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ANDREW L. RUSSELL

INTRODUCTION

Standardization provides a useful starting point for examining the development of technological systems. Its utility comes from the pivotal position of standards within a system: whether they take the form of consistent interfaces, commodified raw materials or regularized labour practices, standards are necessary for integrating a heap of parts into a functional whole. A classic case in point is the Bell Telephone System. A number of excellent studies have shown how the creation of the modern Bell System was the result of extensive technical, administrative and political efforts to combine a variety of disjointed units (including local and regional operating companies, Western Electric, Long Lines and, after 1925, Bell Labs) under the direction of AT&T executives. An ideology of standardization drove the successful creation of the monopoly Bell System –most clearly articulated in Theodore N. Vail's slogan 'One System, One Policy, Universal Service'. As with other large technical systems, standards were both cause and consequence of systematization.[1]

In the formative years of the Bell System, executives and managers pursued a thorough and far-reaching programme of standardization. By 1929, AT&T had defined standards for an astonishing variety of functions, including telephone plant design, underground cables and raw materials; the manufacture, distribution, installation, inspection and maintenance of new equipment, business and accounting methods, and non-technical supplies (such as office furniture, janitors' supplies, cutlery and china); and provisions for safety, health, and even natural disasters such as sleet storms.[2]

This comprehensive programme of standardization, when combined with strategies in the market and political spheres, generated powerful momentum and created the foundations of AT&T's control over the American telephone industry. Indeed, we might see the AT&T standards strategy as the centrepiece of its transformation from a small entrepreneurial venture into the source of American leadership in global communications and electronics. As the many histories of the Bell System have shown, AT&T maintained this momentum during subsequent decades through a sometimes uneasy truce with federal antitrust regulators. This truce eventually began to unravel in the late 1960s and ended with the divestiture of the Bell System in 1984.[3]

It is unfortunate that historians have not studied standardization in the mature Bell System (after 1920) with the same level of scrutiny that they have devoted to standardization in the Bell System's formative years (before 1920). Given what we know from historians and economists of monopoly firms, we might assume that standardization in the monopoly Bell System occurred in a monolithic and almost petulant manner. Indeed, this is precisely the style of standardization that the Federal Communications Commission described in its highly critical 1939 investigation of the American telephone industry. 'Centralized control over engineering, standardization, and manufacturing,' the FCC declared, could provide opportunities for the suppression of inventions, the failure to take advantages of outside improvements, and the sale and installation of outdated or inferior equipment by Western Electric to the regional operating companies.[4] The FCC concluded that AT&T used standards – and the process of standardization – to construct and protect its monopolistic autonomy. But, as a matter of public policy, monopoly was an acceptable compromise so long as the Bell System provided a high-quality telephone service to users and paid consistent dividends to investors.

It is my contention that this caricature of monopoly standardization – sluggish, arrogant and solipsistic – paints a distorted picture of the Bell System's struggle to achieve standardization. If we look more closely at what AT&T executives and engineers were doing, we will of course see a number of projects to develop standards that would bring greater efficiency through centralized control. But, if we persist in viewing the history of the Bell System from the vantage point of standardization, we might be surprised to see dozens of standardization projects that spanned the boundaries of their monopoly system.

In this chapter, I review two of these standardization projects in order to show how system engineers laboured to maintain the momentum of a technological system – despite its secure status as a monopoly – by influencing technical standards that were not under their monopolistic jurisdiction. In today's antitrust parlance, they leveraged their monopoly power to influence competitive lines of business. My first example is an instance of what we might term 'interfering infrastructures' – the problem of inductive interference that resulted from the close proximity of transmission wires used by telephone systems, electrical light systems, electrical power systems and electrical railway systems. My second example is AT&T's efforts to eliminate the use of illegal telephone slugs, some of which were metal washers manufactured to meet existing industry standards.

An important conceptual question lies beneath the surface of these two examples: why did AT&T engineers invest time and energy into standardization projects that reached beyond the boundaries of the

AT&T monopoly? This paper considers three possible explanations. The first is economic: just as intra-firm standardization brought efficiencies to the operation of AT&T's telephone network, AT&T executives might have believed that inter-firm (and inter-industry) standardization would generate similar efficiencies, reduce costs and increase profits. A second explanation is jurisdictional: participation in industry standardization could have provided a channel for AT&T to influence the standards process to benefit its proprietary interests. A third explanation is cultural: by participating in industry and national standardization projects, AT&T engineers could embody the professed public service ethic of AT&T and, at the same time, enhance the prestige and vitality of professional organizations (such as the American Institute of Electrical Engineers) and stabilizing institutions (such as the American Engineering Standards Committee). These three explanations need not be mutually exclusive; indeed, my point is that we need to keep each of these three types of motivation in mind in order to reach a richer understanding of standardization within and beyond the boundaries of the Bell System.

INTERFERING INFRASTRUCTURES: THE PROBLEM OF INDUCTIVE INTERFERENCE

Throughout its early history, AT&T did not encourage its engineers to collaborate openly in technical societies and industry groups. To the contrary, AT&T leaders recognized that their competitive advantages flowed from the company's premium on secrecy and patent protection. These attitudes, however, began to change in the years before the First World War. One indication of changing attitudes may be seen in a speech at the 1915 conference of Bell System engineering and manufacturing personnel, in which H. F. Albright asked the Western Electric and AT&T engineers to reconsider the potential benefits of professional activities outside the Bell System. Albright suggested that individual employees would gain 'an enlarged circle of acquaintances' and learn about other engineering methods. The company as a whole would benefit, as well:

> . . . through such associations the company obtains recognition for its principles and achievements; its worth and position in the community are better known; the quality of its scientific work and its efficiency in production becomes better known and our customers and friends learn to better appreciate our pioneer work in the development of the art of telephony.[5]

AT&T engineers quickly learned that 'outside' cooperation had more than a social function. A good example of the technical benefits of cooperation may be seen in AT&T's efforts to address inductive interference generated by the close proximity of other networks that utilized electrical current, such as electrical power lines, lighting systems and railroad equipment. Some information infrastructures, such as telegraph and railroad networks in the nineteenth century, grew in a largely complementary manner.[6] The electrical networks and infrastructures of the twentieth century, however, created new problems that engineers attacked by using both technical and organizational means.

Telephone engineers had long been familiar with interference, such as 'crosstalk' (speech from one conversation was audible in another) and 'babble' (unintelligible background noise), that resulted from placing telephone circuits in close proximity.[7] By the mid-1910s, however, Bell engineers became concerned with other sources of electrical interference that originated not within their networks, but instead from parallel and intersecting lines operated by power and light companies. This type of 'inductive interference' was deeply problematic because it undercut one of the central technical objectives of Bell engineers: to increase the efficiency and sensitivity of transmission equipment. As Bell engineers were lowering their limits for acceptable levels of interference in an effort to improve call quality, power companies were expanding their reach by building more (and more powerful) lines and transmission facilities.

The first efforts to address the problem of inductive interference systematically occurred in California, under the auspices of the California Railroad Commission. Between 1912 and 1917, the Commission's Joint Committee on Inductive Interference – consisting of and funded by representatives from the telephone, power and railroad industries – performed a number of field and laboratory tests and wrote dozens of technical reports, many of which were compiled in a 1919 final report. The report identified some 'guiding principles' for preventing interference, including standards for minimum distance between power lines and communication lines as well as design and construction rules for apparatus that were incorporated into Commission rules. However, the report's authors also acknowledged the complexities of inductive interference and underscored the need to conduct further studies of the scientific and practical aspects of the problems at hand.[8]

Perhaps the greatest contribution of this effort was its demonstration that a cooperative approach could generate new solutions to technical problems. Despite this lesson, telephone and power companies around the country turned to litigation throughout the 1920s in an effort to deflect the costs of solving the problem onto their rivals. As early as 1920, an internal Bell System conference dedicated an entire session to working through AT&T's approach to the problem of inductive interference. Although existing laws and precedents seemed to indicate that the first party to construct facilities had the right to exclude other parties, AT&T's Chief Counsel N. T. Guernsey stressed that most interference cases were not so clear. Accordingly, Guernsey, in comments echoed by AT&T's newly appointed Vice President and Chief Engineer, Bancroft Gherardi, articulated a preference to avoid litigation if possible. This preference had multiple sources, including the imperative to keep costs down, the 'necessity of avoiding controversy with our friends who are engaged in the power business' and the desire to maintain a favourable image in the eyes of regulators and the general public.[9]

Gherardi personally led AT&T's participation in the effort to settle through cooperation the problems generated by the interfering infrastructures. Beginning in 1921, Gherardi represented the Bell system in two *ad hoc* Joint General Committees: one with the Association of American Railroads and the other with the National Electric Light Association (NELA). Because of his training as an electrical engineer and his longstanding participation in the AIEE, Gherardi was the right man for a task that was part diplomacy, part engineering. His counterpart representing NELA was Robert Pack, a respected power engineer and active member of NELA.[10]

In 1922, NELA and the Bell Telephone System created a Joint Development and Research Subcommittee to investigate further the problems of inductive interference. By 1924, these groups joined with representatives from the electric and steam railroad industries to form the American Committee on Inductive Coordination. Gherardi was the group's Chairman; Pack was one of three Vice-Chairmen. Together, the two men presented a report on the Committee's work to the general session of the NELA convention in May 1926. In his remarks, Pack matter-of-factly noted three areas of effort. First, the committee had created 'Principles and Practices for the Joint Use of Wood Poles' and distributed it to NELA member companies and AT&T associated companies. Secondly, he reported some progress toward a statement on procedures for dividing the costs incident to inductive coordination. Thirdly, he noted the recent approval of funds for further development and research, which, to his regret, had not progressed as far as the first two areas.[11]

Gherardi departed from Pack's reporting style to relay his own personal reflections as a visitor to the NELA. His diplomatic skills were on full display in his short speech: he noted the pleasure of 'wearing the badge' of the group at its convention (his sixth consecutive appearance) and spoke of 'a change in my attitude toward the meeting, and a change in the meeting's attitude toward me'. He continued:

> I can feel that there has been a closer and closer bond between us .... We have put further and further behind us the proposition that inductive coordination was a problem to fight about, and we have more and more fully accepted the view that inductive coordination was a problem to work out together, quite a different attitude from fighting it out.[12]

Reports from NELA's Inductive Coordination Committee at the group's meetings in 1926 and 1927 further indicate that earlier tensions between the power and telephone companies had been reduced to a matter of cooperative research and routinized solutions. The 1926 report by Howard Phelps noted 'In contrast with the experience of previous years, the one now closing has been singularly free from controversy and threatened court actions'. He subsequently directed the rest of his report toward new problems with inductive interference from radio and automatic train control systems. One year later, J. C. Martin opened his report on the committee's work by noting two 'outstanding facts' of the previous year. First, the committee had emerged 'finally and completely' from its reputation as a body that handled a controversial problem with the telephone industry to a body that dealt with a 'common electrical industry problem'. Secondly, he reported that relations between the staff and engineers of NELA and AT&T had been further strengthened. The remainder of Martin's report discussed what he felt were more pressing problems – again, inductive interference from radio and automatic train control.[13] Gherardi himself, speaking from the audience at the 1928 AIEE meeting, confirmed that the group's turn from conflict to collegiality had borne fruit. Reflecting on the joint work between the Bell System and NELA over the past several years, Gherardi declared that 'we came to the conclusion that 10 per cent of our problem was technical and 90 per cent was to bring about between the people on both sides of the question, a friendly and cooperative approach'.[14]

Although these *ad hoc* committees generated standards and recommended practices (such as recommendations for satisfactory distances between electrical wires connected to the same poles), they did not solve the underlying scientific and technical problems associated with inductive interference. Indeed, telecommunications and electrical engineers continue to struggle with similar problems as they seek to use power lines as a delivery mechanism for broadband communications in the twenty-first century.[15] Nevertheless, cooperative organizations such as the Joint General Committees and American Committee on Inductive Coordination created institutional means for defusing a potentially costly confrontation between some of the major forces in American high-tech industry. Through this new approach – perhaps most visible in the rhetorical shift from 'inductive interference' to 'inductive coordination' – they redefined their confrontation as a problem that could be managed through collaborative research and inter-industry standardization.

BANCROFT GHERARDI AND THE AMERICAN ENGINEERING STANDARDS COMMITTEE

Gherardi's enthusiasm for this cooperative solution to a difficult technical and organizational problem foreshadowed his more substantial commitment to the cause of industrial standardization. By the late 1920s, Gherardi's faith in engineering cooperation, combined with his longstanding interest in technical standardization, led him to get closely involved with the activities of the American Engineering Standards Committee (AESC). A small group of respected electrical, mechanical, civil and mining engineers formed the AESC in 1918 as an institution that could negotiate solutions to the same types of inter-industry technical problems as Gherardi had been investigating through the *ad hoc* Joint General Committees. By the mid-1920s, the AESC had proven to be a productive venue for reaching a national consensus among engineers as well as representatives from government, academia, the insurance industry, trade associations and safety groups. Three factors drove the rapid growth of the AESC in the early 1920s: the interest of engineers in the elite technical societies, increasing participation from trade associations, and the support of political leaders such as the highly regarded mining engineer and Secretary of Commerce, Herbert Hoover.[16]

At first, AT&T participated in the AESC in a very limited way. It did not contribute to any AESC projects until 1921, when it sent an engineer to only one committee, 'Symbols for Electrical Equipment of Buildings and Ships'.[17] AT&T joined the AESC in earnest in 1922, when the Bell Telephone System formed the Telephone Group (together with its nominal partner, the United States Independent Telephone Association) and became a dues-paying Member Body of the AESC.[18] By the end of 1927, dozens of Bell System engineers were involved in the work of 21 AESC sectional committees such as the National Electrical Safety Code committee as well as committees that created standards for manhole frames and covers, tubular steel poles, methods for testing wood, direct-current rotating machines, induction motors and machines, and drafting-room drawings.[19]

Each of these projects dealt with technologies that lay at the boundaries between the telephone business and other industries. They each were important (or, in some cases, vital) for the operation of the Bell System, but, unlike standards for the telephone network and equipment, not subject to AT&T's monopoly control. As the AESC formed new committees, it was very careful not to tread on AT&T's turf and there is no evidence that AT&T submitted any of its internal standards for AESC approval. The full name of an AESC committee responsible for standards for insulated wires and cables illustrates the point clearly: 'Wires and Cables, Insulated (Other than Telephone and Telegraph)'.[20]

Gherardi became personally involved in the AESC as the organization reached a turning point in 1928. In response to increasing amounts of interest from all aspects of industry – not just engineers – the AESC made fundamental changes to its structure and process, and reconstituted itself as the American Standards Association (ASA) in July 1928.[21] Most of the organization's reforms were aimed at making it more welcoming and efficient for industry representatives of all stripes – passing control, as the *New York Times* noted blandly, from engineers and scientists to 'the executives of railroad, public utility companies and industrial concerns'.[22] Indeed, the conspicuous omission of the word 'engineering' from the group's new title indicates the extent to which control over standardization had spread from the domain of scientists and engineers into the domain of corporate executives and trade associations. In the reconstituted body, engineers and scientists retained a smaller sphere of influence in the ASA Standards Council, while the industry executives formed a Board of Directors that assumed responsibility for the ASA's financial administration.[23] Gherardi was a member of the Board of Directors from 1929 to 1935, and also played a key role in the ASA Underwriters' Fund, which raised hundreds of thousands of dollars for ASA coffers by soliciting direct contributions from industrial firms.[24]

Gherardi's importance to the ASA – and the ASA's importance to Gherardi – was underscored by his election as ASA President for the years 1931 and 1932.[25] Despite the potentially crippling effects of economic depression, Gherardi could boast by the end of his term in 1932 that the ASA consensus-driven standards process was alive and robust. During 1932, 2,700 individuals from 570 technical, trade and government bodies were involved in ASA projects – more people than ever before.[26] In the standards committees of the ASA, AT&T found venues to leverage its status and power to extend its technical jurisdiction beyond the boundaries of the Bell System. A close look at AT&T's extended efforts to revise a single seemingly mundane standard for lock washers illustrates how the company's engineers used the industry standards process to attack critical system problems that the monopoly Bell System could not solve by itself.

TELEPHONE SLUGS: A 'PETTY RACKET'

To understand why AT&T engineers thought the standardization of lock washers could help solve a critical system problem, it is necessary to take a slight excursion and consider some of the history of coin-operated telephones. The first coin-operated telephone was invented in 1888, but Bell companies did not adopt them immediately on a large scale. When they first appeared, coin-operated telephones were well suited for two different purposes: for convenient on-the-go calls in busy public areas, and for residential customers or shops – particularly in Chicago – who preferred the option to pay on a per-call basis instead of a more expensive monthly subscription.[27]

From the perspective of Bell System engineers, these coin-operated telephones had a major disadvantage: they could be tricked. Instead of inserting nickels, dimes or quarters, some customers used metal objects – known as slugs – that were a similar size and weight to the legal coins. Although the practice of using slugs was tolerated in some cases by local operating companies, in most cases, slugs posed a costly problem. For example, one 1927 report suggested that in Detroit alone, over 15,000 slugs were found in coin-operated phones each month, which translated to $750 in lost revenue.[28]

As engineers from Western Electric, AT&T and the operating companies studied the problem, they realized that any exclusively technical solution to the slug problem would be costly and excessively difficult to engineer. One possibility they considered was to design coin boxes to use non-circular or octagonal tokens; but this solution would have triggered other substantial system problems, such as increased installation and maintenance costs.[29] Bell System engineers also considered making changes to the slots used to filter and collect nickels, dimes and quarters, but these channels were already built to meet precise tolerances designed to allow legitimate coins to work. In both cases – the introduction of irregular tokens and the redesign of coin channels in existing telephones – the costs of fixing the slug problem within a system context were prohibitive, and both alternatives were rejected as short-term solutions.[30]

Unable to solve the slug problem through an internal technological fix, AT&T engineers chose to attack the problem by turning to institutions outside the Bell System. Between 1927 and 1938, AT&T cultivated relationships with two communities: private firms active in industry standards committees and government officials who took an interest either in the standardization process or in connections between 'the slug racket' and other forms of organized crime. In their efforts with both communities, AT&T's strategy was based on a fascinating assumption: it was easier to change the world than it was to change a technology embedded deep within the Bell System.

In 1927, the Superintendent of the Michigan Bell Telephone Company alerted AT&T engineers that a significant portion of slugs discovered in coin boxes were in fact washers that were manufactured to conform to a particular industry standard. Many of the slugs that turned up in Bell coin boxes were, from a different perspective, simply standard iron washers that coincidentally had similar dimensions to nickels, dimes or quarters.[31] Two of the leading engineering societies in the country – the American Society of Mechanical Engineers and the Society of Automotive Engineers – had separately published these washer standards in the early 1920s. Beginning in 1926, these two groups combined efforts under the auspices of the American Standards Association and formed ASA Sectional Committee B27, 'Standardization of Plain and Lock Washers'. Since this was a clear opportunity to eliminate the offending sizes of washers that were being used as slugs, AT&T sent one of its senior equipment engineers, George K. Thompson, to participate on the B27 Committee beginning in late 1927.[32]

The pace of work in the ASA Committee was slow – so slow that when Thompson retired in 1930, the Committee had not even published a draft of the revised washer standards. When he retired, Thompson left the AT&T washer standards campaign in the hands of Eliot W. Niles, an engineer in the Department of Development and Research. By early 1931, progress seemed imminent: the B27 Committee had prepared a tentative standard with revised dimensions for lock washers. However, in June 1931, the ASA Standards Council reviewed the Committee's work and discovered a violation of ASA rules that caused further delay. The problem was that ASA procedural rules required sectional committees to have an even representation of producers and consumers – in this case, manufacturers and buyers of washers. With 18 committee members designated as consumers and only 11 designated as producers, B27's membership failed to meet the ASA's procedural standard. It took the Committee another full year to canvass existing members for manufacturers who might be interested, convince six of these manufacturers to join the Committee and obtain the ASA's approval for this change. After these new members were approved, they needed several additional months to review the proposed specifications.[33]

As the standards process plodded along, AT&T also utilized a second, more aggressive tactic to recruit allies among other industrial firms. Thompson and Niles were eager to learn of companies that manufactured brass tags, commemorative coins or non-standard washers that could be used as slugs, and AT&T was not shy about dispatching company representatives to warn these companies about the damage their products were causing. This approach worked well with small companies, but larger manufacturers or Bell System suppliers – such as Bethlehem Steel – were less easily persuaded (or intimidated) by letters, calls or even visits from AT&T representatives.[34]

In 1933, a full six years after AT&T first identified the standard washers that were being used as slugs, AT&T officials finally found a strategy that helped them bring the work of the B27 Committee to completion. Upon discovering that washer dimensions specified in an Air Corps Standard contained the same specifications as some of the offending slugs, AT&T officials pressured Harry H. Woodring, the Assistant Secretary of War, to support a new standard. Woodring, spurred to action by letters and meetings with Niles and A. E. Van Hagen (an AT&T official based in Washington), persuaded the Army–Navy Standards Board to back the changes favoured by AT&T. This appeal, directed toward a high-ranking military officer, sparked a final surge of support that culminated in the publication of the revised washer specification as an ASA-approved 'American Standard' in 1934.[35]

The long-awaited victory was bittersweet. By itself, the new standard – a significant technical, organizational and political achievement that took 7 years – was not a wholesale solution to the slug problem. ASA standards were used only on a voluntary basis, and the ASA, by design, had no authority to enforce compliance with its standards. Even though AT&T had spent the last 7 years building a strong network of partners through the standardization process, this alliance could not protect the Bell System from those elements of American industrial society who did not want to adhere to the consensus industry standard. The offending standard was eliminated, but the slug problem remained.

By the mid-1930s, exasperated AT&T executives appealed to regulators and law-enforcement officials for their help in stopping the fraudulent manufacture and use of telephone slugs. This political strategy began to pay dividends in 1936. In February of that year, the New York District Attorney arrested three men alleged to be responsible for manufacturing and selling a majority of slugs used to defraud coin-operated boxes used by telephone companies, public utility companies and restaurants. As the arrest was announced, a representative from New York Telephone took advantage of the publicity to disclose the extent of the slug problem: he reported that, in 1935 alone, New York Telephone recovered 4,277,256 slugs, which amounted to $344,524 in lost revenue. This announcement was a shrewd public relations move, calculated to build a sense of indignation against the 'slug racket'. Twenty more suspects were arrested in an April 1936 sting, and 16 of them (including their 'spearhead') were convicted by the end of June.[36] Reflecting on these arrests, an outraged editorial in the *Washington Post* asked the public to rise above this 'petty racket' and suggested that a cultural standard could succeed where a technical standard did not:

> Petty rackets in which the public at large is able to participate with slight danger of detection are not so easy to control. They constantly crop up in one form or another. The ultimate hope of exterminating them lies in *elevating standards of personal conduct* through education in the home and schools ... For immediate relief from mass pilfering a great deal can be done by unrelenting pursuit of the individuals who earn a living by encouraging such practices.[37]

Buoyed by public support for police action against the slug racket, AT&T and the regional Bell Associated Companies pressed state regulators around the country to pass laws that made the use of telephone slugs a crime punishable by fine, imprisonment or both. In December 1937, the *Washington Post* reported the first arrest under the District of Columbia's new law prohibiting the use of telephone slugs. The article concluded by noting the financial benefits of such laws for the telephone company: 'In 38 states where similar laws have been enforced, company officials said losses had "dropped tremendously".'[38] Of all the different tactics used by AT&T men since discovering the slug problem in 1927, this lobbying offensive – a political solution to a technical problem – yielded the best results by far.[39]

This brief history of AT&T's anti-slug efforts illustrates some of the more general features of AT&T's attitude toward industry standardization. Beginning in the 1920s, AT&T engineers joined dozens of consensus standards committees. Their experiences in these committees were as diverse as the standards they sought to influence. In many of these committees, such as those that set standards for wood poles and acoustic terminology, work proceeded in a harmonious fashion.[40] In other cases, such as the battles for control of radio transmission, the standards-setting process became a lightning rod for scientific, technical and political controversy.[41] Sometimes, AT&T participated in more targeted and specific institutions, such as the American Institute of Electrical Engineers, Institute of Radio Engineers, American Society for Testing Materials, and the National Electric Light Association; other times, it participated in larger and more bureaucratic bodies such as the ASA and the International Electrotechnical Commission.[42] AT&T's motivations for joining these committees also varied. In some cases, industry standards helped to improve the efficiency of operations in the Bell System. In other cases, standards work helped AT&T engineers to either establish or enhance their personal reputations and professional status. In still other cases, AT&T strove to shape the industry consensus around solutions and technologies that it favoured.

Amidst this variety, AT&T engineers effectively learned a valuable overarching lesson: they could use industry standards committees to solve critical problems with the telephone system that AT&T could not solve on its own. Moreover, standards committees provided avenues for AT&T to throw its weight around in American industry, politics and society. The standardization process could be painfully slow over the short term, but AT&T managers such as Bancroft Gherardi realized that, over the long term, they could leverage standards committees to extend their influence over separate, non-telephone lines of business. Through these standards committees, AT&T executives and engineers were able to expand their company's influence, even if they also learned that there were limits to the utility of the consensus standards process. It remains unclear if regulators in the FCC and in the Department of Justice failed to notice this activity or if they simply accepted it as a normal feature of monopoly control.

CONCLUSIONS

In recent years, historians of technology and industry have, following the lead of Thomas Hughes and others, moved from a focus on individual technologies and companies as the central units of historical analysis to a broader focus on 'networked systems'. As we broaden our focus and follow the logic of networks, we may soon discover that we should not stop at the boundaries of any single networked system. Instead, we need to locate networked systems within a broader context – in this case, within a number of networked systems that provided the infrastructure for the American industrial economy and the foundations for American world power in the twentieth century.[43]

Two conclusions follow from this point. First, we can see that 'boundary technologies' (such as telephone slugs/lock washers) emerge as important sites for examining the growth of technological systems. These technologies are important, even in monopoly systems that we might expect to be self-contained or subject only to hierarchical managerial control. Secondly, as we follow Hughes's example and continue to study the development of large technical systems, we need to recognize that these systems – and their builders – were not always complementary, and rarely as symbiotic as the growth of the American rail and telegraph networks in the nineteenth century. When did conflicts arise? What were the subjects of dispute? How were such conflicts resolved? Asking these questions can help us extend and refine the important Hughesian concept of technological momentum, specifically by pointing out how momentum is neither effortless nor inevitable. In the history of American telephone networks, momentum did not follow automatically from the entrepreneurial efforts of AT&T's system builders; nor did it emerge naturally from any sort of path dependence. Instead, momentum was the consequence of continuous work and deliberate diplomacy in multiple venues.

The contingencies of momentum are especially evident when we examine standardization efforts that spanned the boundaries of the Bell System – that is, technologies that were vital for the functioning of the Bell System, yet not subject to AT&T's monopoly control. In the introduction, I posed a question: why did AT&T engineers invest time and energy into standardization projects that reached beyond the boundaries of the AT&T monopoly? The examples discussed in this paper illustrate that we need to consider simultaneously three different motivations, namely efficiency, power and culture. When we consider standardization in the mature Bell monopoly, efficiency and power went hand in hand. The participation of Bell executives and engineers in standard-setting projects to diminish inductive interference and to eliminate illegal telephone slugs helped them to solve critical problems that threatened the continued growth and efficient operation of their monopoly network. At the same time, AT&T engineers also found within these standardization projects new opportunities to patrol the boundaries of their technological system.

By considering Bancroft Gherardi, an executive whose career has been ignored by the numerous scholars who study the early Bell System, we can appreciate how power and efficiency can sometimes be achieved through cultural avenues. Gherardi emerges from these episodes as a skilful diplomat and engineer who worked within the Bell System as well as across the boundaries of the System. Even the most cynical readers might concede that he did so in a genuinely cooperative spirit. I do not wish to portray Gherardi as motivated solely by altruism – surely he was not. I do, however, wish to suggest that, by studying Gherardi and his fellow standards engineers, we may come to see with more clarity the cooperative social networks that sustained the American style of competitive managerial capitalism.

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2. Harold S. Osborne, 'The Fundamental Role of Standardization in the Operations of the Bell System', *American Standards Association Bulletin*, September 1931, 3; and O. C. Lyon, 'Standardization of Non-Technical Telephone Supplies', American Telephone and Telegraph Company, *Plant and Engineering Conference of the Bell System*, New York City, December 6–10, 1920, Section IV, 97–103. Throughout the 1920s and 1930s, a number of AT&T engineers published comprehensive overviews of the Bell System and the important role of standardization. See J. N. Kirk, *The Need for Standardization of Design, Construction and Maintenance Practices in Telephone Work and the Effect upon Service* (AT&T Information Department, 1921); Harold S. Osborne, 'Standardization in the Bell System', *Bell Telephone Quarterly*, 1929, 8: 9–28; Harold S. Osborne, 'Standardization in the Bell System – II', *Bell Telephone Quarterly*, 1929, 8: 132–52; Bancroft Gherardi and Frank B. Jewett, 'Telephone Communication System of the United States', *Bell System Technical Journal*, 1930, 9: 1–100; and Frank B. Jewett, 'Some Fundamentals in Standardization', *Bell Telephone Quarterly*, 1938, 17: 17–27.

3. Accordingly, most histories that trace the creation of the Bell System stop around 1920, if not earlier. For a study of the Bell System's momentum throughout the twentieth century, see Louis Galambos, 'Looking for the Boundaries of Technological Determinism: A Brief History of the Telephone System', in Renate Mayntz and Thomas P. Hughes (eds), *The Development of Large Technical Systems* (Boulder, 1988). See also Hughes, *op. cit.* (1) and Thomas P. Hughes, 'Technological Momentum', in Merritt Roe Smith and Leo Marx (eds), *Does Technology Drive History? The Dilemma of Technological Determinism* (Cambridge, 1994).

4. United States Congress, *Report of the Federal Communications Commission on the Investigation of the Telephone Industry in the United States* (Washington, DC, 1939), 252.

5. H. F. Albright, 'The Business Activities and Relations of Members of Engineering and Manufacturing Departments Outside the Western Electric Company', *Manufacturing and Engineering Conference*, 1915, 2.

6. John, *op. cit.* (1), 55–106.

7. M. D. Fagen (ed.), *A History of Engineering and Science in the Bell System: The Early Years* (New York, Inc.), 324–36.

8. Railroad Commission of the State of California, *Inductive Interference between Electric Power and Communication Circuits: Selected Technical Reports with Preliminary and Final Reports of the Joint Committee on Inductive Interference and Commission's General Order for Prevention or Mitigation of Such Interference* (Sacramento, 1919). The 1916 *Transactions* of the AIEE contain the transcripts of two lively discussions on these issues, including implications for the AIEE's standard wave forms. See A. H. Griswold and R. W. Mastick, 'Inductive Interference as a Practical Problem', *Transactions of the American Institute of Electrical Engineers*, September 1916, 16: 1051–94; and Frederick Bedell, 'Characteristics of Admittance Type of Wave-Form Standard', *Transactions of the American Institute of Electrical Engineers*, September 1916, 16: 1155–86.

9. Fagen, *op. cit.* (7), 336. For positions articulated at the AT&T conference, see Bancroft Gherardi, 'Introductory Remarks on "Our Legal Rights in Interference Cases"', N. T. Guernsey, 'Our Legal Rights in Interference Cases', H. S. Warren, 'Interference Problems', Frederick L. Rhodes, 'Remarks on "Interference Problems"', Harold S. Osborne, 'Inductive Interference' and D. H. Keyes, 'Inductive Interference Problems: Method of Attack', all in AT&T, *Plant and Engineering Conference of the Bell System*, 1920, Section IV: 2–55.

10. Gherardi became an AIEE Association member when he graduated from Cornell in 1895, served as AIEE Vice-President from 1908 to 1910, was named an AIEE Fellow in 1912, served on a number of AIEE committees as well as the AIEE Board of Managers from 1905 to 1908 and 1914 to 1917. He was later elected AIEE President for 1927–28. See Fagen, *op. cit.* (7), 336–7; Lewis Coe, *The Telephone and its Several Inventors* (Jefferson, NC, 1995), 158–9; and 'Bancroft Gherardi – Biographical Data', September, 1949, Box 1133, 'Gherardi, Bancroft – Biography – 1873–1941', AT&T Archives, Warren, New Jersey. Pack became NELA President for 1926–27.

11. Bancroft Gherardi and Robert F. Pack, 'Report on Joint General Committee, Bell System and N. E. L. A.', *National Electric Light Association Proceedings*, May 1926, 83: 191–3.

12. Gherardi and Pack, *op. cit.* (11); American Committee on Inductive Coordination, *Bibliography on Inductive Coordination* (New York, 1925).

13. Howard S. Phelps, 'Report on Inductive Coordination Committee', *National Electric Light Association Proceedings*, May 1926, 83: 851–2; J. C. Martin, 'Report of

Inductive Coordination Committee', *National Electric Light Association Proceedings*, June 1927, 84: 625–6.

14. Bancroft Gherardi, 'Discussion at Pacific Coast Convention', *Transactions of the American Institute of Electrical Engineers*, 1928, 47: 50. Another example of this general lesson appears in the preface of a 1936 book on inductive coordination: '. . . a very minor amount of cooperative work in advance planning of facilities or in correction of existing unfavorable situations will in most cases enable both companies to serve the same customers – the public – at no greater cost.' Laurence Jay Corbett, *Inductive Coordination of Electric Power and Communication Circuits* (San Francisco, 1936), xiii. Corbett was a power engineer who was involved with the study of inductive interference since the California Railroad Commission investigations. For a similar quote attributed without reference to Pack, see Fagen, *op. cit.* (7), 337. See also 'Symposium on Coordination of Power and Telephone Plant', *Transactions of the American Institute of Electrical Engineers*, June 1931, 50: 437–78.

15. Osborne, *op. cit.* (2), 151; 'IEEE Starts Standard to Support Broadband Communications over Local Power Lines', 20 July, 2004, online at http://standards.ieee.org/announcements/pr_p1675.html.

16. See Chapter 2, 'From Industry Standards to National Standards: 1910–1930', in Andrew L. Russell (ed.), '"Industrial Legislatures": Consensus Standardization in the Second and Third Industrial Revolutions', 2007, Ph.D. dissertation, Johns Hopkins University.

17. *Work of the American Engineering Standards Committee (Year Book)* (New York, 1921), 20, 25.

18. *American Engineering Standards Committee Year Book* (New York, 1924), 17. At this time, there were 22 other AESC Member Bodies. AT&T engineers, consistent with their company's commanding technical and business position, were far more active and dominant than their colleagues from the independent companies. For example, in 1927, AT&T sent engineers to 21 committees; USITA engineers participated in nine. *American Engineering Standards Committee Year Book* (New York, 1928), 57, 64.

19. *American Engineering Standards Committee Year Book* (New York, 1923).

20. *AESC Year Book*, *op. cit.* (18), 39.

21. 'Standards Group to Broaden Scope', *New York Times*, 1928, 8 July: 40; 'Scientific Events: The American Standards Association', *Science*, New Series, 1928, 68(1751): 53–4.

22. 'Executives to Direct Standards Body', *New York Times*, 1929, 8 July: 36.

23. *American Standards Year Book* (New York, 1929), 7.

24. They found immediate success: in 1929 alone, this fund was responsible for adding $74,000 to the ASA's annual income of $54,000. AT&T was one of the groups of large American firms to contribute. The other contributors were Aluminum Company of America, Bethlehem Steel, Consolidated Gas, Detroit Edison, Ford Motor Company, General Electric, General Motors, Gulf Oil, Public Service Corporation of New Jersey, Standard Oil Corporation of New Jersey, US Steel, Westinghouse Electric and Manufacturing Company, and Youngstown Sheet and Tube Company. In 1930, the ASA announced that they had obtained the means to increase their budget by $500,000 over the next 3 years. 'Plan to Enlarge Standards Work', *New York Times*, 1930, 5 January: N21; William J. Serrill, 'President's Report', *American Standards Year Book* (New York, 1930), 9–10; and 'Milestones of the ASA', *Industrial Standardization*, 1943: 330.

25. 'Gherardi Heads Standards Group', *New York Times*, 1930, 12 December: 17.

26. 'Group Hears of Gain in Standards Work', *New York Times*, 1932, 1 December: 38; 'Industrial Standardization', *Wall Street Journal*, 1932, 2 December: 2. Ten days later, the AIEE awarded its prestigious Edison Medal to Gherardi, 'for his contributions to the art of telephone engineering and the development of electrical communication'. 'Bancroft Gherardi Wins Edison Medal', *New York Times*, 1932, 12 December: 11; and 'Award of the Edison Medal to Bancroft Gherardi', *Science*, New Series, 1932, 76(1981): 562.

27. Fagen, *op. cit.* (7), 153–6, 160–2, 170–1.

28. E. M. Gladden to L. B. Wilson, 11 July 1927, Location 482 07 03 08, 'American Standards Association Committee on Washers, 1927–1934', AT&T Archives.

29. George K. Thompson to C. J. Davidson, 11 October 1927, Location 482 07 03 08, 'American Standards Association Committee on Washers, 1927–1934', AT&T Archives.

30. AT&T Outside Plant Development Engineer to L. F. Morehouse, 7 November 1932,

Location 482 07 03 08, 'American Standards Association Committee on Washers, 1927–1934', AT&T Archives. Eventually, AT&T introduced new models of coin-operated telephones that implemented different designs – none of them completely successful – to detect and prevent the use of illegal slugs.

31. E. M. Gladden to L. B. Wilson, 11 July 1927, AT&T Archives. Gladden reported that the Association members 'did not appear to welcome' AT&T's suggested solution, which was to confiscate dies and commemorative coins of the offending sizes. Many Association members, it turned out, worked for or owned companies that used such equipment for legitimate purposes.

32. George K. Thompson to C. J. Davidson, 11 October 1927, AT&T Archives; F. J. Schlink to George K. Thompson, 19 November 1927, Location 482 07 03 08, 'American Standards Association Committee on Washers, 1927–1934', AT&T Archives; George K. Thompson to W. F. Hosford, 20 December 1928, Location 482 07 03 08, 'American Standards Association Committee on Washers, 1927–1934', AT&T Archives. Thompson had been involved with coin boxes for over 30 years, ever since he filed the first Bell patent for coin telephones back in 1895.

33. C. B. LePage to E. W. Niles, 9 June 1931, Location 482 07 03 08, 'American Standards Association Committee on Washers, 1927–1934', AT&T Archives; American Standards Association, 'American Tentative Standard – Lock Washers', 1931, November; C. B. LePage to P. G. Agnew, 12 July 1932, Location 482 07 03 08, 'American Standards Association Committee on Washers, 1927–1934', AT&T Archives.

34. Correspondence in the AT&T Archives reveals at least three firms that cooperated with AT&T's direct approach: the Rome Brass and Stamping Company of Rome, New York; the Dennison Manufacturing Company of Framingham, Massachusetts; and Patterson Brothers of Park Row, New York City. Gladden to Wilson, *op. cit.* (31); 'Fraudulent Use of Slugs in Coin Box Telephones (Confidential)', 9 October 1933, Location 482 07 03 08, 'American Standards Association Committee on Washers, 1927–1934', AT&T Archives; AT&T Outside Plant Development Engineer to Morehouse, *op. cit.* (30).

35. Harry H. Woodring to A. E. Van Hagen, 13 October 1933, Location 482 07 03 08, 'American Standards Association Committee on Washers, 1927–1934', AT&T Archives; E. W. Niles to Z. Z. Hugus, 22 December 1933, Location 482 07 03 08, 'American Standards Association Committee on Washers, 1927–1934', AT&T Archives.

36. 'Third Man Seized in Sale of Slugs', *New York Times*, 1936, 9 February: 24; 'Merchant is Guilty in Fake Coin Racket', *New York Times*, 1936, 24 June: 19.

37. 'The Slug Racket', *Washington Post*, 1936, 11 February: 8, emphasis added.

38. 'D. C. Property, Telephone Slug Measures Pass', *Washington Post*, 1937, 27 April: 15; 'Police Accuse Two in Phone "Slug Racket" ', *Washington Post*, 1937, 3 December: 30; 'Two Tried in First Phone Slug Case', *Washington Post*, 1938, 10 February: 18.

39. There was no neat ending or systematic solution to the scourge of telephone slugs, which continued to pose a problem for much of the twentieth century. From the 1930s to the 1950s, the manufacture and sale of slugs was closely linked to organized crime. See '7 Indicted in Slug Racket', *New York Times*, 1941, 6 May: 23; and 'Slug Dropped in Phone Box Leads to Mobster's Arrest', *Hartford Courant*, 1952, 21 November. By the 1960s, however, the same technical practice – tricking network devices to pirate network access – took on a new set of cultural meanings and associations when adopted by Yippies and phreakers. A cultural history of slugs would be a fascinating project.

40. See the committee records and correspondence in Location 484 04 04 02, 'A.S.A. Sectional Committee on Wood Poles', AT&T Archives; and Location 419 01 02 16, 'A.S.A. Committee Z24 on Acoustic Terminology, 1932–1938', AT&T Archives.

41. On AT&T's involvement with radio and radio standards more generally, see Reich, *The Making of American Industrial Research*, 170–238; and Hugh R. Slotten, *Radio and Television Regulation: Broadcast Technology in the United States, 1920–1960* (Baltimore, 2000).

42. Osborne, *op. cit.* (2), 150–1.

43. Thomas P. Hughes, 'From Firm to Networked Systems', *Business History Review*, 2005, 79: 587–93.