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Veröffentlichungsversion / Published Version
Sammelwerksbeitrag / collection article

Empfohlene Zitierung / Suggested Citation:
Joerges, B., & Shinn, T. (2001). A fresh look at instrumentation - an introduction. In B. Joerges, & T. Shinn (Eds.), *Instrumentation between Science, State and Industry* (pp. 1-13). Dordrecht: Springer. https://nbn-resolving.org/urn:nbn:de:0168-ssoar-54865-2

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A FRESH LOOK AT INSTRUMENTATION
AN INTRODUCTION

IN BERNWARD JOERGES AND TERRY SHINN (EDS.), *INSTRUMENTATION BETWEEN SCIENCE, STATE AND INDUSTRY*, DORDRECHT: KLUWER ACADEMIC PUBLISHERS 2001, 1-13

In the 1930s, 40s, and 50s, the American Jesse Beams (1898–1977) developed the modern ultra-centrifuge (Elzen 1986; Gordy 1983). The device and the man do not fit neatly into any standard institutional, professional, or intellectual mold. Long-time chairman of the University of Virginia physics department, Beams also sponsored two firms, acted as a key consultant to four additional companies, participated in the Manhattan Project, worked for the military during the 1940s and 50s, and contributed to numerous NSF science programs. Beams was not the classical academic, engineer, entrepreneur, nor technical consultant. Although often located at or near the University of Virginia, his principal connection to that academic institution was the huge and well-equipped workshops that he developed there during decades of arduous endeavor (Brown 1967).

Beams' ultra-centrifuge had a parallel life. The ultra-centrifuge was a by-product of his 1924 doctoral dissertation which focused on rapidly rotating mechanical systems. Assigned by his thesis director to investigate the time interval of quantum absorption events, Beams developed a high-speed rotating technique for the accurate measurement of very short intervals of time. This device, and not the study of physical phenomena, was the centerpiece of his successful dissertation. An interest in multipurpose, multi-audience technical apparatus rather than a focus on the stuff of the physical world emerged as Beams' guiding logic. Yet this focus did not make Beams an engineer or technologist in the usual sense of the term.

His initial devices employed air-driven turbines. However, their performance was limited by mechanical factors as well as by air friction. He first augmented speed by introducing a flexible drive-shaft which allowed for adjustments in the center of gravity, thereby multiplying rotating capacity. He next placed the rotating vessel inside a vacuum, thereby eliminating air friction. But nonetheless shaft mechanics continued to restrict performance. To solve this, Beams employed magnets to spin his vessel. The vessel was suspended inside a vacuum, thanks to a magnet-based servomechanism. This constituted his consummate ultra-centrifuge which rotated at previously unheard-of rates.

The ultra-centrifuge became an important element in bio-medical research on bacteria and viruses, and soon figured centrally in medical diagnosis and treatment.

B. Joerges, T. Shinn (eds.), Instrumentation Between Science, State and Industry, 1–13.

Beams engineered devices for radioactive isotope separation in the late 1930s which were effectively tested in the Manhattan Project and became commercially viable in the 1950s and 1960s. The Beams ultra-centrifuge served in early ram jet propulsion research, and it was also used to do physics and engineering research on the strength of thin films. A Beams device rotating at over three million revolutions per second was used by physicists to measure light pressure. A somewhat different instrument enabled enhanced precision in the measurement of the gravitational constant.

As an author Beams published abundantly, sometimes in disciplinary periodicals, but much more of his written output appeared in instrumentation journals, such as the American *Review of Scientific Instruments*. A high proportion of his writings took the form of unpublished technical reports and he co-sponsored half a dozen patents. Beams' written productions were equally divided between the public and private spheres: between articles and patents on the one hand (public), and confidential reports and consultancy on the other (private). Concurrent with these publications, he continued to build far-reaching artefacts.

Beams and his devices crossed innumerable boundaries. Beams circulated in and out of institutions and shifted from employer to employer. He belonged to many organizations, movements, and interests. He was neither a-institutional nor anti-institutional, but rather multi-institutional. He had no single home; his home lay everywhere. He explored and exploited the laws of nature as embedded in instruments and, like Beams himself, his ultra-centrifuges also crossed a multitude of boundaries. They were open-ended, general-purpose devices which came to perform a host of functions and found their way into a variety of non-academic publications and applications.

A special vocabulary and way of seeing events developed in conjunction with the Beams device. Light pressure and gravitation, isotope separation and thin films, microbes and viruses came to be spoken about in terms of rotational speeds and centrifugal pressures. "Rotation," and with it "specific density," emerged as a lingua franca for a disparate spread of fields and functions, extending from academia and research to industrial production and medical services. The rotational vocabulary and imagery of Beams' instrument percolated outward. Beams' approach and his artefacts thereby helped coalesce dispersed technical, professional, and institutional worlds.

RESEARCH-TECHNOLOGY

The Beams ultra-centrifuge is just one instance of what we label "research-technology." The term research-technology first arose in the early 1930s in an exchange of letters between the Dutch Nobel Laureate Pieter Zeeman (1865-1943) and the French physicist Aimé Cotton (1869-1951) – director of the laboratory that housed the Bellevue giant electromagnet (Shinn 1993). In the context of that correspondence, "research-technology" referred to multipurpose devices for detection, measurement and control that were conceived and developed by a community connected to both science and industry – yet at the same time also separate from each of these. In this book, we appropriate their conception of research-technology, and extend it to many other phenomena which are less stable and less localized in time and space than the Zeeman/Cotton situation. In the following pages, we use the concept for instances where research activities are orientated primarily toward technologies which facilitate both the production of scientific knowledge and the production of other goods. In particular, we use the term for instances where instruments and methods traverse numerous geographic and institutional boundaries; that is, fields distinctly different and distant from the instruments' and methods' initial focus.

We suggest that instruments such as the ultra-centrifuge, and the trajectories of the men who devise such artefacts, diverge in an interesting way from other forms of artefacts and careers in science, metrology and engineering with which students of science and technology are more familiar. The instrument systems developed by research-technologists strike us as especially general, open-ended, and flexible. When tailored effectively, research-technology instruments potentially fit into many niches and serve a host of unrelated applications. Their multi-functional character distinguishes them from many other devices which are designed to address specific, narrowly defined problems in a circumscribed arena in and outside of science. Research-technology activities link universities, industry, public and private research or metrology establishments, instrument-making firms, consulting companies, the military, and metrological agencies. Research-technology practitioners do not follow the career path of the traditional academic or engineering professional. They pursue "hybrid careers," shifting back and forth between different employers. Others, while remaining with a single employer, establish strong, albeit intermittent contacts with a variety of arenas which are not otherwise connected.

In conventional parlance, the analytic language used by sociologists and historians of science and technology often draws a distinction between technology and academic learning. The world of research-technology, we suggest, bridges the two. The bridging occurs with respect to knowledge, skills, artefacts, language and imagery, and their attendant interactions. In a research-technology frame, conventional oppositions such as theoretical and experimental, science or engineering, technology and industry are largely effaced. In this frame, the focus is neither on scientific practices, in the sense of theorizing about experimentally produced phenomena, nor on engineering practices, in the sense of constructing and producing definite end-user goods and services. Instead, the focus is on practices oriented toward the production and theorizing of open devices which potentially serve multiple spheres.

The research-technology perspective raises issues in three problem domains. Firstly, how can the research-technology phenomenon be situated with respect to the ongoing debate about the dynamic relationships of science and society? Secondly, how can it be situated with respect to a gradual scientization and increased occupational fluidity of engineering professions which characterizes the changing relationships between science and engineering? Thirdly, how can it be situated in the contemporary debates in philosophy and social studies of science over the relationships between theory and experiment? In this introductory chapter, we will briefly address each of these points before outlining the general analytic coordinates that structure the book.

Science and Society

The theme of “instrumentation between science, state and industry” does not square well with the venerable discourse which opposes “science” and “technology” in social studies of science. In this discourse, “technology” stands for the contrary of “science”; it represents the practical uses of science in society at large and is understood as separate from the somehow autonomous sphere of “science” (Layton 1971a). This vocabulary, widespread as it may be, is not very useful for our purposes, and, for that matter, for any inquiry into the role of instruments. Technology, in the sense of technical instruments and the knowledge systems that go with them, pervades all societal systems. There are technologies of science, of industry, of state, and so forth, and it would be ill-advised to assume that, in the end, they all flow out of “science.” But even if the crude opposition of science and technology has little analytic value, the dual problem remains: how to effectively conceive the dynamic relationship between scientific spheres and other societal spheres, and how to conceive the role that technological matters play in this relationship.

Much of the debate surrounding these issues is framed in terms of “What drives what?” Does science drive technology (that is production technology, the field of utilitarian technology aimed at producing things for use outside science) or does technology drive science? Using “industry” and “state” as we do in this book as shorthand for extra-scientific social spheres, this translates into the question: Do science and its technologies drive those of industry and the state, or is it the other way around?

Schematically speaking, the relationship can take four forms: science drives industry/the state; industry/the state drives science; the relationship is independent; or it is dialectical. In terms of ideal types, these four positions have all had their protagonists. The current fashion seems to be a special version of the dialectical answer where science and industry/the state are inextricably interrelated (e.g. Latour 1992). In extreme formulations, the science/technology nexus has become a hybrid field of seamless webs where the distinction between them is no longer considered useful. According to this view, there is only technoscience, in which the boundaries between science and industry/the state are discursive artefacts that must be looked at in terms of their strategic utility. Moreover, these boundaries are in constant flux depending on the interests of dominant players.

The research-technology perspective does not accord with seamless analytical frames of this kind. We will argue that research-technology instrumentation is a phenomenon “in the middle” which does not coincide with either science or industrial production. We see it as a field of instrumentation outside both science and industry, yet important for both.

It is possible then to distinguish three spheres of instrumentation and instrument-makers: inside science, as in conventional studies of scientific instrumentation (Heidelberger and Steinle 1998; Heilbron, van Helden, and Hankins 1992; Löwy and Gaudillière 1998); inside industrial production, as in conventional studies of non-scientific technology, such as the assembly line (Noble 1984); and outside science and production, but for both. This third type belongs to research-technology. In other words, we wish to bypass one erstwhile notion whereby instrumentation in science and technology has two distinctly different sources, and another erstwhile notion whereby technology is an applied side of science.

The strong thesis that guides the analyses presented in this book is that research-technology generates broad fundamental impulses that drive scientific research, industrial production and technology-related state activities along their respective paths. Of course, the research-technology hypothesis does not deny that much instrumentation is conceived, developed and diffused within the strict confines of a narrow industrial (von Hippel 1988) or scientific (Edge and Mulkay 1976) context, nor does it imply that research-technology mechanisms account for all types of transfer from one sphere to another.

Science and Engineering

To better understand the emergence of research-technology, it is useful to see it against broad transformations in engineering practice and institutions. Historically, the knowledge base and professional practices of engineers in many fields have changed appreciably as technology has become ever more scientized. In the past, engineering was often associated with practical craft skills and with the application of technical recipes to concrete problems. Since at least the second World War, the intellectual and professional gap that separated science and engineering has gradually diminished. Emblematic of this rapprochement is the increasing use of the terms "engineering science" in the Anglo-American world, "Ingenieurwissenschaften" in German-speaking countries and "science physique pour l'ingénieur" in France.

The professional identity of engineering groups in civil engineering, mechanics, chemistry, electricity and electronics often entailed a demarcation from mathematized esoteric learning and disciplinary academic science, as well as a demarcation from the university departments that taught and researched such learning. While engineers trained in university schools of engineering, in many important respects they nevertheless stood outside of academia. Engineers' principal intellectual and professional identity instead lay with their industrial employers. Professional engineers generally centered their careers in non-academic organizations, where they usually remained (Layton 1971b). This traditional profile has changed appreciably, however. Today, engineering knowledge and practice increasingly bear the mark of high science as, in turn, academic disciplines depend increasingly on scientized engineering (Bucciarelli 1994).

The scientization of engineering is associated with growing cognitive specialization. New fields of academic learning have emerged, and many of them are directly relevant to engineering. Mastery of these fields by engineers often entails a grasp of advanced mathematics, as well as a firm grounding in academic science. Concurrently, many technical systems have become ever more complicated and large-scale, thereby requiring additional learning and skills. Beyond this, the scientization of engineering has involved significant professional changes. Engineers had long been envious of the luster of science and the high social status of scientists. The emerging links between engineering and academia have provided engineering professions with an opportunity to share the elevated status of academic learning. Also, scientized engineering involves enhanced career fluidity. Engendered by fast-moving technical frontiers, many practitioners move from project to project.

The last few years have seen the rise of two analytic schemata that focus on a convergence between scientists and engineers. In *The New Production of Knowledge*, Gibbons and his colleagues have suggested that the development of new knowledge-intensive economic spheres is accelerating the de-differentiation between scientists and engineers, and is producing a new category of cognitive and technical personnel whose point of reference is the solution of socially relevant problems (Gibbons et al. 1994). The Triple Helix perspective similarly hypothesizes a radical convergence between scientists and engineers – a convergence which putatively yields a historically new intellectual and technical breed expressed as a synthesis of the two professional groups (Etzkowitz and Leydesdorff 2000, 109–23; Leydesdorff and Etzkowitz 1998). This synthesis does not, however, take the form of a de-differentiation but instead a neo-differentiation (Shinn 1999). At first glance, research-technology might appear to belong to the New Production of Knowledge or Triple Helix schemata. However, it has to be established whether the kind of fluidity we associate with research-technology is of the same sort described in these two perspectives, particularly as regards the intellectual and social work connected with instrumentation.

Theory and Experiment

With few exceptions, students of science have long considered that experimentation was paramount in scientific research. Experimentation was seen as guiding theory, or even as governing it. This stance is reflected in many of the classical studies on Newton, Galileo, and Huygens, and it underpinned the work of philosophers in the logical positivist tradition (Suppe 1974; Westfall 1980). Pierre Duhem was among the first to question the dominance of experimental orthodoxy, and Kuhn successfully extended Duhem’s thesis (Duhem 1915; Kuhn 1962). The relationship between theory and experimentation continues to be reassessed, and today many scholars believe that theory often guides, and even dictates experiments and their outcome (Bachelard 1951; Pickering 1984; Pinch 1986; Quine 1972, 1986).

Nevertheless, a handful of historians and sociologists question whether the relationship between theory and experimentation is as direct and unmediated as it is often made out to be. Peter Galison, for example, has argued that the old debate about the interplay of experiment and theory, and the attendant ideological debates about the epistemological correctness of idealist and empiricist positions, needs to be revised by introducing a third dimension; namely, instruments and the theories attached to them (Galison 1997). Galison does not suggest that instrumentation provides a panacea for establishing the validity of a knowledge claim; he instead indicates that instruments constitute a third reference against which statements can be tested, and are a semi-autonomous input into both experimentation and theory. Nevertheless, his approach also focuses predominately on the role of instrumentation inside science proper. It is a debate about science and technology in the procrustean framework of technology in and of science. Beyond Galison’s influential contribution, one can observe a general renewal of interest in the technical, cognitive-epistemological and socio-cultural aspects of metrological devices throughout the field. How does the research-technology perspective fit into this debate?

In positing that research-technology is a specific kind of instrumentation, one which is explicitly characterized as poly-disciplinary and potentially extra-scientific in its purposes and effects, we confront the theory/experimentation problem from a different angle. It may safely be said that mainstream philosophical and sociological schools in the study of science have generally paid scant attention to boundary-crossing practices and representations of the sort common to research-technology where instrumentation transcends experimentation and the theory/experimentation matrix. This line of inquiry extends recent claims that independently of measuring and representing effects, experimental systems also perform controlling and productive functions for purposes beyond scientific knowledge and theory validation (Hagner and Rheinberger 1998: 355–73; Heidelberger 1998: 71–92).

A SPECIFIC KIND OF INSTRUMENTATION

Against the backdrop of ongoing debates around science/society relationships and theory/experimentation relationships, and changes in engineering practice and institutions, we can now turn our attention to the emergence and workings of research-technology. Referring back to the example of Jesse Beams and the ultra-centrifuge which opened this chapter, three major features of research-technology come to the fore. The first characteristic is its trans-community positioning, or as we say, its “interstitiality.” Research-technologists wear many hats. Secondly, their devices exhibit a peculiar openness or “generic” quality. Research-technology devices branch outward to many spaces. Thirdly, research-technologies involve the development of standardized languages or “metrologies.” Research-technologists create a lingua franca for theoretical and extra-theoretical uses.

The case histories presented in this book explore social interstitiality, generic instrumentality and metrological codification in a variety of trans-disciplinary, trans-science and extra-science settings. What accounts for this configuration and how do research-technologies acquire their distinct feature of travel between otherwise unconnected fields? How is it possible that local instrument achievements become global in the sense of a re-embedding in many other places, both inside and outside science?

Interstitial Communities

In what sense can one talk about research-technology communities? Jesse Beams, and to a greater or lesser degree the research-technologists who appear in this book, exhibit peculiarly “subterranean” modes of multi-lateral professional and institutional association which do not accord well with standard sociological notions of communities as ensembles of stable, institutionalized interactions. These research-technologists admittedly work within universities, industry, state or independent establishments, yet at the same time they maintain some distance from their organizations. In many instances, they pursue “hybrid careers,” shifting back and forth between different employers or, while remaining with a single employer, lend their services to changing outside interests. We will also show that many research-technologists develop a personality make-up suited to sustain many-sided professional relationships and "multi-lingual" cognitive worlds.

Some sociologists will say that research-technology's social configurations should not, for these reasons, be called "communities," but rather non-communities, since research-technologists are not concentrated within one type of scientific, industrial or state organization which provides them with stable, recognized positions reserved for experts in generic precision instrumentation. Indeed, research-technologists' community identity cannot be mapped in terms of an organizational or professional referent. The referents of "academic scientist" or "industrial engineer" are not relevant to research-technology. Neither can the identity of research-technologists be based on the production of a definite category of fact (in science) or artefact (in production). Instead, we suggest that the shared project which conveys a semblance of community in the familiar sense of the term is their elaboration of diffuse, purposefully unfinished devices (not-yet facts and not-yet artefacts) to be distributed across the broadest possible landscape.

In cases where research-technology involves a shared project for groups of practitioners working within the same field of instrumentation, the term community, in the classical sociological sense, will be acceptable to most analysts. In other cases though, "shared project" merely means that research-technologists recognize each other's pursuits when they happen to meet. The term research-technology community refers here to something akin to the way tribesmen know they belong to the same tribe. In order to avoid confusion with other tribes, various insider/outsider affiliations are invoked. Rather than by tracing stable membership and hierarchical/promotional career structures, research-technologists can more easily be identified through specialized academic or trade journals and by their participation in national or international instrument fairs and expositions. Historically, instrument fairs have played a major role in the constitution of the research-technology movement (Shinn, chapters 3 and 5).

In connection with interstitiality we need to understand how research-technologists avoid standard forms of professionalization. What are the sources of their open and flexible group identities? Their interest as a class of experts seems to lie in expanding the sphere of unaffiliated, open-to-all, dispersed generation of devices that promise solutions to problems where precision detection and measurement, precision control of certain phenomena and even the controlled production of certain effects are crucial for success (Roqué, chapter 4). How do research-technologists manage to articulate and defend group interests in the absence of membership organizations with established boundaries? Separate as research-technology groups are from both conventional science and industrial engineering, yet parasitic on both, how do these quasi-communities assure community reproduction and growth? How do they sustain their autonomy in environments which have customarily rewarded monopolistic organizational linkages? (Nevers et al., chapter 6; see also Johnston, chapter 7.)

Generic Devices

We refer to the particular kind of technical artefacts research-technologists deal with as “generic devices.” Research-technology communities first arose in the nineteenth century with precision mechanics and optics (Jackson, chapter 2) and today specialize in the invention, construction and diffusion of precision instrumentation for use both inside and outside academia. They develop packages or whole systems of generic detection, measurement, and control devices that focus on particular parameters which are potentially of interest to scientists, laboratory technicians, test personnel, production engineers, and planners (Gaudillière, chapter 9; Johnston, chapter 7, Rheinberger, chapter 8). Sometimes, as in the case of early lasers and masers, or in the case of laboratories producing new semi-conducting materials, research-technologists and their generic devices produce novel physical effects in order to explore their measurability and controllability.

In many instances, these devices are not designed to respond to any specific academic or industrial demand. Research-technologists may sometimes generate promising packets of instrumentation for yet undefined ends. They may offer technological answers to questions that have hardly been raised. Research-technologists’ instruments are then generic in the sense that they are base-line apparatus which can subsequently be transformed by engineers into products tailored to specific economic ends or adapted by experimenters to further cognitive ends in academic research. Flexibility is part of the product. One could say that “interpretive flexibility” constitutes in itself a goal and an achievement. This is a precondition for research-technology’s extended market that stretches from academia to industry and the state.

Roqué and Rheinberger, in chapters 4 and 8 respectively, show that research-technologists are typically involved in prototyping, in the sense that they avoid early closure of design processes that keeps devices generic. In connection with genericity we need to understand how research-technologists manage to maintain an instrument chain in which “core devices” are developed, that then spawn cascades of secondary apparatus, which are in turn used to solve a range of problems. How do generic devices make their way into both research and production?

Metrology

Metrologies can be seen as systems of notation, modeling and representation, including their epistemic justifications. Metrology is integral to the development of generic devices and the maintenance of interstitiality. Either the nomenclatures, units of measurement and standards of existing metrologies are refashioned in creating generic instrumentation, or else new ones are formulated. The lingua franca of metrology constitutes the vehicle that allows generic apparatus access to many audiences and arenas. At the same time, it preserves research-technologists from becoming caught up in the particular discourses of these audiences and arenas.

On one level, research-technologists may generate novel ways of representing, visually or otherwise, events and empirical phenomena. On a broader level, they may impose a novel view of the world by dint of establishing and legitimating new functional relations between recognized categories of elements that were previously perceived in a different light. In some cases, research-technologists' metrological work is instrumental in coalescing and crystallizing notations, analytic units and formulae into a corpus of rules or procedures which deserve to be called a methodology, and that eventually make their way into textbooks as state-of-the-art procedures. How is this achieved?

Ultimately, the issue of metrology includes questions concerning the particular epistemological stances, and even world views, associated with research-technology work. Do research-technologists sometimes even stylize and theorize their own practice and procedures in a manner that deserves to be called the advancing of a world view or episteme? (An example is the sweeping and comprehensive views of cyberneticists who see nature as a grandiose engineering feat, see Heims 1991.)

Dis-Embedding, Re-Embedding

One way of drawing together considerations of the institutional, instrument and metrological aspects of research-technology processes is to look at them in terms of an iteration of dis-embedding and re-embedding episodes in the far-flung trajectories of a particular device or prototype. Recent approaches in the philosophy and sociology of science and technology have consistently pointed to the situatedness, localness and embeddedness of all knowledge production. Arguments about instruments are at the core of these positions, whether they are framed in terms of tacit knowledge, craft, the bodies of experimenters, or science vernaculars (including Pidgin and Creole). At the same time, claims about universal standards of rationality in experimentation and engineering tend to be presented as mere representations or legitimations of scientific and technological practice.

In contrast, research-technology, as a distinctive mode of producing instrumentation for de-situated and trans-local uses both inside and outside science, appears as a distinct achievement of dis-embedding which lies outside the purview of such approaches. In this perspective, dis-embedding does not occur by default, as in diffusion theories, but is instead tied to specific skills and forms of representation. While admittedly all knowledge production, including instrument knowledge, is local, and all knowledge consumption is local too, the central question remains: how can knowledge be consumed far from its place of production, and how does it travel?

We suggest that generic instruments comprise a sort of dictionary that enables the translation of local practices and knowledge into diverging and multiple sites, and constitutes the transverse action of research-technology. Can something akin to universality arise through the sharing of common skills and representational systems located in something like a template, or "hub matrix?" Could one say that research-technologists design dis-embedded generic devices so that they can be readily re-embedded? Local re-embedding by engineers or scientists occurs within the limitations contained in the template of the generic instrument and also within the limitations of the local cultural and material context. Re-embeddings can thus differ considerably from one another, yet a certain fidelity to the hub template persists. To what extent does the use of a specific template by practitioners in different locales allow them to communicate effectively through the development of converging skills, terminologies and imagery? It may be this feature that makes research-technology the potent, universalizing motor that we take it to be.

THE BOOK

The instrument-related phenomena dealt with in this book may be seen as new in the sense that they have become more varied and broadly visible since World War II, yet it would be inappropriate to see research-technology as something radically new. Also, while research-technology may eventually increase in size and scope, this does not indicate that it is a new form of science. Instead, we consider research-technology as a new perspective, an alternative way of looking at instrumentation for social studies of science and technology. Since it is very much a phenomenon "in-between" and often relatively invisible to outside observers, it is not surprising that it has gone largely unnoticed by students of science and technology.

The episodes examined in this book span more than a century, beginning in the early 1800s and ending in the 1980s. Part I, on German optics and the *Zeitschrift für Instrumentenkunde*, traces early beginnings. In the remainder of the book contributions are organized according to the emphasis given to key analytic parameters set out in this introduction. To differing degrees and in different ways, the case histories explore how many interests, institutions, disciplines, and professions are traversed by generic instrumentation and its dis-embedders and re-embedders. Interstitiality provides the focus of Part II: While historians and sociologists generally concentrate on the genesis of stable relations and stabilizing structures, the very essence of research-technology is its fluidity and its operation between established institutions and interests. Part III explores instrument genericity: authors examine the trajectories of generic instrumentation systems and their specific applications. Part IV deals with metrological issues, in particular the roles played by generic instrumentation and interstitial communities in the work of standardization.

The ten studies presented in this volume explore the circumstances under which research-technology fields have emerged and evolved in light of changing demands inside and outside of science. Contributors deal with the places, times, and technological fields where research-technology occurs. They present the institutions, journals, meetings, forms of association, and the multi-professional and multi-personal identities that sustain research-technologies. In the concluding chapter we will situate research-technology in the landscape of social studies of science and technology and reflect on some of the broader societal corollaries of the research-technology movement.

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