

What, exactly, is a paradigm? The Kuhnian replies: an exemplary problem-solving achievement, plus the disciplinary matrix supporting its extension. But what makes some examples paradigmatic and others not? Kuhn struggled for decades to identify criteria that satisfied him or anyone else. In working out what Kuhn was striving for, Norton Wise counsels, we should take seriously Kuhn's belief that his 1978 book *Black-Body Theory and the Quantum Discontinuity, 1894–1912* was the fullest historical expression of the general analysis of *Structure*. On that view, a paradigm for Kuhn was highly technical, even esoteric – which made seminars with him exercises in re-inhabiting the problem worlds of very difficult past science. As for Kuhn's inability to give a clear explication of paradigms, that just makes Kuhn, for Ian Hacking, the inheritor of a muddle that goes all the way back to antiquity, when deductive logic first became the gold standard for reasoning, and the artful use of enlightening examples got filed under 'rhetoric'. Ever after, it has been nearly impossible to make sense of, much less vindicate, reasoning based not on truth-preserving syllogisms but on examples and their extensions. Turning that pessimistic message on its head, Lorraine Daston suggests that if anyone is in a position to contribute constructively to the understanding of example-based knowledge, it is, thanks to Kuhn, historians of science. In taking up that mission, furthermore, they would not only help with a timely research programme but also recapture something of the generalizing ambition that got lost when the historicizing of science became an end unto itself.

From the mid-1960s, Kuhn was being sent the essays of students asked to evaluate this or that scientific change as a Kuhnian revolution. The assignment may be an oldie but, in certain hands, it is nevertheless a goodie. As one would expect from Wise's chapter, Daniel Garber judges that the Scientific Revolution was not a Kuhnian revolution, because, argues Garber, there was no comprehensive regime that replaced the rejected Aristotelianism, but instead lots of distinctive bodies of theory and practice – Cartesian, Baconian, chymical, etc. – pursued in tandem. In a survey of biomedicine in the latter half of the twentieth century, Angela Creager looks at the role of model systems and their extensions as in some ways bearing out Kuhnian points about the functioning of exemplars, and in other ways not, notably in the materiality of such systems as itself a driver of change.

The volume closes with the sociologist Andrew Abbott's reflections on '*Structure* as cited, *Structure* as read'. The citation data suggest that, on the whole, *Structure* has for a long time been cited generically, as a standard source for the idea – not at all original to Kuhn – that views about what counts as knowledge and how to acquire it change. Abbott also reports on his own rereading of the book, especially on the speculations it provoked about systems of knowledge that, as with the social sciences in our day, seem not so much to progress as to cycle endlessly through the same set of basic conceptual and methodological options. It is a fitting tribute to Kuhn's book that it can be seen even now to raise challenges that we barely know how to articulate, let alone answer.

GREGORY RADICK
University of Leeds

THOMAS J. MISA and JEFFREY R. YOST, **FastLane: Managing Science in the Internet World**. Baltimore: Johns Hopkins University Press, 2016. Pp. ix + 206. ISBN 978-1-4214-1868-1. \$34.95 (hardback).
doi:10.1017/S0007087417000796

Since the year 2000, all proposals for research funding from the US National Science Foundation (NSF) have been managed through a platform called FastLane. Developed in the 1990s, FastLane consolidated the traditional paper processes of grant application, approval and financial disbursement into a single computer system. This book examines its design and implementation and situates FastLane within the longer institutional history of the NSF and early Internet-era computing.

Its authors, Thomas J. Misa and Jeffrey R. Yost, draw on a remarkable body of some eight hundred interviews with users of the system. Because FastLane became mandatory for grant applications in 2000, their user-centred history reveals much about the practices of scientific funding across a range of institutions. As a technology developed through a systematic design and management process, FastLane offers a case study in the development of computer systems in the decade that produced the World Wide Web and the commercial Internet.

Following an introductory chapter, Chapter 2 ('Origins of e-government') describes the political environment in which the NSF developed its system of paper administration of the grant process. They situate NSF's practices within two historical episodes: first, the well-known debates between Vannevar Bush and Senator Harley Kilgore over the governance of science after the Second World War; and second, the 1970s MACOS (Man as a Course of Study) controversy and Senator William Proxmire's Golden Fleece awards for government waste. They argue that the NSF's political arrangement – its mix of scientific independence and fiscal oversight by Congress – contributed to a material result: the proliferation of huge amounts of paperwork: an 'avalanche of paper – proposals, assessments, and reports was soon aimed at and flowing through NSF's Washington Offices' (p. 23).

The authors describe how computers came to the paper processes both of the NSF's office in general, and of application submission in particular. They attribute this to a number of factors, including the spread of personal computers in offices in the US, forward-looking management (for instance the directorship of ex-IBM executive Erich Bloch), the NSF's connections to sites of computer research, a system called EXPRES (Experimental Research in Electronic Submission) developed at the University of Michigan and Carnegie Mellon University, and the 'tremendous enthusiasm' about computer communications at NSF and in American culture more generally in the period 'that fanned the dot-com bubble' (p. 38).

Among the technical challenges for electronic grant submission were the requirements that the system handle multimedia and that it be agnostic to the manifold computer systems that populated science and administration. In Chapter 3, they show how FastLane grew up in the technical milieu that produced e-commerce and the commercial Web. The NCSA Mosaic browser developed at the NSF-supported National Center for Supercomputing Applications (NCSA) at the University of Illinois plays a particularly important role in this story. The PDF document format was also a crucial element in the FastLane submission, but it was controversial as a proprietary standard. The book shows how FastLane depended on many of the same technologies – Web browsers, the programming languages C and Perl, the Common Gateway Interface (CGI), and Sun Microsystems hardware – on which Amazon's early empire was built.

Following this history of development, the authors then provide three chapters synthesizing the user experiences of principal investigators, research administrators and the NSF. Drawing on extensive interviews, these chapters offer an account of a technical system in the making and how early adopters shape technologies. The authors move beyond users at elite institutions and show the technology in use in the diverse contexts of science at American research universities. We learn, for instance, how computerized grants allowed researchers in Hawaii to wait until the last minute to submit proposals (a privilege once afforded only to applicants in the DC area who could walk their materials to the NSF office). Their account also provides rich details about the practices of scientific collaboration, including a depiction of 'sneaker net'. This was the name one University of North Dakota researcher ascribed to the human infrastructure of carrying a floppy disc around from office to office.

Misa and Yost discuss the experience of historically black colleges and universities (HBCUs) and institutions supported by the NSF's Experimental Program to Stimulate Competitive Research (EPSCoR), an effort beginning in 1978 to expand research grants beyond the small group of research universities that traditionally received the lion's share of federal grant dollars. Their

interviews with researchers and administrators in Hawaii, Puerto Rico, EPSCoR-supported institutions and HBSCUs reveal the ways computer communication was positioned as a means to reduce the effects of geography on institutions far from the administrative hubs of Washington, DC or separated from centres of concentrated social capital. FastLane, they argue, ‘took form with unusual attention to equity and open access’, and making it into a required system spurred an effort to extend ‘the Internet to become a universally accessible resource’ (p. 8). Their extensive publicly available dataset and oral-history collection will be of great interest to scholars of the early Internet and its social geography, as well as to historians of science interested in the effects of computers on scientific practice.

It would have been helpful to know more about the history of concepts like ‘user-driven’ innovation or ‘human-centred’ design. Although the authors document these design processes in practice, it is less clear where these concepts came from. Did federal e-government software – technology that in principle should aspire to democratic accessibility – play a specific and pioneering role in imagining engineering methods for a diverse user base through iterative feedback processes?

Separately, it would have strengthened their account to offer historical context to their chapter on the development process of FastLane. Although they situate the NSF’s paper processes in the controversies around science funding in the 1950s and 1970s, they do not do the same for the period in which FastLane was developed. The move from paper to computer is narrated as a straightforward, if iterative, project from managerial conceptualization, to user feedback, to early deployment at pilot sites, to outreach and ultimate standardization in 2000. Furthermore, the book does not say much about how governance, peer review or fiscal transparency – in practice or imagination – changed in FastLane or the Internet era. They note in the conclusion that FastLane did not unilaterally ‘cause’ NSF to attend to the ‘broader impacts [of research], [scientific] interdisciplinarity [or] congressional scrutiny’ (p. 160), but the subtitle raises the question, what changes in scientific ‘governance’ when it becomes ‘e-governance’?

The conclusions Misa and Yost draw will be of interest to historians of the development of computing systems and managers of large technical projects themselves. Making reference to the highly visible stumbles of more recent government-developed software, including the rollout of the Healthcare.gov website, this book offers an important reminder of the state’s vital role as a developer and caretaker of critical electronic infrastructure.

DEVIN KENNEDY
Harvard University