PREPRINT

James Sumner and Graeme J N Gooday

"Introduction: does standardization make things standard?"

Published in final form in: James Sumner and Graeme J N Gooday, eds. *By Whose Standards? Standardization, stability and uniformity in the history of information and electrical technologies*. Volume 28 of *History of Technology* (series editor: Ian Inkster). London: Continuum 2008. Pages 1-13

Introduction

JAMES SUMNER AND GRAEME J. N. GOODAY

DOES STANDARDIZATION MAKE THINGS STANDARD?

Technical standards, so often designed to promote their own invisibility, have received increasing analytical attention in recent years.[1] Successful acts of standardization may redistribute labour, risk and responsibility, mediate the boundaries of human and automated activity, and re-present socially motivated changes as objective necessities. With the growth of modernity theory, depersonalized systems and standardized artefacts have been identified as a key factor in the emergence of the present-day social order.[2] Management historians perceive standards-based systematization as responsible for bringing corporate behaviour into a 'rational' state – or, alternatively, for concealing its contingent aspects.[3] Historians of science and technology, similarly, have focused on the role of standardization, established via expert authority and precision measurement, in directing the course of everyday life.[4] In cases ranging from the Whitworth screw, through units of absolute electrical resistance, to the information communication networks so culturally prominent in the twenty-first century, the emergence of uniform standards and expectations serves as a focus of enquiry and explanation.[5]

Yet, this well established historiography of uniformity sits alongside an equally familiar motif: the seemingly unending ability of heterogeneity and cultural localism to survive and flourish in the modern world.[6] How can we reconcile the two? The first step is to note that *standardization* is widely understood as the enterprise of specifying standards in general, which is not the same thing as achieving universal acceptance for any standard in particular. As the old joke has it, 'The nice thing about standards is that you have so many to choose from'.[7] Increased standards-setting activity may actually frustrate convergence, by helping to articulate and stabilize a range of possibilities. Standardization, moreover, may be sought on distinct and conflicting criteria: in a world where conditions and opportunities for production vary, insisting on uniform *product* standards can lead to variations in *process*, and vice versa. On top of this, there is the role of the technological consumer: when the uniformity of 'modern' artefacts becomes conspicuous, individuals and groups often rebel, expressing their cultural identities by personalizing their preferred configurations or reclaiming abandoned options. Like mundanity and creativity, the homogeneous and the heterogeneous seem inextricably entwined.

This tension informs current work on standardization from a variety of disciplinary viewpoints. Economists formerly characterized standards-setting policy in terms of an optimal static balance between 'freedom' and 'order'; more recent work emphasizes the dynamic complexity of the acts of coordination involved.[8] Studies of regulatory science, mass culture and European cities have found trends of globalizing homogeneity and local negotiation co-existing in striking tension over the long term.[9] Some political scientists and management theorists favour understanding standards as a form of 'soft law', potentially as coercive as formal directives, yet often derived from cultural norms, and subject to various forms of contest and revision.[10] Accounts based on historically distant case studies, too, have begun to affirm the lesson that standards 'are neither simplifying nor uniform in their effects'.[11] The present collection, addressing standardization in broad terms across the nineteenth and twentieth centuries, is intended as a contribution to this literature.

A generation ago, historians of science and technology were closely influenced by social-constructivist accounts that typically saw trajectories of technical change ending in convergence to universal interpretations (consensus) or stable technologies (closure).[12] Latourean analysis, in particular, saw metrological standardization as a foundation of 'universal' technoscience.[13] But historians find that their narratives rarely have such neat endpoints. Dissent and controversy are hard to erase altogether: steam locomotion, for instance, faced critics and competitors from its earliest beginnings until its (developed-world) obsolescence, while the technical arguments mustered against nuclear power seem unlikely to vanish in the foreseeable future. Convergence of material forms is correspondingly limited, as illustrated by the iconic case of the mains electrical power connector. 'Why isn't there a single plug that could be used everywhere?' is an oft-quoted condensation of the plea for uniformity: the answer lies not in any lack of a suitable standard, as the International Electrotechnical Commission (IEC) makes clear, but in the want of any determining reason for this standard to overcome an established, stable plurality.[14]

The technoscientific enterprise has, in fact, survived remarkably well for long periods without universal uniformity. Perhaps the only really famous victim of mixed standards was the catastrophic failure of a NASA orbiter in November 1999, resulting from a confusion between US conventional ('English') measurements and the metric system mandated by the project guidelines.[15] Even here, humiliating as the loss was, the orbiter could be replaced; US engineers' commitment to feet and inches has not been, despite repeated efforts.[16] This kind of exceptionalism may even be bolstered by such 'modernizing' effects as globalization and large-scale manufacturing concentration, which permit parallel technical artefacts (as in the power-plug case) to be produced quickly and easily under multiple standards regimes.[17]

In previous work, one of the editors has drawn attention to the *metrological fallacy*: '... the view that well-defined universal standards and

units are somehow *necessary and sufficient* to facilitate the practice of measurement and thus that the history of measurement consists in explaining how past measurers overcome the lack thereof.'[18] Here, we apply the same critical approach to uniform standards in general. If universal specifications are not a defining feature, necessary outcome or conscious goal of technoscience (or 'modernity'), we must ask in whose interests, and for what purpose, the drive for homogeneity *does* arise – where, indeed, it does. Pressure for a 'single plug that could be used everywhere' may reasonably be located among technological consumers (specifically, frustrated international travellers), but, elsewhere, a variety of interest groups and motivations may be at work: producers seeking monopoly advantage; mediators seeking a reliable basis for dealing; expert communities seeking to destroy rival communities' status by abolishing the demand for their expert judgement.

Moreover, when no standard is present, what prevails instead? Not chaos, by and large, and certainly not the cessation of technical change. One possible answer, as John Staudenmaier has observed, is *negotiation*.[19] Standardization is itself a negotiated process, as all the accounts in this collection attest; indeed, standards have elsewhere been characterized as crystallized expressions of the coordinations (i.e. settled negotiations) between actors in technical systems.[20] Yet, what an agreed standard provides, above all, is the means to replace some process of negotiation, formerly ongoing and mutable, with a settled understanding. Looking back from within a standardized culture, such negotiations often seem wilfully irrational: endless unloading and repackaging of goods to accommodate local spatial constraints; unreliable translations among a Babel of languages; incommensurable value definitions leading to heated, irresolvable disputes between traders. It is the task of the enlightened historian to bring some symmetry to the account, considering also the ends of status, identity and integrity that negotiation may serve. Such is the aim of this collection.

STANDARDS STORIES

Historians tell stories: the seven accounts in this collection seek to characterize not states, but processes of standardization. All draw attention to the contested nature of these processes, but the controversies they focus on emerge at various levels of abstraction. Debate may concern whether standardization should be introduced at all, as discussed in Karen Sayer's chapter; or the appropriate conceptual arena for invoking standardization, as Stathis Arapostathis relates; or else which of the competing standards structures to accept, as demonstrated by Laura DeNardis. Some of the standards initiatives narrated here succeed, to varying degrees; some fail; others undergo so much conceptual change that the question becomes hard to judge or meaningless. What is common to all the accounts is that conforming to standards, or doing otherwise, is a *conscious* (and contingent) act on the part of nearly all those involved.

Of the seven chapters, DeNardis' perhaps has most in common with the 'standards battle' narrative familiar from economic literature: two or more standards regimes, often incommensurable and mutually hostile, are presented as such to a community able to select between them, the result usually being that only one survives.[21] For the historian, such accounts owe their interest to the variety of cultural and institutional meanings bound up in the points of technical distinction: the 7ft ¼in rail gauge spoke for smooth running and Brunel's personal vision of an independent system; DIN specifications, in Cold War East Germany, for the validity of continued technical association with the West; the metric system in general, for the ethic of rational universalism.[22] A variant is the 'standards battle that never was', typified by the case of the Dvorak Simplified Keyboard. Here, a well specified but largely unadopted standard is given prominence in the narrative, counterpointing a dominant standard whose nature (often including serious alleged failures) would otherwise be invisible.[23]

What is distinctive about the case DeNardis presents is that it concerns competition not only between standards regimes, but between underlying *modes of standardization*. Open Standards Interconnection (OSI) offered an ethos of top-down prescription by an international authority; the opposing mentality, grounded among practising engineers in the Internet Engineering Task Force, saw legitimacy as constructed from the bottom up, striving to modify the established working norms by 'rough consensus'. Being, in essence, professional standardizers, these internet architects were keenly attuned to the philosophies underlying successive proposals as they were distributed (in, for the time, an uncommonly systematic standard fashion) via the internet itself.

The OSI philosophy, though supported by 'most Western European governments, the United Nations, influential vendors and user organizations', was ultimately rejected as the established advisory bodies endorsed the 'bottom-up' approach – and, thereby, reinforced their own legitimacy. To some extent, this is a story about national style: there is a strong hint of 'can-do' frontiersman rhetoric in the comments of members of the United States-focused IETF, and evident mistrust of the international(ist) bureaucracy promoting OSI. The senior standardizers responsible for the choice did much to conceal this element by portraying the issue as purely technical. We can, however, discern a species of technical advocacy that appears quite distinct from conventional political concerns, manifested above all in the IETF rejection of 'kings, presidents and voting'. Authoritarianism, representative government and direct participatory democracy were all equally suspect, as liable to inhibit the established internet standardizers' paramount virtue: continued smooth running.

Andrew Russell's story, too, concerns a debate over which standards should apply, but introduces an extra degree of freedom. DeNardis' actors on all sides confined their battle to the conceptual territory of 'the internet' (although the nature, governance and perhaps geographic scope of that internet were subject to negotiation). Russell, tracing the standards

activities of AT&T, shows the corporation's approach to be essentially unbounded: in doing so, he breaks new ground in characterizing the relationship between systems and their associated standards.

The wonderful example of the hardware-store washers – useful, by pure happenstance, as 'slugs' for the defrauding of AT&T's coin-operated telephones, and thus subject to sustained attack from the corporation's sophisticated standards lobbying – produces two revelations that deserve close attention. The first is that many at AT&T believed, in Russell's words, it would be 'easier to change the world' outside the Bell System than to modify the coin boxes within it. The second is that they were partially correct: standards redefinition ultimately played a part in the diminution of the 'slug racket', albeit after many years of wrangling, and with the aid of more conventional legislative and law-enforcement lobbying.

Russell frames this activity as extending *across the boundaries* of the Bell System (the boundaries, that is, of AT&T's switched telephone network). We might, however, prefer to interpret AT&T's business not (only) as telecommunications in general, but as standards-management in general. The AT&T engineers who pursued the washer campaign through ASA committees, though dealing largely with representatives of industries they did not know well, must have found the formalities and procedures of their task rather familiar. From a standards perspective, AT&T was not a monopoly: ranged against manufacturers in other sectors, it proved a powerful yet resistible combatant. This perception may help us to avoid what Russell identifies as a caricature of the 'sluggish, arrogant, and solipsistic' corporate monolith: further work may shed light on the role of the industry standards committee as an institutional space allowing competitors to cooperate, and collaborators to compete.[24]

Arapostathis' story, likewise, captures a battle between two communities, each seeking to legitimate and extend its activities through a process we may term 'standardization'; but the distinction here is more radical. On one side, manufacturers of electrical equipment sought the kinds of regime addressed in most standards literature: agreed, uniform specifications of material dimensions, operating capacities, procedures and protocols. Opposing them were the *consultants*, a community whose status and livelihood depended, by definition, on the need for *ad hoc* measures in design and execution. Put another way, the consultant's role was to negotiate and achieve accommodation between the constraints of the site, the customer's expectations and the electrical system itself: if the manufacturers' standardization culture became dominant (extending to both site and expectations), this skill of negotiation would become redundant.

In response to this situation, Arapostathis reports, the consultant electricians imposed an alternative standards rhetoric of their own: the public good, they argued, would be best served by regulation not of the *practice* of electrification, but of the *profession*, with agreed modes of negotiation affirmed by standard contractual formulations. In some cases,

these consultants actively opposed uniform specifications as liable to promote a monopoly culture: far better that the skilled consultant choose, from among 'many manufacturers with many standards', the best materials for his individual client. Crucially, this was promoted not as a subjective process, but as a disinterested selection among various precisely specified possibilities. In terms of the taxonomy offered by Timmermans and Berg, the consultants sought authoritative 'procedural' and 'performance' standards that would govern standards selection at the 'design' level.[25] Not all standardization, then, is even hypothetically part of a search for *one* standard.

Arapostathis' account closely engages the themes of moral authority and trust, reflecting prevailing trends in the historiography of nineteenth-century British engineering and precision measurement.[26] Trust is a form of codified expectation, as, of course, is all standardization; yet, trust is necessary only where there remains some process of negotiation. Whereas Arapostathis' conception of the consultant involves some innovation in the use of standards as an analytical category, Chris Otter's piece probes the limits of the approach. Readers accustomed to economic history and business strategy literature may question whether the issue of the gas mantle's eclipse or survival, for instance, is a 'standardization' issue at all. Otter addresses no specifications, proprietors or systems formalisms, instead telling how the general principles of certain technical strategies were accepted, and displaced, at the cultural level.

There is merit, however, in assimilating to standardization the processes generally described as 'technological stabilization' and 'closure'.[27] In the ascendancy of the cultural norms associated with the mature gas mantle or electric filament bulb, what is (partially) *closed* is the same process of negotiation (over such questions as: what is acceptable? what is in keeping? what modifications ought to be made?) seen to be curtailed in more generally recognized standards cases. Further, successfully stabilized technologies tend to resemble successful standard specifications in presenting the appearance of a unidirectional *trajectory*. Electric lamps, having been enshrined as the 'basic illuminants in Western society', spread their light ever increasingly across that society and beyond.

It is this trajectory that Otter deconstructs, drawing on the contextual approach that challenges linear or progressive narratives of technical development. Ostensibly 'old' and discredited technical forms may actually represent the majority use pattern, be considered more appropriate to the context of their use and undergo innovations of their own; they may co-exist indefinitely with their 'newer' rivals, and may even supplant them.[28] As Donald MacKenzie has pointed out:

> Instead of one predetermined path of advance, there is typically a constant turmoil of concepts, plans, and projects. From that turmoil, order (sometimes) emerges, and its emergence is of course what lends credibility to notions of 'progress' or 'natural trajectory'. *With hindsight*, the technology that succeeds usually does *look like* the best or the most natural next step.[29]

Such contingentism is now mainstream in the discussion of broad technical forms. For dominant standard specifications, however (especially as described by economic historians), a kind of determinism persists: indeed, the most striking feature of path-dependency theory is that the path has some determining agency in its own right.[30] Whereas we may readily understand how electric lighting may, in some contexts, be challenged by the gas lamp, it appears difficult to conceive challenges to the standard rail gauge or QWERTY keyboard.

If we interpret stable technical forms as 'soft standards', however, we may realize that the paths associated with 'harder', more formally specified standards are often meaningfully challenged by alternatives of lesser formalization. Standard-gauge rail systems are commonly considered 'standard' as a result of their success relative to broader and narrower gauges; their crucial battles, in fact, have been against road and water transportation. To what extent has QWERTY displaced Cyrillic keyboards in Russia or Bulgaria? How has it fared against paper and pen, digitizing tablets and various voice transcription approaches in different periods? There is no reason why the alternatives in a standards debate must be equivalent in their mode of action or level of formal codification; and often much reason why they might not, as the narratives of DeNardis and Arapostathis in their different ways make clear.

This shift to address the 'softer' side of standardization, we may note, accords with ongoing analysis of recent innovations in public standard-setting practice, notably the ISO 9000 'quality management' initiative, which mandates in general terms such activities as goal-setting and record-keeping. The growing body of literature concerned with such measures sees no problem in addressing as 'standards' such entrenched cultural norms as the requirement to shake hands.[31] One valuable insight from this literature is that the successful standardization of assertions and expectations *about* a practice may altogether fail to standardize the practice itself.[32] Also germane to the 'soft standards' perspective is the focus on *classification* as an explanatory category, elaborated in the work of Bowker and Star: classifications may be more or less rigorously formalized and, like standards, manipulate the boundaries of perceived objectivity to 'valorize' or 'silence' contested points of view.[33]

Notions of 'harder' and 'softer' standards are more fully explored in James Sumner's tale of the IBM PC-compatible computing platform. Sumner weighs up the explanatory relevance of a gamut of normative possibilities, from the specification of a microprocessor, through the contents of an instruction manual, to loose received notions of what a computer or its user interface ought to look like. The PC cannot be explained satisfactorily as a formal set of integrated standards: it is a 'broad constellation of specifications, varying in their exactitude, across the levels of hardware, operating software, applications software and user culture'. Within this framework, Sumner is keen to stress that acceptance and rejection of standards are not the only possible responses to a standards agenda: *compatibility* deserves particular attention, being a form

of co-option of that agenda that nevertheless strives to retain some mode of working outside it, to subvert its terms, or perhaps to supersede it.

Like Otter, Sumner frames his account as a defence of contingency: the hegemony of the PC was not as inevitable as is conventionally represented. Indeed, a narrative focusing purely on the success of IBM's promoted standards must be unsatisfactory, as its consequence was the *opposite* of 'vendor lock-in'. IBM had enjoyed an almost AT&T-like dominance of large commercial computing systems, yet, within the 'PC' culture it had ostensibly created, its hardware production activities declined to marginal status: the corporation could neither farm revenues from its standards agenda, nor determine its development. If there is a chief inheritor of IBM's cultural monopoly, it is Microsoft, a software corporation barely engaged in the hardware business. Microsoft reaped the rewards of proprietary control, to an extent that IBM did not, because computer users came to see software alone, not integrated hardware/software systems, as the fundamental defining characteristic of use. The significance of this kind of perceptual shift again demonstrates the value of tracing the interplay between asymmetrical standardization (or stabilization) agendas.

Frank Veraart's approach, too, softens the boundaries of how standardization is seen to act: guidelines for the structuring of computer programs in the Basic language, though interpreted subjectively by users, were ultimately refined into algorithmic rigour and used as a basis for automated interconversion. Veraart aptly characterizes the Basicode specification as a 'microcomputer Esperanto': a consciously designed *universal* language. Universalism, as an ethical principle in standards initiatives, is of course rather different from the drive to apply a given standard universally. Instead of seeking to 'change the world' into conformity with one common standard (as did Russell's innovative monopolists), the universalist enthusiasts of Basicode hoped to evolve a common mode of action, suited to the world as it stood, using formalized translation to surmount divergence among the dialects of Basic. A similar ethos informed the UCSD 'p-System' discussed briefly by Sumner; indeed, the approach has its precursors in mechanical cases, including the iconic railway break-of-gauge problem.

Universalism, however, tends not to prevail: heterogeneous standards, though mutually incommensurable, have advantages particular to the contexts of their production and use. Esperanto, borrowing elements from many language communities, has a user base in none. Basicode's automatic translation came at the expense of denying all its programmers certain possibilities conventional in their proprietary Basic dialects. The price of obviating such restrictions, as seen in the functionally elegant p-System, is a degree of complexity that slows the system and may call for drastically improved technical resources – at which point, the object of universal running across available systems is defeated.

By common consent, the world's second language is not Esperanto, but English; adoption of the p-System wilted in the face of Microsoft's PC-

DOS. Was Basicode, correspondingly, trumped by the emerging dominance of a proprietary Basic? No. Much as in the PC hegemony case, perceptions shifted to the extent that the question no longer held meaning. Basic, with its familiar English-language borrowings, had achieved notability around the beginning of the microcomputer boom as the coding language of the wider public;[34] by the 1990s, with microcomputers well established as software-playing consumer durables, the public no longer coded, while professional coders turned to other languages. The ultimate consequences for the Basicode standard are particularly intriguing. With the relevant mass culture gone, the hobbyist subculture that had created the standard re-appropriated it, directing it towards teaching and exemplification rather than applications development. Faced with their explicit avowal – 'We do not strive for a system to make professional programs. We do not want a Basicode where everything is possible' – we cannot treat the undoubted marginalization of Basicode as an instance of *failure*.

All six of the papers addressed so far engage cases with a principally electrotechnical or informatic dimension. While this is largely a consequence of the project's IEC sponsorship, it is true that the standardization of life processes was, until recently, somewhat overlooked; it is now a thriving field, however, and deserves to be better integrated with the literature studied by historians of the physical sciences and engineering. Russell, in his overview of the field, highlights the crucial role of standardized organisms such as *Drosophila* in the development of scientific consensus.[35] We might add literature on the rise of evidence-based medicine, the standardization of vaccines and drugs, and the increasingly informatic character of genetics research.[36]

Sayer, who provides our seventh paper, provides a useful bridge towards this literature: her chickens and eggs are themselves profoundly electrotechnical. Parallels with Thomas Hughes' classic account of the nature of technical systems, articulated with reference to electrical power, are unmistakeable.[37] Chickens, barn, lighting and electrical supply form the interacting components of a system; the system's boundaries are also the boundaries of its maintainers' ability to control events directly. The system has a variety of inputs, and one valued output – egg supply – that serves straightforwardly as a metric for problem solving. The key purpose of the artificial lighting regime is to induce chickens to lay all year round, rather than seasonally: this is the quintessential engineer's project of levelling the load graph, bringing the output at any point in time as close as possible to the average. The chief advantage of electrical lighting over alternatives is not cost or convenience, but the controllability needed for this project of load-levelling. The spread of systematic egg production across Britain followed the spread of ready electrical inputs from the National Grid; the distribution of output eggs was similarly systematic in character, customer satisfaction resting on the standardizing initiative of the Lion Mark test process.

At the same time, standardized life processes seem to provoke tensions

not found in the physical and informatic cases, particularly where, as in the case of the breakfast egg, they are routinely encountered by a mass consuming public. While the standardization of internet protocol packets is generally deemed a benign necessity (by those who have the remotest inkling that such entities exist), the standardized egg is suspect. Sayer highlights the vexed issue of consumer demand for the *natural* in agricultural production: 'technology' and 'nature' are seen to be opposed, and the marketers' guile is stretched to its utmost in reconciling hazily pastoral rhetoric with reliability guarantees founded on standards-based systematization. Equally prized, and similarly counterpointed to the 'standard' in popular thinking, is the idea of the *authentic*: authenticity is a consideration as regards not only agriculture, but also such technological commodities as beer, furniture and 'vintage' equipment of all kinds.[38] Yet, some forms of standardization seem to count in favour of Nature and authenticity. Sayer points out that concerned consumers today are increasingly drawn to the organic sector – a phenomenon based on distinct standards of permitted production technology and backed by an extensive certification regime.

The nature of 'Nature', we may note in closing, is not a new concern for standardization theorists. In the 1920s, Albert W. Whitney, a mathematician who had become an influential consultant to the insurance industry, became concerned with the issue that frames our own investigation: the state of tension between stability and freedom. Whitney drew a direct analogy between planned technical development by humans and evolutionary nature. Both produced not a continuum of forms, but a 'discrete and actually enumerable ordered assemblage'; this 'sameness' was, however, accompanied in both cases by 'a strong flavour of variety and individuality'.[39] Both tendencies were crucial to Whitney's conception of progress, and both were indefinitely sustainable in a relationship that Whitney, through explicit gendering, presented as a marriage:

> Variation is creative, it pioneers the advance; standardization is conservational, it seizes the advance and establishes it as an actual concrete fact. Variation is primarily concerned with quality, standardization is primarily concerned with quantity … If nature had no mechanism for fixing and holding the type, she would have no way of capitalizing her discoveries … Variation is the active, creative, masculine force in evolution; standardization is the passive, brooding, conservational, feminine force out of which comes the potency of the next advance … Standardization is thus the liberator that relegates the problems that have already been solved to their proper place, namely to the field of routine, and leaves the creative faculties free for the problems that are still unsolved. Standardization from this point of view is thus an indispensable ally of the creative genius.[40]

Similarly, in human production, says Whitney, whereas the opponents of standardization characterize it as 'producing a world of universal, dull mediocrity in place of the world of color and scintillating lights and

shadows and heights and depths that we have under the play of individual initiative', its stabilizing effect in fact protects us from the 'mad, restless, wearying world of infinite but meaningless variety' that would otherwise ensue; it is nothing more than 'kiln-dried custom', necessary for the creative act to function.[41]

Whitney, who as an insurance consultant, focused particularly on safety issues, was himself professionally engaged in promoting standards and norms; most of the standards participants discussed in this collection, we suspect, would endorse his legitimation of the standardizer's role as part not only of 'modern' life, but of life in general. Yet, his characterization of the marriage between uniformity and variation offers no direction on how the matrimonial responsibilities should be decided: how far should we standardize, and in what cases, and why? As our contributors demonstrate, this question admits of many localized responses, but no standard answer.

ACKNOWLEDGEMENTS

This introduction has benefited greatly from comments by the contributors, particularly Andrew Russell and Stathis Arapostathis, and by two anonymous referees.

Notes and References

1. Excellent surveys of recent and classic literature on technological standardization exist from a variety of disciplinary standpoints. The most influential texts in the history of science and technology are noted in A. Slaton and J. Abbate, 'The Hidden Lives of Standards: Technical Prescriptions and the Transformation of Work in America', in M. T. Allen and G. Hecht (eds), *Technologies of Power* (Cambridge, MA, 2001), 95–143. A more detailed survey, by a historian of technology addressing standards practitioners, is A. Russell, 'Standardization in History: A Review Essay with an Eye to the Future', in S. Bolin (ed.), *The Standards Edge: Future Generations* (Ann Arbor, 2005), 247–60. For the science and technology studies tradition in relation to economic and policy literature, see T. Egyedi, 'A Research Autobiography from an STS Perspective', in J. Schueler, A. Fickers and A. Hommels (eds), *Bargaining Norms, Arguing Standards* (The Hague, 2008), 34–47. For economic theory, see K. Blind, *The Economics of Standards: Theory, Evidence, Policy* (Cheltenham, 2004), 14–54. For socially informed perspectives in political science, see N. Brunsson *et al.*, *A World of Standards* (Oxford, 2000), 1–17. Some critique of the overall state of the field is offered in J. Yates and C. N. Murphy, 'From Setting National Standards to Coordinating International Standards: The Formation of the ISO', *Business and Economic History On-Line*, 2006, 4: 1–25.

2. A. Giddens, *The Consequences of Modernity* (Cambridge, 1990); U. Beck, *Risk Society: Towards a New Modernity* (London, 1992). A useful review of some relevant literature is T. Misa, 'The Compelling Tangle of Modernity and Technology', in T. Misa, P. Brey and A. Feenberg (eds), *Modernity and Technology* (Cambridge, MA, 2003), 1–30.

3. A. Chandler, *The Visible Hand: The Managerial Revolution in American Business* (Cambridge, MA, 1977); and, for a contingentist response, Y. Shenhav, *Manufacturing Rationality: The Engineering Foundations of the Managerial Revolution* (Oxford, 1999).

4. Notable cases addressing state institutions in this context are P. Lundgreen, 'Measures for Objectivity in the Public Interest', in P. Lundgreen, *Standardization, Testing, Regulation: Studies in the History of the Science-Based Regulatory State* (Bielefeld, 1986); D. Cahan, *An Institute for an Empire: The Physikalisch-Technische Reichsanstalt, 1871–1918* (Cambridge, 1989).

5. A. E. Musson, 'Joseph Whitworth and the Growth of Mass-Production Engineering', *Business History*, 1975, 17: 109–49; S. Schaffer, 'Late Victorian Metrology and its

Instrumentation: A Manufactory of Ohms', in R. Bud and S. Cozzens (eds), *Invisible Connections: Instruments, Institutions, and Science* (Bellingham, WA, 1992), 24–55; J. Abbate, *Inventing the Internet* (Cambridge, MA, 1999).

6. G. Basalla, *The Evolution of Technology* (Cambridge, 1988); N. Oudshoorn and T. Pinch (eds), *How Users Matter* (Cambridge, MA, 2003); C. Geertz, *Local Knowledge* (New York, 1983).

7. This aphorism appears in Andrew S. Tanenbaum's textbook, *Computer Networks*, 1st edn (Upper Saddle River, NJ, 1981), 168 – itself a standard work – and is widely attributed to Tanenbaum, though the underlying sentiment is older. Tanenbaum adds that if you do not like the available standards, 'you can just wait for next year's model'.

8. P. David, 'Standardization Policies for Network Technologies: The Flux between Freedom and Order Revisited', in R. Hawkins, R. Mansell and J. Skea (eds), *Standards, Innovation and Competitiveness: The Politics and Economics of Standards in Natural and Technical Environments* (Aldershot, 1995).

9. H. Rothstein *et al.*, 'Regulatory Science, Europeanization, and the Control of Agrochemicals', *Science, Technology and Human Values*, 1999, 24(2): 241–64; T. Misa, *Leonardo to the Internet: Technology and Culture from the Renaissance to the Present* (Baltimore, 2004), 225–9; M. Hård and T. Misa (eds), *Urban Machinery: Inside Modern European Cities* (Cambridge, MA, 2008).

10. Brunsson *et al.*, *op. cit.* (1), esp. 3–13; S. Krislov, *How Nations Choose Product Standards and Standards Change Nations* (Pittsburgh, 1997).

11. Slaton and Abbate, *op. cit.* (1), 136; and see also M. Hård and A. Jamison (eds), *The Intellectual Appropriation of Technology: Discourses on Modernity, 1900–1939* (Cambridge, MA, 2003); B. Marsden and C. Smith, *Engineering Empires* (Basingstoke, 2005).

12. Characterizations of 'closure' are usually informed by the account presented in T. Pinch and W. Bijker, 'The Social Construction of Facts and Artifacts', in W. Bijker, T. Hughes and T. Pinch (eds), *The Social Construction of Technological Systems* (Cambridge, MA, 1987), 17–50, on 44–6. Bijker later nuanced the account, preferring the term 'stabilization' to refer to the semantic conventionalization of a technology within one social group, and 'closure' for the shift to a conventional understanding across social groups (i.e. the decline of interpretive flexibility): W. Bijker, *Of Bicycles, Bakelites, and Bulbs: Towards a Theory of Technological Change* (Cambridge, MA, 1995), 84–8.

13. In particular, Joseph O'Connell, 'Metrology: The Creation of Universality by the Circulation of Particulars', *Social Studies of Science*, 1993, 23(1): 129–73.

14. 'Why Are There So Many Different Plugs and Sockets?', n.d., IEC website, available online at www.iec.ch/zone/plugsocket/ps_intro.htm, accessed 13 August 2008.

15. Arthur Stephenson *et al.*, *Mars Climate Orbiter Mishap Investigation Board Phase 1 Report* (1999), available online at ftp.hq.nasa.gov/pub/pao/reports/1999/MCO_report.pdf, accessed 19 June 2008.

16. For the roots of anti-metrication activity in US engineering, see Shenhav, *op. cit.* (3), 60–1.

17. Krislov, *op. cit.* (10), 23.

18. G. Gooday, *The Morals of Measurement* (Cambridge, 2004), 11, emphasis added.

19. J. Staudenmaier, 'The Politics of Successful Technologies', in S. Cutcliffe and R. Post (eds), *In Context: History and the History of Technology* (Cranbury, NJ, 1989), 150–71, on 157–61.

20. S. Schmidt and R. Werle, *Coordinating Technology: Studies in the International Standardization of Telecommunications* (Cambridge, MA, 1998).

21. For an overview of literature in this tradition, see V. Stango, 'The Economics of Standards Wars', *Review of Network Economics*, 2004, 3(1): 1–19. Notable standards-battle case studies not cited by Stango are P. David and J. Bunn, 'The Economics of Gateway Technologies and Network Evolution: Lessons from Electricity Supply History', *Information Economics and Policy*, 1988, 3(2): 165–202; M. Cusumano, Y. Mylonadis and R. Rosenbloom, 'Strategic Maneuvering and Mass-Market Dynamics: The Triumph of VHS over Beta', *Business History Review*, 1992, 66: 51–94.

22. Marsden and Smith, *op. cit.* (11), 151–5; R. Stokes, *Constructing Socialism* (Baltimore, 2000), 117–25; K. Alder, *The Measure of All Things* (London, 2002).

23. For further details, see Sumner's contribution to this volume.

24. A theme addressed briefly with respect to the railway case in Chandler, *op. cit.* (3),

122–44; and see also C. Shapiro, 'Setting Compatibility Standards: Cooperation or Collusion', in R. Dreyfuss, D. Zimmermann and H. First (eds), *Expanding the Boundaries of Intellectual Property: Innovation Policy for the Knowledge Society* (Oxford, 2001), 81–101.

25. S. Timmermans and M. Berg, *The Gold Standard: The Challenge of Evidence-Based Medicine and Standardization in Health Care* (Philadelphia, 2003), 24–5. Modes of standardization that address practice, as opposed to output, have drawn increasing attention from management theorists, as formal standards-setting bodies have become increasingly engaged with the management process: Brunsson *et al.*, *op. cit.* (1), 4–5, 71–84.

26. Gooday, *op. cit.* (18); T. Porter, 'Precision and Trust: Early Victorian Insurance and the Politics of Calculation', in M. Wise (ed.), *The Values of Precision* (Princeton, 1997), 173–97.

27. A similar project was undertaken by Schmidt and Werle: inspired by Bijker's 1990s characterization of 'stabilization' (note 12, above), they present stabilized artefacts, having semiotic as well as material 'obduracy', gaining standard-like agency in the world. Schmidt and Werle's research focus, however, is on standards committees, and their account is therefore framed by the distinction between the actualities of stability and the potentialities of standards; the focus in our collection is on standardization in practice. Schmidt and Werle, *op. cit.* (20), 19–20.

28. See, in particular, D. Edgerton, *The Shock of the Old* (London, 2007). On the problematics of 'technological failure' assessed in light of this kind of contingentist framework, see K. Lipartito, 'Picturephone and the Information Age: The Social Meaning of Failure', *Technology and Culture*, 2003, 44(1): 50–81.

29. D. Mackenzie, 'Introduction', in D. Mackenzie, *Knowing Machines: Essays on Technical Change* (Cambridge, MA, 1996), 6, emphasis added.

30. See the extensive literature proceeding from P. David, 'Clio and the Economics of QWERTY', *American Economic Review*, 1985, 75(2): 332–7.

31. Brunsson *et al.*, *op. cit.* (1), 13.

32. Brunsson *et al.*, *op. cit.* (1), 145.

33. G. C. Bowker and S. L. Star, *Sorting Things Out: Classification and its Consequences* (Cambridge, MA, 1999). In Bowker and Star's conception, standards arise when classification is applied, and themselves have the power to classify, in a manner that persists over time and/or spatial and cultural distance: see 5, 13–16.

34. 'Basic is the people's language!' was jocularly presented as a campaign slogan in the foundational activist–enthusiast newsletter *People's Computer Company*, 1972, 1(1), October: back cover.

35. Russell, *op. cit.* (1). Russell draws our attention to the writings of Robert Kohler (on *Drosophila*), Karen Rader (on standardized mouse strains for biomedical research) and Daniel Todes (on the industrially inspired physiological research of Ivan Pavlov).

36. Timmermans and Berg, *op. cit.* (25); C. Bonah, 'The "Experimental Stable" of the BCG Vaccine: Safety, Efficacy, Proof and Standards, 1921–1933', *Studies in History and Philosophy of Biological and Biomedical Sciences*, 2005, 36: 696–721; C. Gradmann and J. Simon (eds), *Evaluations: Standardising Pharmaceutical Agents, 1890–1960* (Basingstoke, forthcoming); S. Rogers and A. Cambrosio, 'Making a New Technology Work: The Standardization and Regulation of Microarrays', *Yale Journal of Biology and Medicine*, 2007, 80: 165–78.

37. T. Hughes, *Networks of Power* (Baltimore, 1983); T. Hughes, 'The Evolution of Large Technological Systems', in W. Bijker, T. Hughes and T. Pinch (eds), *The Social Construction of Technological Systems* (Cambridge, MA, 1987), 51–82.

38. Addressing the brewery case, one of the editors has written on attempts to finesse the conceptual divide between systematization and authenticity, through the grounding of a rhetoric of 'specialness' in the particularities of large-scale production. J. Sumner, 'Status, Scale and Secret Ingredients: The Retrospective Invention of London Porter', *History and Technology*, 2008, 24(3): 289–306.

39. A. Whitney, 'The Place of Standardization in Modern Life', *Annals of the American Academy of Political and Social Science*, 1928, 137: 32–38, on 33. Our thanks to Andrew Russell for drawing our attention to this source. For some comparable past approaches, see Basalla, *op. cit.* (6), 1–25.

40. Whitney, *op. cit.* (39), 34–35.

41. Whitney, *op. cit.* (39), 34–35, 37.