous discussion with them has made not only us, but also them, see many things in a new light. I hope that our contribution has nudged the human spare parts industry a bit in a new direction. What I know, is that we have a very good data for several publications—and it's been truly enjoyable.

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Catherine Westfall, Visiting Associate Professor at Michigan State University, is one of the leading historians of big science labs. She has conducted a wide range of historical studies at national laboratories in the US, including the Jefferson Laboratory, Fermilab, and the Los Alamos National Laboratory. Her current research project focuses on how physicists construct scientific intent in the design and construction of their instruments in the era of the new big science. Westfall has further been influential in the debate about how to conceptualize big science.

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This anthology is the outcome of an interdisciplinary research theme at the Pufendorf Institute for Advanced Studies at Lund University. The editors Josephine V. Rekers and Kerstin Sandell are both social scientists, affiliated with the Department of Human Geography and the Department of Gender Studies respectively.

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