“INDUSTRIAL LEGISLATURES”: CONSENSUS STANDARDIZATION IN THE SECOND AND THIRD INDUSTRIAL REVOLUTIONS

by

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Abstract

Consensus standardization is a social process in which technical experts from public, private, and non-profit sectors negotiate the direction and shape of technological change. Scholars in a variety of disciplines have recognized the importance of consensus standards as alternatives to standards that arise through market mechanisms or standards mandated by regulators. Rather than treating the consensus method as some sort of timeless organizational form or ever-present alternative to markets or laws, I argue that consensus standardization is itself a product of history.

In the first two chapters, I explain the origins and growth of consensus standards bodies between 1880 and 1930 as a reaction to and critique of the existing political economy of engineering. By considering the standardization process—instead of the internal dynamics of a particular firm or technology—as the primary category of analysis, I am able to emphasize the cooperative relations that sustained the American style of competitive managerial capitalism during the Second Industrial Revolution. In the remaining four chapters, I examine the processes of network architecture and standardization in the creation of four communications networks during the twentieth century: AT&T's monopoly telephone network, the Internet, digital cellular telephone networks, and the World Wide Web.

Each of these four networks embodied critiques—always implicit and frequently explicit—of preceding and competing networks. These critiques, visible both in the technological design of networks as well as in the institutional design of standard-setting bodies, reflected the political convictions of successive generations of engineers and network architects. The networks described in this dissertation were thus turning points in the century-long development of an organizational form. Seen as part of a common history, they tell the story of how consensus-based institutions became the dominant mode for setting standards in the Third Industrial Revolution, and created the foundational standards of the information infrastructures upon which a newly globalized economy and society—the Network Society—could grow.

Advisor: Stuart W. Leslie

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My list of acknowledgments could be—should be—as long as the dissertation itself, but custom (a social standard, if you will) encourages brevity.

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My first stop was at the History Department at the University of Colorado at Boulder. The faculty there, especially Virginia Anderson, Ralph Mann, Mark Pittenger, and Thomas W. Zeiler, helped me grow as an historian. My advisor, Susan D. Jones, understood that my interests would lead me to departments and schools all over the university, and she did everything she could to help me find my way both inside and outside the History Department. Dale Hatfield, Diane Sieber, Phil Weiser, and Mark Werner nurtured me as a scholar and a teacher, and helped me secure vital financial support from Colorado's Interdisciplinary Telecommunications Program and the Alliance for Technology, Learning, and Society. Scott Miller and Ken Wilber, each in their own way, provided moments of clarity and inspiration during my stay in Boulder.

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The central irony involved in performing research on standardization is that there are no standards for archival records. As a result, I have relied on a vast number of people who have helped me find existing records. I would not have been able to complete this project without the aid of archivists and librarians at Johns Hopkins University, the Herbert Hoover Presidential Library, the MIT Archives, the National Archives, the AT&T Corporate Archives, the IEEE History Center, and the Charles Babbage Institute for the History of Information Technology. Further, JoAnne Yates and Craig Murphy, who succeeded where I failed to gain access to records of the American National Standards Institute, generously shared their discoveries and interpretations with me.

One of the biggest delights (and perils) of writing about recent events is that historical subjects talk back. Oral histories and frank recollections provide a necessary antidote to the dry and lifeless accounts that one typically encounters in the official records generated during the standardization process. Scott Bradner, Vinton Cerf, David D. Clark, John Day, David Farber, Dale Hatfield, David Mills, Steve Oksala, Mike Padlipsky, and Joe Reagle were very kind to share their time, their memories, and their opinions of my work. James Pelkey also shared his unpublished interviews and historical interpretations, for which I am most grateful.

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Introduction

The standards bug bit me sometime in the late 1990s. I'm not sure exactly when it happened, but the symptoms were unmistakable: standards were everywhere I looked, and I began to see the world as a massive compilation of standards. It started with computers—why did the new machines have USB ports and Zip drives, and where was I supposed to put my 3.5 inch floppy disks?—but soon spread to almost everything else I noticed in my daily activities. Who decided if a #2 pencil is not a 3 or a 1.5? Why were all the cement bricks in the high school gym 8 inches by 16 inches? How was it that any telephone would work when I plugged it into the jack in the wall?

Although the presence of standards—once I noticed them—was puzzling, the *lack* of standards was infuriating. When my cell phone battery died, I couldn't use my friend's charger (or his battery) to power my phone. My web page looked fine on Netscape Navigator, but awful on Internet Explorer. The nuts and bolts aisle of Home Depot was utterly baffling, a vivid demonstration that the term "standard" could very well be somebody's idea of a sick joke. Andrew Tanenbaum, a Dutch computer scientist, captured the irony of the situation in his 1981 textbook *Computer Networks*: "The nice thing about standards is that you have so many to choose from; furthermore, if you do not like any of them, you can just wait for next year's model."[1]

My conclusion from this initial exploration was: standardization is the social process by which we come to take things for granted. Through standardization, inventions become commonplace, novelties become mundane, and the local becomes

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[1] Andrew S. Tanenbaum, *Computer Networks* (Englewood Cliffs, NJ: Prentice Hall, 1981), 168.

universal. It is, in short, the *historical* process by which discoveries are rendered into the material and immaterial substance of our everyday lives. The standardization process is lengthy, laborious, and often contested at every step. However, for standards to be successful, this contested process must be transparent (or at least opaque) so that the resulting standards are perceived as authoritative and objective. The history of standardization provides opportunities to explore this authority and objectivity and reveal how people sought to resolve fundamental tensions—scientific, economic, political, and cultural—as they laid the technological foundations of modern society.

In this dissertation I examine the creation of our modern communication networks—telephone networks, the Internet, digital cellular networks, and the World Wide Web—by keeping an eye on the standardization process. There are, of course, other ways to examine the history of these networks. Previous studies have mentioned standards in passing, but typically these analyses revolve around a particular person or company, a specific technology, the processes of invention and research, government regulation, or user adoption. While many of these studies are excellent, they often fail to examine what occurred within the black box of standardization.

My dissertation began with a hunch—that this history might look different if I adopted the standardization process itself as my primary unit of analysis. Standardization could be interrogated, not assumed. Because its effects are so pervasive, standardization provides an ideal vantage point for integrating insights produced by historians who have focused on other units of analysis—individuals, firms, innovation, regulation, adoption, and so on. Because they are crucial components of the infrastructure of modern society, communication networks provide important examples of standardization in action, and are thus an ideal subject for this study.

One of the many ironies of standardization is that there are no standard definitions of what standards are, what they do, and how they are made. The term "standard" often refers to customs, norms, and regular social practices. In technical realms, however, it has more specific meanings that refer to documented practices. In my usage of the term, I follow a definition that the economic historians Paul David and Shane Greenstein articulated in a seminal 1990 article, in which they defined a standard as "a set of technical specifications adhered to by a producer, either tacitly or as a result of a formal agreement."[2]

Having adopted this basic definition of what a standard is, two fundamental questions remain: first, what do standards accomplish? And second, who makes standards? In response to the first question, theorists of standardization agree that most standards fall into three general categories: performance, measurement, and compatibility.

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[2] Paul A. David and Shane Greenstein, "The Economics of Compatibility Standards: An Introduction to Recent Research," *Economics of Innovation and New Technology* 1 (1990): 4. This section draws on a large body of literature that offer various versions of my general typology. See for example Carl Cargill, *Open Systems Standardization: A Business Approach* (Upper Saddle River, NJ: Paladin Consulting, 1997); Ross E. Chiet, *Setting Safety Standards: Regulation in the Public and Private Sectors* (Berkeley: University of California Press, 1990); U. S. Congress, Office of Technology Assessment, *Global Standards: Building Blocks for the Future* (Washington, DC: U.S. Government Printing Office, 1992); Geoffrey Bowker and Susan Leigh Star, *Sorting Things Out: Classification and its Consequences* (Cambridge: The MIT Press, 1999); and Urs von Burg, *The Triumph of Ethernet: Technological Communities and the Battle for the LAN Standard* (Stanford: Stanford University Press, 2001).

1. *Performance*: These standards specify ways to perform certain tasks. Performance standards seek to ensure a minimum level of quality by specifying either a *process*, such as the ISO 9000 "Quality Management Principles," or a *result*, such as a safe and accident-free workplace.

2. *Measurement*: These standards specify an objective quantifiable unit of measurement, such as a meter, a gallon, or ohm. Measurement standards make it possible for people to compare physical qualities, such as length, volume, or electrical current.

3. *Compatibility*: These standards define interfaces between discrete objects. Compatibility standards create efficiencies and economies of scale in the production process, and promote interoperability between complementary products. Interfaces between various components of computer hardware—as well as computer software—provide many familiar examples of compatibility standards, such as Universal Serial Bus (better known as USB) ports and the Ethernet local area networking protocols.

Two important concepts emerge when we consider these three types of standards in the context of communication networks. The first is what economists refer to as network externalities. Standards (especially compatibility standards) facilitate the connection of components into networks that provide electrical power, telephone service, and computer communication. In general, networks become more valuable as more people use them. In successful networks, externalities grow and are sustained by "positive feedback" (or "bandwagon effects"), which make large and valuable networks even larger and more valuable. Numerous strategic implications flow from this economic concept, and many books and articles have examined strategies for generating and capturing value from network externalities, as well as the process by which consumers get "locked in" to specific networks and the high "switching costs" they sometimes face when moving to a competing network.[3] Further, some scholars argue that communication networks can be fruitfully understood as "information platforms" or "information infrastructure." Both metaphors indicate the potential for communication networks to sustain more advanced and complex social and economic activity.[4]

The second concept is actually a puzzle about the essential character of standards: are standards static or dynamic? This question invites philosophical reflection on uniformity and diversity. In Paul David's assessment, this puzzle "may be construed as nothing more and nothing less than the fundamental issue with which all social organizations are confronted: where to position themselves on the terrain between the poles of 'order' and 'freedom.'"[5]

Is standardization the tool of order and control? Or does it facilitate innovation and creativity? Numerous critics, most notably Aldous Huxley and George Orwell, imagined the homogenous and oppressive societies that would result if the logic of

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3 See for example Paul A. David and W. Edward Steinmueller, "Economics of Compatibility Standards and Competition in Telecommunications Networks," *Information Economics and Policy* 6 (1994): 217-241; Michael L. Katz and Carl Shapiro, "Systems Competition and Network Effects," *The Journal of Economic Perspectives* 8 (1994): 93-115; Carl Shapiro and Hal Varian, *Information Rules: A Strategic Guide to the Network Economy* (Boston: Harvard Business School, 1999); and W. Brian Arthur, *Increasing Returns and Path Dependence in the Economy* (Ann Arbor: University of Michigan Press, 1994).

4 Philip J. Weiser, "Law and Information Platforms," *Journal of Telecommunications and High Technology Law* 1 (2002): 1-35; Steven W. Usselman, Public Policies, Private Platforms: Antitrust and American Computing," in Richard Coopey, ed., *Information Technology Policy* (New York: Oxford University Press, 2004), 97-120; Richard R. John, "Recasting the Information Infrastructure for the Industrial Age," in Alfred D. Chandler, Jr. and James W. Cortada, eds., *A Nation Transformed By Information: How Information Has Shaped the United States from Colonial Times to the Present* (New York: Oxford University Press, 2000), 55-106; and Paul N. Edwards, Steven J. Jackson, Geoffrey C. Bowker, and Cory P. Knobel, *Understanding Infrastructure: Dynamics, Tensions, and Designs*, Report of a Workshop on "History & Theory of Infrastructure: Lessons for New Scientific Cyberinfrastructures," National Science Foundation, January 2007.

5 Paul A. David, "Standardization Policies for Network Technologies: the Flux Between Freedom and Order Revisited," in Richard Hawkins, Robin Mansell, and Jim Skea, eds., *Standards, Innovation and Competitiveness* (Aldershot: Edward Elgar, 1995), 15-35.

standardization was left unchecked.[6] On the other hand, advocates of standardization argued that variation and standardization were the two processes that drove evolution and thus progress in both nature and society. In a 1924 essay, the safety advocate Albert Whitney suggested that

> Variation is creative, it pioneers the advance; standardization is conservational, it seizes the advance and establishes it as an actual concrete fact… 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.[7]

On the whole, I am most convinced by Whitney's interpretation—that standardization is part of a dynamic and arguably evolutionary process that consists in part of the codification of existing knowledge.[8] However, critics are right to point out that authority figures can use standards to stifle innovation that does not suit their purposes. The three types of standards listed above—performance, measurement, and compatibility—help us to think more concretely about these philosophical dilemmas. All standards attempt to create a certain permanency, especially measurement standards. However, upon closer consideration it becomes clear that all standards—even measurement standards such as the meter or the kilogram—can be updated, revised, or overthrown as time passes and conditions change. This process of change, even for

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[6] Aldous Huxley, *Brave New World: A Novel* (Garden City, NY: Doubleday & Company, 1932); George Orwell, *Nineteen Eighty-Four: A Novel* (New York: Harcourt, Brace and Company, 1949).
[7] Albert Whitney, *The Place of Standardization in Modern Life* (Washington, DC: Central Executive Council, Inter American High Commission, 1924), 5.
[8] J.S. Metcalfe and Ian Miles, "Standards, Selection and Variety: An Evolutionary Approach," *Information Economics and Policy* 6 (1994): 243-268.

standards that are designed to be permanent, reminds us that standards are products of power structures that also change over time.

The second fundamental question posed above—who makes standards?—also reminds us that standardization is a power-laden process. On whose authority does something become "standard"? How are different types of standards created and enforced? In response to these questions, theorists have identified three different institutional origins of standards: *de facto*, *de jure*, and voluntary consensus.

1. *De facto* standards arise from common usage or market adoption. Individual people or single firms often generate these standards, which spread either through the efforts of a sponsor or in a more organic way. Two examples of *de facto* standards include Microsoft's word processing software and the QWERTY keyboard.

2. *De jure* standards are mandated by regulators at the local, state, federal, or international level. Governments commonly test *conformance* with mandated standards, and can legally (and at times severely) punish non-compliance. Two examples of *de jure* standards are the European GSM transmission standards for cellular telephones, and the American Federal Communications Commission Part 68 rules that govern the telephone terminal equipment.

3. *Voluntary consensus* standards are specified within a range of private institutions, including engineering societies, trade associations, accredited standards setting organizations, and industry consortia. *Consensus* refers to the collaborative and non-coercive process in which these standards are developed; *voluntary* indicates that nobody is legally compelled to adopt these standards. However, there can be strong economic incentives that encourage conformance with voluntary standards, and many parties involved in developing these standards make *a priori* commitments to adopt them. Two examples of consensus standards include the TCP/IP networking protocols and the HTML language for the World Wide Web. This is the central subject of my dissertation, and further examples will be provided in chapters 1-6.

In practice, these three styles of standardization co-exist, and have porous boundaries: for example, *de facto* standards frequently gain wider approval through voluntary consensus bodies, and consensus standards can be either referenced in government regulations or codified through government procurement specifications. Of these three styles, the voluntary consensus process is the most complicated and perhaps most important—a vital component of the American system of standardization that embodies the characteristically American preference for voluntarism, local control, and private control over commercial activity.[9]

Historians, sociologists, and economists all have studied standards that were created through a consensus process. This literature demonstrates that consensus standardization is a fundamentally *political* process, one where different stakeholders seek to exercise control over the direction and shape of technological change. Our technological world, therefore, needs to be understood as a consequence of the power negotiations and social tensions inherent in the creation of technical knowledge and artifacts, and we must not forget that "consensus" is as much about exclusion as it is about inclusion.[10]

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[9] U. S. Congress, *Global Standards: Building Blocks for the Future*, 45-50. See also Samuel Krislov, *How Nations Choose Product Standards and Standards Change Nations* (Pittsburgh: University of Pittsburgh Press, 1997), 83-133; Jay Tate, "National Varieties of Standardization," in Peter A. Hall and David Soskice, eds., *Varieties of Capitalism: The Institutional Foundations of Comparative Advantage* (New York: Oxford University Press, 2001); and Andrew L. Russell, "Industrial Legislatures: The American System of Standardization," in *International Standardization as a Strategic Tool* (Geneva: International Electrotechnical Commission, 2006).

[10] Janet Abbate, *Inventing the Internet* (Cambridge: The MIT Press, 1999); Amy Slaton, Reinforced Concrete and the Modernization of American Building, 1900-1930 (Baltimore: The Johns Hopkins University Press, 2001); Stefan Timmermans and Marc Berg, *The Gold Standard: The Challenge of Evidence-Based Medicine* (Philadelphia: Temple University Press, 2003); Theodore Porter, *Trust in Numbers: The Pursuit of Objectivity in Science and Public Life* (Princeton: Princeton University Press,

My contribution to this literature is to point out that the consensus process *is itself a product of history*. Rather than treating the consensus method as some sort of timeless organizational form or ever-present alternative to markets or laws, we need to understand that consensus standardization arose under specific historical circumstances, and in response to specific technological, organizational, and political problems. It is an idea manifest in institutions. Moreover, this organizational form faced moments of crisis in which the survival of specific consensus standards committees were called into question. Some of these committees failed; others reformed themselves and survived. At all points, the system was in flux. It was dynamic, not static—and organizations that participated in the system were no less susceptible to the gale of creative destruction than were firms in competitive markets.[11]

My history starts in the late nineteenth century, when engineers and scientists created the first consensus standards bodies as a response to the inadequacies of existing institutions. The collaborative institutions and negotiated procedures in consensus standardization bodies matured during the first three decades of the twentieth century, not only as a response to the limitations of existing forms of technological cooperation but also as a political critique of these limitations. The creation of subsequent standard-setting bodies also advanced this implicit—and at times, explicit—critique: consensus

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1995); Peter Grindley, *Standards, Strategy, and Policy: Cases and Stories* (New York: Oxford University Press, 1995); Joseph Farrell and Garth Saloner, "The Economics of Telecommunications Standards," in Robert Crandall and Kenneth Flamm, eds., *Changing the Rules: Technological Change, International Competition, and Regulation in Communications* (Washington, DC: The Brookings Institution, 1989).

[11] Joseph Schumpeter, *Capitalism, Socialism and Democracy* (New York: Harper & Row, 1976 [1942]).

standardization was a technologically and politically superior means for coordinating technological change.

These critiques were particularly sharp during the 1920s, a decade in which Secretary of Commerce Herbert Hoover advocated greater cooperation within the private sector and between private and public organizations.[12] The leading forum for consensus standardization during this era was the American Engineering Standards Committee (AESC), a federation of engineering societies, trade associations, safety groups, and government departments. Members of the AESC created consensus standards within sectional committees that consisted of experts drawn from the public, private, and non-profit sectors and fell into technological categories, such as Civil Engineering and Construction, Electrical Engineering, and Ferrous Metals and Metallurgy. Paul Gough Agnew, the longtime Secretary of the AESC, described each committee as "a miniature industrial legislature organized upon a subject basis instead of upon a geographical basis."[13]

Agnew's term "industrial legislature" is a fitting title for this dissertation because it characterizes standardization as political economy—a topic at the intersections of economics, politics, and law. Agnew was experienced in all aspects of consensus standardization, worked tirelessly to promote consensus standards and the institutions that made them, and was one of the most vocal advocates of the cause. Throughout his career, Agnew argued that self-government among technical experts was superior to the

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[12] Ellis W. Hawley, "Herbert Hoover, the Commerce Secretariat, and the Vision of an 'Associative State,' 1921–1928," *Journal of American History* 61 (1974): 116–40.
[13] P. G. Agnew, "Work of the American Engineering Standards Committee," *Annals of the American Academy of Political and Social Science* 137 (May, 1928): 13-16.

adversarial, winner-takes-all style of rulemaking as practiced in the United States Congress and judicial system. For example, in an article published in the *New Republic* in 1926 he wrote:

> Experience in diverse fields has amply shown that the [cooperative] method combines many of the advantages of the common-law and the statutory-law methods… while it avoids many of the limitations and abuses that have grown up about the legislative process."[14]

We will explore these political and cultural critiques as we consider the technical and economic aspects of standardization. First, I will explain how consensus standardization originated during the Second Industrial Revolution as a reaction to the existing political economy of engineering. Second, I will build on that foundation an examination of the history of communications networks during the twentieth century from a standardization perspective. This history illustrates how successive generations of engineers and network architects adopted and adapted consensus standardization practices. What they did was and is today important. By the end of the twentieth century, these new networks—including the Internet, digital cellular telephone networks, and the World Wide Web—emerged as the core information infrastructure of the Third Industrial Revolution.

In Chapters One and Two I discuss the origins of the organizational form of consensus standardization. Chapter One contains a literature review built around three themes in the historiography of standardization: efficiency, power, and trust. In the late nineteenth century, scientists and engineers in the electrical and chemical industries

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[14] P. G. Agnew, "A Step Toward Industrial Self-Government," *The New Republic* (March 17, 1926), 95. Albert Whitney advanced a similar critique in "The Place of Standardization in Modern Life."

created the first consensus standards committees to solve technical problems that threatened the efficient development of telegraph and railroad networks. In the United States, the first consensus standardization committees brought together producers and consumers of technologies (such as steel rails) who came from different firms and industries. During this era, respected engineer/scientists such as Charles Dudley and Elihu Thomson leveraged their status in order to construct these committees as trusted and impartial forums. By considering standardization itself—instead of the internal dynamics of a particular firm or technology—as the primary category of analysis, I am able to emphasize the cooperative relations that sustained the American style of competitive managerial capitalism during the Second Industrial Revolution.

In Chapter Two I discuss the creation and growth of the American Engineering Standards Committee (AESC). The AESC was a national federation of standards setting organizations, created in 1918 through the joint effort of five professional engineering societies. During the 1920s, the AESC aligned its practice of consensus standardization with Herbert Hoover's "associative" vision, in which efficiency and cooperation between the public and private sectors were promoted as the keys to progress and prosperity. The AESC attracted significant interest from engineering societies as well as trade associations and safety groups: by 1928, individuals from over 350 organizations were participating in AESC "industrial legislatures." The AESC experienced growing pains during this period of rapid expansion. In response to demands that it work with greater speed and more flexibility, it reconstituted itself into the American Standards Association in 1929. 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 remaining four chapters I examine the processes of network architecture and standardization in the creation of new communications networks during the twentieth century. These chapters discuss four examples: AT&T's monopoly telephone network, the Internet, digital cellular telephone networks, and the World Wide Web. I do not treat these examples as isolated networks, or merely as sites to compare and contrast divergent strategies for developing new standards. Instead, I link these four examples within a longer historical narrative, one that shows how individuals adapted and changed the practice of consensus standardization in ways that suited their needs in a particular time and place. When viewed in historical succession, these examples reveal a process of "learning by doing" in which we can see refinements to and permutations of the core ideas and institutions of consensus standardization.[15] These examples also illustrate the variety of organizational forms in the "middle ground" between *de facto* and *de jure* standardization, as well as the instability and tensions that scientists and engineers confronted within consensus standard-setting bodies.

Further, each of these examples illustrates a central argument of this dissertation: that new networks were designed as critiques of their predecessor networks. These critiques are visible both in the technological design of networks as well as in the design of the institutions created to sustain the standardization process. In each chapter, I shed light on these critiques, which were always implicit but frequently explicit. These

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[15] Naomi R. Lamoreaux, Daniel M. G. Raff, and Peter Temin, eds., *Learning by Doing in Markets, Firms, and Countries* (Chicago: University of Chicago Press, 1999).

critiques reflected the ideological convictions of their network architects, who were responding to the specific challenges and opportunities of their own historical situations.

In Chapter Three, I examine standardization within the archetypical regulated monopoly, the American Telephone and Telegraph Company (AT&T). From the very beginning, American telephone networks were designed as a political critique of Western Union's telegraph network. Gardiner Hubbard, who backed Alexander Graham Bell's initial telephone patents and created the Bell Telephone Company in 1877, believed that Western Union's telegraph monopoly concentrated too much power among business elites. Telephones, in Hubbard's view, presented opportunities for middle-class Americans to gain access to the information they needed to be prosperous citizens and to make American democracy successful.[16] In the late nineteenth and early twentieth centuries, AT&T executives such as Edward J. Hall and Theodore N. Vail rejected the notion that the telephone industry should be divided between competitors. Instead, they sought to create a standardized national network over which they would exercise monopoly control—"One System, One Policy, Universal Service."[17] AT&T engineers were obsessed with standardization as they assimilated local and regional systems into a national network. Beginning in the 1920s, AT&T engineers, led by their Vice President and Chief Engineer Bancroft Gherardi, also began to participate in consensus standards

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[16] W. Bernard. Carlson, "The Telephone as Political Instrument: Gardiner Hubbard and the Political Construction of the Telephone, 1875-1880," in Michael Thad Allen and Gabrielle Hecht, eds., *Technologies of Power: Essays in Honor of Thomas Parke Hughes and Agatha Chipley Hughes* (Cambridge, MA: The MIT Press, 2001), 25-55.

[17] Theodore N. Vail, *Annual Report of the Directors of American Telephone and Telegraph Company to the Stockholders for the Year Ending December 31, 1909* (Boston: Geo. H. Ellis, Co., Printers, 1910), 18.

bodies and learned to use these bodies to attack critical problems that they could not resolve inside the Bell monopoly.

In Chapter Four I examine the development of a new global communications infrastructure that used electronic computers as communication devices. In the second half of the twentieth century, researchers in the United States and Europe designed new networks that, in stark contrast to the circuit-switched networks ruled by the national telephone monopolies, utilized electronic computers and digital packet-switched transmission. The American effort, led by Robert Kahn and Vinton Cerf, was at first funded by the Department of Defense, and eventually developed into the Internet. The European effort was coordinated by the International Organization for Standardization (ISO), a standard-setting body that consisted of representatives of national governments around the world. Although most experts assumed that the ISO network architecture would become the global standard, users found that they could adopt Internet standards more quickly and easily. The Internet's victory in this "standards war" was a function of its informal methods for creating standards. On the other hand, ISO's effort failed because its consensus-building efforts suffered from excessive bureaucracy: too much consensus, it seems, can hinder the speedy production of standards.[18]

In Chapter Five I again contrast American and European efforts to build new communications networks—in this case, digital cellular networks. In both places, fundamental changes in regulation shaped the technological and strategic choices that engineers made. With the demise of regulated monopoly control in both settings,

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[18] Roy Rada, "Consensus Versus Speed," *Communications of the ACM* 38 (1995): 21-23.

engineers and regulators were forced to create new institutions to coordinate the production of new standards and new networks. European engineers designed their network—the Global System for Mobile Communications (GSM)—to enable users to stay in touch while they "roamed" across national borders. Unlike the ISO effort to create a computer network architecture (discussed in Chapter Four), pan-European technical cooperation for digital cellular standards was a successful diplomatic initiative to establish a common European market.

In the United States, political change influenced the standardization process in a completely different manner. American regulators, having dismantled the AT&T telephone monopoly in the early 1980s, refused to mandate a digital cellular standard or network architecture. Instead, they decided that market forces were the best means for creating new digital cellular standards—an implicit critique of the conditions of regulated monopoly that had prevailed in the American telecommunications industry since the early twentieth century. This regulatory restraint, combined with the divestiture of AT&T, created a temporary leadership vacuum in the nascent cellular industry that was soon filled by a number of trade associations and technical bodies. The resulting delay allowed the European GSM standard to become the global leader over the short term. However, by refusing to lock all American firms into the development of a single standard, the American decision provided venues for continued radical innovation, a process which seems likely to generate greater technological and economic benefits—as well as a new generation of legal problems—over the long term.

In Chapter Six I examine the creation and growth of a new institutional form to coordinate consensus standardization—industry consortia—during the 1980s and 1990s. Because they limited participation and focused narrowly on specific technologies, consortia provided opportunities for firms to create standards much more quickly than could traditional consensus bodies—an important feature for fast-moving markets for information and communication technologies. These advantages, however, were accompanied by claims that standards violated existing patents or so-called "submarine patents" disclosed late in the standardization process or after the process was completed.

The history of one such consortium, the World Wide Web Consortium (W3C), illustrates some of these problems. In 1994, Tim Berners-Lee, the inventor of the World Wide Web, created the W3C in order to maintain his authority in the rapidly expanding Web community and prevent the balkanization of new Web standards. The Web grew successfully during the 1990s because Berners-Lee built the Web based on non-proprietary and freely available standards, but in 2001 the W3C proposed to change this tradition and allow patents into Web standards. Open source Web developers protested furiously. They threatened to look for new venues to develop their own non-proprietary Web standards. Faced with this renewed danger of balkanization, the W3C responded by forging a patent policy consistent with its founding values and the patent-free convictions of open source programmers. The W3C was able to maintain its legitimacy during this crisis, but its leading position in the market for Web standards remained under constant attack from competing standards organizations—each operating with its own definition of "consensus" and most willing to accept patents in its standards.

Seen as part of a common history, these examples illustrate a striking trend in the political economy of technological systems. In the Second Industrial Revolution, systems such as electrical power networks and telephone networks were developed within individual firms, led by entrepreneurial "system-builders" such as Thomas Edison and Theodore Vail.[19] By the late twentieth century, the combined effects of technological and regulatory change presented fundamental challenges to this centralized style of system architecture. The design of computer systems that utilized electronic components occurred within an increasingly decentralized and highly competitive industry structure. The firms that had once exercised complete control over system architecture—AT&T and IBM—were hindered by antitrust and agency regulations that strove to facilitate competitive entry. They now missed opportunities to pursue radical innovations. The locus of control over compatibility standards changed from the domain of the dominant single firm to the domain of industry standards bodies, thus facilitating the emergence of a new style of global "alliance capitalism."[20]

This change—from systems innovation to modular innovation—not only occurred within a broader trend of social and economic globalization. It was, in fact, one of the

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[19] Thomas P. Hughes, *Networks of Power: Electrification in Western Society, 1880-1930* (Baltimore: The Johns Hopkins University Press, 1983).

[20] Thomas McCraw, ed., *Creating Modern Capitalism: How Entrepreneurs, Companies, and Countries Triumphed in Three Industrial Revolutions* (Cambridge: Harvard University Press, 1995); and Alfred D. Chandler, Jr., "The Information Age in Historical Perspective: Introduction," in Alfred D. Chandler, Jr. and James W. Cortada, eds., *A Nation Transformed By Information: How Information Has Shaped the United States from Colonial Times to the Present* (New York: Oxford University Press, 2000), 3-38; and Louis Galambos and Eric John Abrahamson, *Anytime, Anywhere: Entrepreneurship and the Creation of a Wireless World* (New York: Cambridge University Press, 2002).

drivers of globalization, and it created the information infrastructure upon which a newly globalized economy and society—the "Network Society"—could grow.[21]

The networks described in this dissertation were thus turning points in the century-long growth of an organizational form that was responsible for fundamental changes in the history of the twentieth century. The networks were simultaneously extensions and critiques of the Industrial Age. Viewed together, they tell the story of how consensus-based institutions became the dominant form for setting standards in the Third Industrial Revolution. They reveal the growth of a political economy within a political economy, designed to accomplish what existing forms of governance and engineering could not. These network architectures—and the institutions created to sustain them—were political statements, critiques of the existing order, and innovations that articulated a different vision of the future and new means of getting there.

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[21] Richard N. Langlois, "Modularity in Technology and Organization," *Journal of Economic Behavior and Organization* 49 (2002): 19-37; Manuel Castells, *The Rise of the Network Society* (Cambridge: Blackwell Publishers, 1996); Akira Iriye, *Global Community: The Role of International Organizations in the Making of the Contemporary World* (Berkeley: University of California Press, 2002); Louis Galambos, "Recasting the Organizational Synthesis: Structure and Process in the Twentieth and Twenty-First Centuries," *Business History Review* 79 (2005): 1-37; and Louis Galambos, "Globalization, Competition, and *The Information Age* of Manuel Castells," unpublished manuscript, courtesy of the author.

Chapter 1: Trust in Institutions: Engineering Standards for the Second Industrial Revolution, 1880-1910

1.1 Introduction

The search for order. The control revolution. The managerial revolution in American business. The rise of corporate capitalism. The emergence of modern America. Students of American history recognize each of these summary descriptions from the canonical histories that document the interrelated and far-reaching changes in the sciences, technology, industry, and society that occurred between roughly 1880 and 1930. These concepts all describe how of a new class of professionals, inspired by the power and methods of science, developed a new social and technological order that enhanced their abilities to control nature, machines, markets, and other men and women.[1]

My own preferred term for this era in American history is "the second industrial revolution." Historians define the second industrial revolution as sparked by major advances in technical knowledge—especially knowledge of electricity and chemistry—and driven by corporations that developed managerial hierarchies to exploit knowledge within a market economy. These developments occurred in the United States, Britain, Germany, and France between the 1880s and 1930s, and were characterized by advances in communication and transportation technologies, the widespread adoption of the internal combustion engine and electrical power, and the emergence of large corporations

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[1] Robert H. Wiebe, *The Search for Order, 1877-1920* (New York: Hill and Wang, 1967); James R. Beniger, *The Control Revolution: Technological and Economic Origins of the Information Society* (Cambridge: Harvard University Press, 1986); Alfred D. Chandler, Jr., *The Visible Hand: The Managerial Revolution in American Business* (Cambridge: Belknap Press, 1977); David F. Noble, *America by Design: Science, Technology, and the Rise of Corporate Capitalism* (New York: Knopf, 1977).

that integrated the functions of scientific research, technical production, and mass marketing. The concept of the "second industrial revolution" is useful because it indicates that social and technological innovations were integrated within a longer and broader trajectory, with the implicit recognition of the cumulative, contested, and punctuated character of these changes.[2]

Standardization was a fundamental aspect of American economic growth during the second industrial revolution. The distinction between a standard and standardization is important. The term "standard" typically refers to a product—a specification for the composition, interfaces, or characteristics of a given material, such as the quality of a steel rail, the size and angle of a screw thread, or a common measure of electrical resistance. "Standardization," on the other hand, describes a process—a more comprehensive range of practices and ideas. In broad terms, standardization was part of a broader discourse of rational planning and attempts to exert systematic control over the complexities of the modern industrial world. Standardization was one manifestation of an ideology that was influential among the expanding ranks of professional engineers and corporate managers, and an element of a broader strategy to apply knowledge toward practical ends and commercial gain. Standards, therefore, were by-products of broader social and technological transformations. Standards and standardization were vital elements in the broader rationalization and systematization of American technology,

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[2] See Thomas K. McCraw, ed., *Creating Modern Capitalism: How Entrepreneurs, Companies, and Countries Triumphed in Three Industrial Revolutions* (Cambridge: Harvard University Press, 1997); and Louis Galambos, "Recasting the Organizational Synthesis: Structure and Process in the Twentieth and Twenty-First Centuries," *Business History Review* 79 (2005): 1-37.

business, and society—trends that concerned leading social critics of the era, including Joseph Schumpeter, Thorsten Veblen, and Max Weber.

Historical examinations of the second industrial revolution tend to focus either on a particular person, company, or technology. We are fortunate to have a large literature on industrial development that occurred *inside* second industrial revolution firms; but we know comparatively little about how technical knowledge functioned in relationships *between* firms and the ways that this knowledge became embedded in artifacts, specifications, and industry standards. This overarching historiographical trend—and the few exceptions to it—suggests the need to look more deeply into the production and use of technical knowledge across the boundaries of second industrial revolution firms and technologies.[3] If we consider standardization itself—instead of the internal dynamics of a particular firm or technology—as the primary category of analysis, a richer picture of the second industrial revolution emerges, one that highlights the cooperative relations that sustained the American style of competitive managerial capitalism.

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[3] On science and technology within second industrial revolution firms, see Leonard S. Reich, *The Making of Industrial Research: Science and Business at GE and Bell, 1876-1926* (New York: Cambridge University Press, 1985); Margaret B. W. Graham and Bettye H. Pruitt, *R & D for Industry: A Century of Technical Innovation at Alcoa* (New York: Cambridge University Press, 1990); David A. Hounshell and John Kenly Smith, Jr., *Science and Corporate Strategy: Du Pont R&D, 1902-1980* (New York: Cambridge University Press, 1988); and David A. Hounshell, "The Evolution of Industrial Research in the United States," in Richard S. Rosenbloom and William J. Spencer, eds., *Engines of Innovation: U.S. Industrial Research at the End of an Era* (Boston: Harvard Business School Press, 1995), 13-86. The clearest exceptions to this historiographical trend include the studies conducted by a team of scholars under the auspices of the National Bureau of Economic Research, including Naomi R. Lamoreaux and Daniel M. G. Raff, eds., *Coordination and Information: Historical Perspectives on the Organization of Enterprise* (Chicago: University of Chicago Press, 1995); Naomi R. Lamoreaux, Daniel M. G. Raff, and Peter Temin, eds., *Learning by Doing in Markets, Firms, and Countries* (Chicago: University of Chicago Press, 1999); and Naomi R. Lamoreaux, Daniel M. G. Raff, and Peter Temin, "Beyond Markets and Hierarchies: Toward a New Synthesis of American Business History," *American Historical Review* 108 (2003): 404-433.

Existing historical studies of industrial standardization concentrate on interchangeable parts manufacturing within private industry and, to a lesser degree, within government agencies such as the National Bureau of Standards and the Bureau of Public Roads.[4] Important developments in industrial standardization also occurred in a number of institutions, such as professional engineering societies and trade associations, that have attracted significantly less scrutiny. The few existing studies of these engineering societies treat standardization as one of many developments in a broader trend toward professionalization.[5] As a result of their preoccupation with the internal dynamics of firms and government agencies, historians have not been looking in the right places to fully appreciate the character and importance of inter-firm, industry-wide, and national standardization.

The most revealing sites for examining the initial growth of industry-wide standardization in the second industrial revolution are in the communities of engineers that began to take shape in the middle and latter decades of the nineteenth century. Standards committees—venues where industry participants negotiated common technical specifications—quickly emerged as an important function of these societies. These committees provided engineers with the opportunity to forge technical solutions within a

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[4] David Hounshell, *From the American System to Mass Production, 1800-1932* (Baltimore: The Johns Hopkins University Press, 1984); Chandler, *The Visible Hand*; Rexmond C. Cochrane, *Measures for Progress: A History of the National Bureau of Standards* (Washington, D.C.: U. S. Department of Commerce, 1966); Bruce E. Seely, "Engineers and Government-Business Cooperation: Highway Standards and the Bureau of Public Roads, 1900-1940," *Business History Review* 58 (1984): 51-77.

[5] A. Michal McMahon, *The Making of a Profession: A Century of Electrical Engineering in America* (New York: Institute of Electrical and Electronics Engineers, 1984); Bruce Sinclair, *A Centennial History of the American Society of Mechanical Engineers, 1880-1980* (Toronto: University of Toronto Press, 1980); Louis Galambos, *Cooperation and Competition: The Emergence of a National Trade Association* (Baltimore: The Johns Hopkins Press, 1966).

network of like-minded practitioners from a wide variety of institutions, including private firms, universities, and government agencies. Standards committees functioned as venues for disseminating "state of the art" technical information and as fora that could generate an industry-wide consensus over technical matters through negotiations between all interested firms and organizations.

One of the important insights that emerges from looking at standardization across corporate boundaries is that the successes of the second industrial revolution were not exclusively the accomplishments of entrepreneurs and managers working within large, vertically integrated firms. We must also consider the contributions of engineers whose loyalties were not exclusive to individual companies, but who also worked in the interests of the engineering professions and were driven by a shared desire to build and improve new technologies, even if these technologies could not be controlled by a single firm. These standardization efforts were vital not only for the second industrial revolution; they also laid some of the organizational groundwork for important developments in the twentieth century, including the extension of bureaucratic power, the rise of the administrative state, and, by the end of the century, a third industrial revolution.

1.2 Creating Industrial Standards: Efficiency, Power, and Trust

Standards permit a consistent approach to routine tasks that are technically complex or require a high degree of precision. When adopted broadly, standards facilitate the transfer of scientific and engineering knowledge from one person or location to another—from the local to the universal. Many economic considerations of standardization situate standards within a transaction-cost interpretation, in which standards serve the goals of efficiency by lowering costs and reducing complexity.[6] Efficiency goals also are prominent in many historical interpretations of the growth of corporate capitalism, where various forms of standardization were important strategies for managing complexity in technical, labor, and administrative functions.[7] For some historians, professional engineers were united by the single-minded pursuit of efficiency: as Bruce Seely argued, "engineers, regardless of their institutional affiliation, pursued a common goal."[8] Although this claim is helpful as a broad generalization, we can discover a great deal of variety in the meaning and purposes of "efficiency" by examining how social, cultural, and institutional factors shaped the practice and ideology of efficiency in particular settings. In other words, a drive toward efficiency does not fully explain the creation of standards in technologies and industries that lacked a single overarching authority.

Two concepts—*power* and *trust*—are essential for establishing a richer historical understanding of the standardization process. Although standardization frequently was justified in the rhetoric of efficiency and consensus, it was not simply a rational or frictionless endeavor. Many familiar episodes in the history of technology, such as the "battle of the systems" between Thomas Edison's direct current and George

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6 See for example Charles P. Kindleberger, "Standards as Public, Collective and Private Goods," *Kyklos* 36 (1983): 377-396; Paul A. David and Shane Greenstein, "The Economics of Compatibility Standards: An Introduction to Recent Research," *Economics of Innovation and New Technology* 1 (1990): 3-41; and Cristiano Antonelli, "Localized Technological Change and the Evolution of Standards as Economic Institutions," *Information Economics and Policy* 6 (1994): 195-216.

7 See Robert Kanigel, *The One Best Way: Frederick Winslow Taylor and the Enigma of Efficiency* (New York: Viking, 1997); Chandler, *The Visible Hand*; and Beniger, *The Control Revolution*.

8 Seely, "Engineers and Government-Business Cooperation," 52.

Westinghouse's alternating current, illustrate how the standardization process often functioned as an arena for conflict between powerful interests.[9] Such standards wars occurred with more regularity in the latter half of the twentieth century, which prompted economists and management scholars to generate an extensive body of literature describing the strategic importance of "winning" the standard-setting process—even if the cost of victory leads to the establishment or "lock-in" of a less efficient standard.[10] In other cases, market power led to *de facto* standardization. Hence, not only did standardization function as a route to achieving a powerful market position; industry leaders, in turn, could chart the future technological course of their industry by using that market power to set new standards. Firms such as AT&T, Alcoa, and DuPont provide good examples of *de facto* standardization achieved through market power.

A third concept—*trust*—adds further contextual richness to the social and cultural dimensions of standardization. Because it is a fundamentally social activity, standardization cannot occur without at least a minimum level of trust, even between rivals. Historians and sociologists of science and technology have developed an extensive literature that examines the dynamics of trust across a range of collaborative activities. One strand of this literature examines the activities of natural philosophers and scientists—such as Robert Boyle, Pierre Laplace, and Lord Rayleigh—whose elite status

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[9] Tom McNichol, *AC/DC: The Savage Tale of the First Standards War* (San Francisco: Jossey-Bass, 2006), 77-142; and James Surowiecki, "Standard-Bearers," *The New Yorker* (October 16, 2006).
[10] See for example Carl Shaprio and Hal Varian, *Information Rules: A Strategic Guide to the Networked Economy* (Boston: Harvard Business School Press, 1998), especially Chapter 9, "Waging a Standards War," 261-296. Economists debate whether it is theoretically or empirically demonstrable that "inferior" technologies can or have won market acceptance. The opening salvo was Paul David, "Clio and the Economics of QWERTY," *American Economic Review* 75 (1985): 332-337; an important response was S. J. Liebowitz and Stephen Margolis, "The Fable of the Keys," *Journal of Law and Economics* 33 (1990): 1-33.

established them as leading figures of their respective social networks. Aided by a fortunate mix of wealth, social standing, and technical ability, these men pioneered experimental methods and instruments that became authoritative points of reference for their peers. Their preeminence in technical and experimental realms was based on their privileged positions in the moral economies of their respective local settings.[11]

The production of accurate and objective standards in second industrial revolution technological practice—including electricity, chemicals, and materials testing—was contingent upon social and cultural perceptions of morality and trust. In his insightful study of electrical practice in Victorian Britain, Graeme Gooday demonstrates how moral judgments of "fairness, fidelity, and honesty" were key indicators of the trustworthiness of the instruments and measurements of a given physicist, chemist, electrician, or engineer.[12] Trust—in instruments, institutional practices, theories, and individuals—was the key factor in spread of tools and techniques for electrical measurement. An example from a leading American chemist supports Gooday's observation of the importance of morality and trust for Victorian electrical practice. In 1893, Charles Benjamin Dudley, the founder of the first industrial laboratory in the United States (at the Pennsylvania Railroad), emphasized that hard work, skill, and a "sincere disposition" were necessary

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[11] Steven Shapin, *A Social History of Truth: Civility and Science in Seventeenth-Century England* (Chicago: University of Chicago Press, 1995); Robert Fox, "The Laplacian School," in Charles Coulston Gillispie with the collaboration of Robert Fox and Ivor Grattan-Guinness, *Pierre-Simon Laplace, 1749-1827: A Life in Exact Science* (Princeton: Princeton University Press, 1997), 209-215; and Simon Schaffer, "Rayleigh and the Establishment of Electrical Standards," *European Journal of Physics* 15 (1994): 277-285. See also Martin J. S. Rudwick, *The Great Devonian Controversy: The Shaping of Scientific Knowledge Among Gentlemanly Specialists* (Chicago: University of Chicago Press, 1985).

[12] Graeme J. N. Gooday, *The Morals of Measurement: Accuracy, Irony, and Trust in Late Victorian Electrical Practice* (New York: Cambridge University Press, 2004), xv.

for determining standards for accurate chemical analyses of steel and iron.[13] In her study of materials testing in the early twentieth century, Amy Slaton found a similar emphasis on morality and trust: "experts instantiated the notion that it was *the tester, not the test*, that assured quality production."[14]

A second strand of the historical and sociological literature emphasizes the processes by which instruments, organisms, and methods functioned as standards in the production of scientific knowledge. Classic examples include Galileo's use of telescopes and Lavoisier's use of balances and calorimeters as part of their scientific and social authority claims.[15] In the twentieth century, scientists came to rely upon standardized "model organisms," such as T.H. Morgan's *drosophila* and Ivan Pavlov's dogs, as instruments for abstracting objective facts in disciplines such as genetics and physiology.[16]

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[13] C. B. Dudley and F. N. Pease, "The Need of Standard Methods for the Analysis of Iron and Steel, with Some Proposed Standard Methods," *Journal of the American Chemical Society* 15 (1893): 510.
[14] Amy E. Slaton, *Reinforced Concrete and the Modernization of American Building, 1900-1930* (Baltimore: The Johns Hopkins University Press, 2001), 8. See also Amy Slaton and Janet Abbate, "The Hidden Lives of Standards: Technical Prescriptions and the Transformation of Work in America," in Michael Thad Allen and Gabrielle Hecht, eds., *Technologies of Power: Essays in Honor of Thomas Parke Hughes and Agatha Chipley Hughes* (Cambridge, MA: The MIT Press, 2001), 95-143.
[15] Albert van Helden, "Telescopes and Authority from Galileo to Cassini," *Osiris* 9, 2nd Series (1994): 9-29; and Jan Golinski, "'The Nicety of Experiment': Precision of Measurement and Precision of Reasoning in Late Eighteenth-Century Chemistry," in M. Norton Wise, ed., *The Values of Precision* (Princeton: Princeton University Press, 1995), 72-91. See also Peter Galison, *Image and Logic: A Material Culture of Microphysics* (Chicago: University of Chicago Press, 1997).
[16] Robert E. Kohler, *Lords of the Fly: Drosophila Genetics and the Experimental Life* (Chicago: University of Chicago Press, 1994); Daniel P. Todes, "Pavlov's Physiology Factory, 1891-1904," *Isis* 88 (1997): 205-46. See also Gerald Geison and Manfred Laubichler, "The Varied Lives of Organisms: Variation in the Historiography of the Biological Sciences," *Studies in the History and Philosophy of the Biological and Biomedical Sciences* 32 (2001): 1-29; and Karen Rader, *Making Mice: Standardizing Animals for American Biomedical Research, 1900-1955* (Princeton: Princeton University Press, 2004).

During this period, quantitative methods became an essential component of authority claims in scientific, mathematical, economic, and political realms. In his book *Trust in Numbers*, Theodore Porter demonstrates how quantification—including numbers, graphs, and formulas—functioned as communicative strategies that facilitated the abstraction of knowledge from its localized and particular origins to more general and universal status. Porter's description of quantification in accounting, actuarial practice, and engineering—much like Amy Slaton's history of building materials and construction—reveals how elites used standardized and mathematical techniques to construct themselves as objective experts who were worthy of power and control. Rather than a Machiavellian grab for power, claims of objective expertise came to be essential aspects of moral claims to fairness in democratic societies.[17]

As a complement to this extensive literature on trust in individuals, instruments, and quantification, historians have (to a lesser extent) paid attention to the institutionalization of trust in organizations and networks that sustained the creation and distribution of valid technical knowledge. Trusted scientific institutions have a rich history that reaches back to the seventeenth-century gatherings of elite natural philosophers and savants in the Royal Society of London and the Paris Academy of Sciences. These types of collaborative institutions became increasingly common during the nineteenth and early twentieth centuries, and slowly established themselves as legitimate and impartial arbiters of technical knowledge.

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[17] Theodore Porter, *Trust in Numbers: the Pursuit of Objectivity in Science and Public Life* (Princeton: Princeton University Press, 1995); Slaton, *Reinforced Concrete and the Modernization of American Building*.

Just as non-commercial institutions (like the Royal Society and Paris Academy) became trusted sites of collaborative scientific activity, so too did institutions such as engineering societies and trade associations become trusted sites for technological and commercial activity. A hypothetical example illustrates this point. In the early 1800s, a firm in the market to buy steel or concrete would have relied on local contractors to find reliable materials either by virtue of their reputation or through a process of *ad hoc* trial and error. After 1900, the forces of mechanization and modernization made it highly unlikely that a buyer in a similar situation still would rely primarily on personal contacts or local networks to guide their purchasing decisions. Instead, buyers could choose from a variety of producers whose steel or concrete passed a series of laboratory tests performed by university-trained experts, to ensure uniformity through compliance with industry standards created within an impartial body such as the American Society for Testing Materials or the Association of American Portland Cement Manufacturers.[18] In short, technical standards—and standard-setting organizations—were part and parcel of a broader shift from traditional to impersonal social relationships.[19]

Rather than taking the existence of such intermediary organizations as a given, we need to examine more closely the processes by which trust became institutionalized in organizations and codified in technical standards. How were institutions and standards constructed as "impartial"? The utility of a standard is in its perceived objectivity; this

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[18] Slaton, *Reinforced Concrete and the Modernization of American Building,* 64-66; Thomas J. Misa, "Controversy and Closure in Technological Change: Constructing 'Steel,'" in Wiebe E. Bijker and John Law, eds., *Shaping Technology/Building Society: Studies in Sociotechnical Change* (Cambridge: The MIT Press, 1992), 109-139.
[19] Beniger, "The Control Revolution," 121-168.

objectivity must be constructed, and this construction should be understood as a historical process, set in a particular technological and social context. Trust in these institutions enhanced, rather than replaced, the trust in instruments and men of elite status that were vital elements of the social production of technical knowledge. Ironically, elite mechanics, electricians, and chemists were the prime movers behind this institutionalization of trust. In a number of industries, technical and social elites lent their reputations and leveraged their stature in order to help establish new institutions as legitimate, impartial, and trusted forums for industry standardization, thus embedding their social and moral standing into rules and norms that governed these new institutions. Standardization projects that were pursued within a range of institutional settings thus provide revealing sites for examining the historical tension between efficiency, power, and trust in the second industrial revolution.

1.3 Industrial, Commercial, and Scientific Standardization in the Nineteenth Century

In the nineteenth century, standardization occurred within a variety of institutional settings, including federal armories, private factories, scientific associations, and government laboratories. In each setting, bureaucrats, entrepreneurs, scientists, and engineers acted on the belief that collective action—mediated through relations of power and trust—would be an essential step for rationalizing and improving the quality and quantity of mechanical production.

The first instances of interchangeable parts manufacturing occurred in France as part of the military reforms led by Jean-Baptiste Vaquette de Gribeauval and Honoré

Blanc in the late eighteenth century. By utilizing interchangeable parts in guns, Gribeauval and Blanc pursued complementary technical and political objectives: a more efficient means of making and repairing guns, and a new method of production that would obsolete the "ancien régime of the manufactures."[20] In his account of these events, Ken Alder emphasized that the new techniques—and the artifacts they produced—were not a manifestation of some sort of "inexorable logic" of efficiency-seeking technological development, but, instead, material consequences of an exercise of bureaucratic state power. In his subsequent work, Alder demonstrated how similar political and bureaucratic impulses motivated the expeditions that generated a global standard for measurement, the metric system.[21]

Americans began to experiment with interchangeable parts manufacturing after Thomas Jefferson, the American minister to France, witnessed Blanc's demonstration of his new guns and urged Congress to introduce similar methods in American armories. The new techniques were first introduced in federal armories at Springfield and Harper's Ferry between 1815 and 1845. Managers at these armories developed equipment to manufacture interchangeable parts for muskets, as well as procedures to inspect and test the parts to ensure uniformity. Led by private contractors such as Simeon North and Eli Whitney, the use of standard interchangeable parts in arms manufacturing began as part

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[20] Ken Alder, "Innovation and Amnesia: Engineering Rationality and the Fate of Interchangeable Parts Manufacturing in France," *Technology and Culture* 38 (1997): 273.
[21] Charles C. Gillispie and Ken Alder, "Engineering the Revolution," *Technology and Culture* 39 (1998): 733-754; and Ken Alder, *The Measure of All Things: The Seven-Year Odyssey and Hidden Error That Transformed the World* (New York: The Free Press, 2002).

of the conditions of military procurement contracts, and spread as entrepreneurs such as Colonel Samuel Colt used these techniques to bring new products to market.[22]

This "American System of Manufactures"—as it was termed by admiring British observers in the middle decades of the nineteenth century—spread to other industries as armory mechanics moved to new jobs. The pivotal means for the spread of the new techniques was the machine tool industry itself. Throughout the second half of the nineteenth century, makers of machine tools dealt with similar problems—namely, the use of specialized machinery to create standardized products—across a number of industries. As mechanics built skill into precision machinery in new firms and industries, an increasing number of American factories adopted standard methods, precision measurements, and standardized parts.[23]

This period in American history is rich with examples of firms that introduced the new manufacturing techniques to a succession of new products. For example, the Pratt and Whitney Company introduced machinery to create interchangeable parts for manufacturing firearms, and then moved on to pioneer machinery for sewing machines, bicycles, and automobiles. Another significant example is Henry Leland, a mechanic who worked at the Springfield Armory before he went on to manufacture machine tools and sewing machines, and eventually created the Cadillac Automobile Company. In each of these cases, efficiencies and cost savings did not flow in a rational and seamless

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[22] Merritt Roe Smith, *Harpers Ferry Armory and the New Technology: The Challenge of Change* (Ithaca: Cornell University Press, 1977).
[23] Nathan Rosenberg, "Technological Change in the Machine Tool Industry, 1840-1910," *The Journal of Economic History* 23 (1963): 414-443; L. T. C. Rolt, *A Short History of Machine Tools* (Cambridge: The MIT Press, 1965), 137-177.

manner simply from the introduction of mechanized production and interchangeable parts. And, as scholars such as Jack Brown and Philip Scranton have shown, many firms did not abandon custom and batch production in industries where mass production and standardized products would not meet the needs of their customers.[24]

Historians frequently trace the roots of the "American System" to the experiences of federal armories, but the adoption of interchangeable parts in American manufacturing may also be seen in a separate group of entrepreneurs who were producing wooden movement clocks (as early as the 1820s), watches, and typewriters. Thus, not only did the power of the state—manifest in military objectives and government investment—drive the development of standards in American industrial production; so too did private capital and the impulses of profit-seeking entrepreneurs who created products for consumers in the private sector.[25]

As early as the 1820s, Americans began to create cooperative institutions to apply scientific knowledge to shared technical and industrial problems. The first successful efforts to establish technical standards through such institutions occurred within Philadelphia's Franklin Institute for the Promotion of the Mechanic Arts. The membership of the Franklin Institute was dominated by Philadelphia-area mechanics, who, despite their rhetoric of democracy and professed opposition to class distinctions, consisted more of social and commercial elites than rank-and-file workers or artisans.

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[24] Hounshell, *From the American System to Mass Production*; John K. Brown, *The Baldwin Locomotive Works, 1831-1915: A Study in American Industrial Practice* (Baltimore: The Johns Hopkins University Press, 1995); Philip Scranton, *Endless Novelty: Specialty Production and American Industrialization, 1865-1925* (Princeton: Princeton University Press, 1997).

[25] Donald R. Hoke, *Ingenious Yankees: The Rise of the American System of Manufactures in the Private Sector* (New York: Columbia University Press, 1990).

The Franklin Institute pursued several strategies to raise its own profile (and the status of the mechanic arts) through popular lectures, exhibits, the establishment of a *Journal*, and the provision of technical advice to the State of Pennsylvania, the U. S. Patent Office, and U. S. Congress. As a result, the Franklin Institute became the leading technical society in the United States by the 1840s.[26]

The stated aim of the Franklin Institute was to "promote the useful arts by diffusing a knowledge of mechanical science."[27] One early and prominent manifestation of this application of scientific knowledge to practical affairs occurred through the Institute's investigation of steam boiler explosions between 1830 and 1837. Steamboats had proven to be a vital means for transportation and commerce in the expanding nation, but the explosion of steam boilers was a chronic problem that had cost over 300 lives (by 1830), destroyed dozens of boats, and threatened to undermine public confidence in steamboat travel. In 1830, leaders of the Franklin Institute decided that they, as a group of public-minded technical experts, were ideally positioned to examine the causes of these accidents and publish a way to prevent or diminish their severity. Supported with funds from the U. S. Treasury Department, mechanics from the Franklin Institute performed a number of tests on machines and materials used in boilers.

Although the Institute's *General Report on the Explosion of Steam Boilers* provided clear advice for enhancing safety, their recommendations were not immediately enacted. Steamboat operators, despite more explosions and continued loss of life, did not

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[26] Bruce Sinclair, *Philadelphia's Philosopher Mechanics: A History of the Franklin Institute, 1824-1865* (Baltimore: Johns Hopkins University Press, 1974).
[27] Sinclair, *Philadelphia's Philosopher Mechanics*, 32.

seem interested in complying voluntarily with stricter (and more costly) safety measures; and Congress, as historian Bruce Sinclair observed, "had yet to accept the principle that public safety demanded constraints on private industry." It took until 1852 for Congress to reverse course and pass legislation that backed the recommendations of the *General Report* with the force of law.[28]

The establishment of standards for screw threads was a second project where the Franklin Institute mobilized its technical expertise and social connections to influence an area of fundamental importance for mechanical practice. Unlike English mechanics, who had adopted Sir Joseph Whitworth's 1841 proposal for a standard system of screw threads, American mechanics were using a vast array of threads that varied according to locality and the customary practice of respective firms. In 1864, William Sellers, Philadelphia's leading machinist and president of the Franklin Institute, presented a paper to the Franklin Institute that proposed a new system for uniform American screw threads. Sellers promoted his own system (and rejected the Whitworth system) by arguing that it would make screws easier and cheaper to produce and use. Such practical features would

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[28] Sinclair, *Philadelphia's Philosopher Mechanics*, 170-191. See also Bruce Sinclair, *Early Research at the Franklin Institute; The Investigation Into the Causes of Steam Boiler Explosions, 1830-1837* (Philadelphia: Franklin Institute, 1966). Boiler standards and safety codes continued to be a source of controversy well into the twentieth century: for many years, the boiler code committee was the most important of the technical committees hosted by the American Society for Mechanical Engineers (ASME), and the process for creating and enforcing boiler codes was at the heart of a high-profile lawsuit against the ASME in the 1980s. See Sinclair, *A Centennial History of the ASME*, 213-221; and Samuel Krislov, *How Nations Choose Product Standards and Standards Change Nations* (Pittsburgh: University of Pittsburgh Press, 1997), 129-132.

enable American machinists to utilize a greater number of less skilled workmen in their workshops, thus enhancing interchangeability and increasing output at the same time.[29]

Sellers saw the Franklin Institute, dominated as it was by a network of mechanics from Philadelphia's leading firms, as the best vehicle for promoting the widespread acceptance of his system. By 1868, Sellers convinced the secretary of the Navy to declare his system—also known as the Franklin Institute system—as the Navy standard. In his account of these events, Sinclair argued persuasively that the Franklin Institute's technical prestige, combined with the power of the Institute's members and its allies in the Navy and powerful institutions in the railroad industry, were keys to establishing the Sellers system in American mechanical practice. Sinclair, reflecting on the sources of this success, concluded that the Franklin Institute "gave Sellers an institutional framework for his system, providing a platform, a mechanism for its advancement, and an aura of objectivity."[30] Relations of trust institutionalized within the Franklin Institute were key to the success of the Sellers system. Unlike the earlier example of the Franklin Institute's recommendations for steam boiler safety, the Sellers system did not need the power of federal legislation to be adopted in private industry. Instead, to the extent that machinists reaped efficiency gains—in the shape of interchangeability of parts and simplification of machinery—from the Sellers system, these efficiencies should be seen as the consequences of a sustained effort to mobilize the status and power of men in the Franklin Institute to effect changes in industrial practice.

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[29] Bruce Sinclair, "At the Turn of a Screw: William Sellers, the Franklin Institute, and a Standard American Thread," *Technology & Culture* 10 (1969): 20-34.
[30] Sinclair, "At the Turn of a Screw," 34.

As with the recommendations from their investigations of steam boiler explosions, the Franklin Institute's promotion of standard screw threads was not the final word on this important and controversial topic. Throughout the nineteenth and twentieth centuries, numerous organizations, conferences, and prestigious scientists (including the Johns Hopkins physicist Henry Rowland) continued to address the need for accuracy and standardization of screw threads. The catastrophic 1904 fire that destroyed downtown Baltimore—in part because fire departments from neighboring cities were forced to stand by helplessly when their hoses did not fit the Baltimore water hydrants—demonstrated the consequences of the persistent lack of interoperability among threaded devices.[31] Even today, one needs only to walk the aisles of any hardware store to recognize that screws, nuts, and bolts are nowhere near a universal level of standardization.

As their commercial ambitions outgrew their traditional local communities and markets, Americans developed new institutions to serve as trusted intermediaries that could sustain commercial activity on a regional and national scale. One of the earliest applications of this "spirit of voluntarism" may be seen in the United States Pharmacopeial Convention, founded in 1820 by delegates from eleven state societies of medicine. The delegates produced the U. S. Pharmacopeia, a compendium of *materia medica* organized according to a standard nomenclature that intended to bring uniformity

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[31] Henry A. Rowland, "Screw," *Encyclopedia Britannica* Ninth Edition, Volume XXI (1900), 506-511; *Report of the National Screw Thread Commission* (Washington, D.C.: U. S. Government Printing Office, 1933 [4th edition]). On the 1904 Baltimore fire, see Cochrane, *Measures for Progress*, 84-86.

to medical and pharmacy practice throughout the young nation.[32] Similar associational efforts to create quality standards—an essential step in the development of a national economy—occurred through the evaluation of wheat in the Chicago Board of Trade in the 1850s and the establishment of standards in beer production by the United States Brewers Foundation beginning in the 1860s.[33] In these and other industries, producers acted on the growing recognition that institutions and standards could generate the confidence needed for consumers to trust unknown merchants and manufacturers. These types of associations seemed to confirm Alexis de Tocqueville's observation that Americans, more than any other people, were constantly forming voluntary and private associations to accomplish a wide variety of social, commercial, and political objectives.

Voluntary associations, important to sustain the creation of new commercial networks at a national level, were equally important for sustaining scientific, commercial, and technological networks on an international level. One important example, the establishment of standards for electrical technologies, grew out of the intersections of scientific investigations, commercial ambitions, and imperial desires. Beginning in the early 1860s, elite physicists, electrical scientists, and telegraph engineers met under the auspices of the British Association for the Advancement of Science to establish precise and consistent units of resistance. Founded in 1831, the British Association was a multilateral institution designed to create space for learned discussion among "gentlemen

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[32] Lee Anderson and Gregory J. Higby, *The Spirit of Voluntarism: A Legacy of Commitment and Contribution: The United States Pharmacopeia 1820-1995* (Rockville, MD: United States Pharmacopeial Convention, 1995), 1-41.

[33] William Cronon, *Nature's Metropolis: Chicago and the Great West* (New York: W. W. Norton, 1991), 104-142; Morris Weeks, Jr., *Beer and Brewing in America* (New York: United States Brewers Foundation, 1949).

of science." British Association meetings attracted leading scientists from Britain and beyond, and, according to historians Jack Morrell and Arnold Thackray, "quickly assumed a central role in early Victorian culture."[34] The British Association soon became a forum for groundbreaking announcements and controversial discussions, vividly demonstrated at Oxford in 1860, when Thomas Huxley and Bishop Samuel Wilberforce engaged in their famous debate over the theories presented in Charles Darwin's book *On the Origin of Species*.

The leading authorities of electrical science, including James Clerk Maxwell, Fleeming Jenkin, James Joule, John William Strut (later Lord Rayleigh), JJ Thomson, and William Thomson (later Lord Kelvin), participated in the British Academy's Electrical Standards Committee that was formed in 1861. In order to identify the best methods for measuring electrical resistance, the committee invited contributions from a number of distinguished foreign scientists, including Ernst Esselbach, Joseph Henry, Henry Rowland, Werner von Siemens, and Wilhelm Weber. The topic of standardization drew such an illustrious crowd because of the scientific interest in electricity and the strategic importance of the primary technological application of electricity, in cable telegraphy. After a period of tests and negotiations, the committee eventually arrived at a consensus on a standard unit of resistance—known first as the "unit of 1862," then as the

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[34] Jack Morrell and Arnold Thackray, *Gentlemen of Science: Early Years of the British Association for the Advancement of Science* (Oxford: Clarendon Press, 1981), xxi. See also Roy MacLeod, "Introduction: On the Advancement of Science," in Roy MacLeod and Peter Collins, eds., *Parliament of Science: The British Association for the Advancement of Science, 1831-1981* (Northwood, England: Science Reviews, Ltd., 1981), 17-43.

"BA unit" or "BA ohm"—that was acceptable both to the theoretical physicists and practical electricians who worked closely with telegraph networks.[35]

The British Academy's Electrical Standards Committee provided an institutional middle ground to help resolve the numerous rivalries and disagreements among the various constituencies—academics and practitioners, British and Germans—who were interested in the advancement of electrical technologies. Moreover, these meetings in the early 1860s laid the technical and organizational foundations for more regular and formal international electrical standardization in the International Electrical Congresses that met in conjunction with World's Fairs, beginning in Paris in 1881.[36] At the 1904 Congress in St. Louis, the leaders of these Congresses (including the British inventor and engineer Colonel R. E. B. Crompton, Swedish Nobel Prize winner Svante Arrhenius, Lord Kelvin, and the American inventor Elihu Thomson) created the International Electrotechnical Commission (IEC) as a representative body that could bring the "cooperative spirit that animates electrical workers" into a formal and permanent organization.[37] Like the Franklin Institute (but on an international scale), the IEC was an institution created by

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[35] Several historians have examined various aspects of this period of electrical standardization. See Bruce J. Hunt, "The Ohm Is Where the Art Is: British Telegraph Engineers and the Development of Electrical Standards," *Osiris* 9, 2nd Series (1994): 48-63; Bruce J. Hunt, "Doing Science in a Global Empire: Cable Telegraphy and Electrical Physics in Victorian Britain," in Bernard Lightman, ed., *Victorian Science in Context* (Chicago: University of Chicago Press, 1997), 312-333; Larry Randles Lagerstrom, "Constructing Uniformity: The Standardization of International Electromagnetic Measures, 1860-1912" (Ph.D. diss., University of California at Berkeley, 1992), 7-81; Joseph O'Connell, "Metrology: The Creation of Universality by the Circulation of Particulars," *Social Studies of Science* 23 (1993): 129-173; and Simon Schaffer, "Rayleigh and the Establishment of Electrical Standards."

[36] Subsequent IEC Congresses met in Paris (1889), Frankfurt (1891), Chicago (1893), Geneva (1896), Paris (1900), St. Louis (1904), and Turin (1911).

[37] William Goldsborough, address to the 1904 Electrical Congress, St. Louis, quoted in Jeanne Erdman, "The Appointment of a Representative Commission," *ANSI Reporter: A Commemorative Tribute* (2004): 6.

scientists and engineers that was neither government nor firm, but nevertheless performed a valuable scientific and economic function. By the time the IEC was formed in the early twentieth century, electrical scientists understood perfectly well that standards were not exclusively technical matters, but rather technically oriented instances of diplomacy, with a heavy dose of international prestige and commercial power on the line.

In addition to (and partially in response to) the industrial, engineering, and scientific institutions already discussed, governments in industrializing nations created institutions that contributed to the growth of industrial and scientific standardization. These institutions represent the clearest instance of the close links between standards and science, industry, and international politics. In 1887, Germany established the first government institution dedicated to the production of standards through laboratory research.[38] The success of the German Imperial Institute soon stimulated institutional imitators abroad, including the British National Physical Laboratory (founded in 1899) and the American National Bureau of Standards ("Bureau of Standards," founded in 1901).

Ever since the creation of the American state in the late eighteenth century, Americans grasped that the establishment of standards was, in principle, essential for integrating the fragmented economy of the nascent Republic. In both the Articles of Confederation and the 1789 Constitution, the Founders explicitly granted Congress the power to set uniform national weights, measures, and duties. However, despite the urgings of leaders such as George Washington, Thomas Jefferson, James Madison, and

[38] David Cahan, *An Institute for an Empire: the Physikalisch-Technische Reichsanstalt, 1871-1918* (New York: Cambridge University Press, 1989).

John Quincy Adams to act on its Constitutional grant, Congress found it easier (and cheaper) to succumb to the inertia of local conventions, thus adhering to a policy of "laissez-faire standards." Only in the 1830s, when federal standards were implicated in the politically-charged issue of the collection of tariffs, did Congress establish an Office of Weights and Measures within the Treasury Department to help impose uniform customs and duties at the numerous American ports of entry.[39]

Throughout the nineteenth century, the effectiveness of the Office of Weights and Measures was limited on a practical basis by insufficient funds and personnel, and on a philosophical basis by the predominant political preference not to interfere in the domains of commerce and entrepreneurship. A major force behind Congress's establishment of the National Bureau of Standards in 1901 was a desire to match the scientific capabilities of the national labs created in Germany, Britain, and other major commercial powers including Austria, France, and Russia. The Bureau of Standards, like German Imperial Institute and British National Physical Laboratory before it, represented a mobilization of state power to control the direction of standardization and capture its benefits.

At first, the American institution struggled to catch up with the quantity and quality of original research conducted by its German and British rivals. Although one of the principal motivations behind the creation of the Bureau was to assist the American electrical industry, the early work of the Bureau, hamstrung by limitations to its budget, staff, and equipment, was limited to the comparison of instruments for weights and measures and testing instruments to measure heat, light, water, and electrical current. In

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[39] John Perry, *The Story of Standards* (New York: Funk & Wagnalls Company, 1955), 56-72. Cochrane, *Measures for Progress*, 21-38.

its first decade, substantial resources also were devoted to surveys of standards and equipment used in each state of the Union as well as—in keeping with its mission as a national servant of science—technical assistance and product evaluations for purchases made by the federal government. However, staff in the Bureau's electrical division, under the direction of Edward B. Rosa, began to raise the quality and profile of the Bureau's research on absolute units of measurement and accurate instruments needed to compare the variety of standards circulating among the international electrical community of the early twentieth century. In 1910, the contributions of Bureau scientists helped establish new, more precise values for the international ampere, ohm, and volt. Congress, convinced by Bureau Director Samuel Stratton's testimony that constant work would be required to maintain and refine these standards, agreed to appropriate $175,000 to the construction of a new electrical laboratory for Rosa and his staff to continue their work.[40]

As the Bureau of Standards began to establish its role in the early twentieth century, American engineers in the private sector recognized that they needed to take positive steps in order to control the character and direction of industrial standardization. Consequently, they followed the institutional examples of the Franklin Institute, the British Association for the Advancement of Science, and the International Electrical Congresses, and created standards through new and existing institutions. To administer these institutions, they relied upon the strategic, technical, and administrative experiences

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[40] Cochrane, *Measures for Progress*, 38-108; and Henry S. Pritchett, "The Story of the Establishment of the National Bureau of Standards," *Science*, New Series, Volume 15, Number 373 (February 21, 1902), 281-284.

they learned from standardization efforts in industry, science, and government in the nineteenth century. As they sought to apply these institutional lessons within a dynamic national and international industrial setting, engineers also struggled to define their own professional identities and niches. Professionalization and standardization would operate hand-in-hand as engineers established their position in American industry.

1.4 Standardization in American Professional Engineering Societies

By the end of the nineteenth century, American engineers had created a number of national societies to help them accomplish their technical and professional goals. Through these societies, they developed professional group identities that included commitments to social responsibility and mutual cooperation as well as the objective application of scientific knowledge to advance material and social progress. Engineers used their professional societies to infuse scientific and academic values—namely the pursuit of efficiency and a deference to trusted technical experts—into commercial engineering practice.[41] The standardization activities within these societies provide a clear expression of the mix of social, scientific, and commercial values at the heart of the nascent engineering professions.

While many engineers described their participation in professional societies in scientific or altruistic terms, these societies also provided platforms for engineers to advance a self-serving agenda: to consolidate their ability to control the trajectory and pace of technological development, and to elevate their own status over a wide variety of

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[41] Edwin T. Layton, *The Revolt of the Engineers: Social Responsibility and the American Engineering Profession* (Cleveland: Press of Case Western Reserve University, 1971).

competing workers from construction sites to the factory floor. One example of their ambitions may be seen in the construction industry, where scientifically-trained engineers used technical standards to enforce boundaries between their own expert labor and that of lesser-trained workers.[42] This mobilization of technical expertise into a source of power in the workplace was articulated most famously through the time and motion studies of Frederick W. Taylor and those who applied his theories of "scientific management" in Western Electric's Hawthorne experiments in the 1920s and 1930s.[43] Still, we should be careful not to interpret the rise of professional engineering—through individuals, their societies, and their technical standards—strictly as a site of power relations between engineers and their capitalist managers (on the one hand) and less-skilled laborers (on the other).[44] Standardization illustrates how the values of efficiency and trust (or scientific status) also were key motivating factors within engineering societies that cut across the boundaries of industrial firms in capitalist America.

The movement for industrial standardization was led at first by mechanical engineers who used professional societies like the Franklin Institute and, later, the American Society of Mechanical Engineers (ASME, founded in 1880), as a forum for discussing concerns that were not restricted to one firm but rather shared across the entire

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[42] Slaton, *Reinforced Concrete and the Modernization of American Building*.
[43] Richard Gillespie, *Manufacturing Knowledge: A History of the Hawthorne Experiments* (New York: Cambridge University Press, 1991).
[44] This emphasis on power relations is the most prominent theme in the work of David Noble and Amy Slaton and, in a less critical way, Edwin Layton. See especially Noble, *America by Design*, 321-324.

industry.[45] American engineers pursued standardization through a number of national professional engineering organizations along specialized lines, including the ASME, the American Society for Civil Engineers (founded in 1852), the American Institute of Mining Engineers (founded in 1871), the American Institute of Electrical Engineers (AIEE, founded in 1884), and the Society of Automotive Engineers (founded in 1905).

To illustrate the challenges facing those who wished to promulgate industry-wide standards on a voluntary basis, I will discuss only two of the many examples of early standardization initiatives that occurred within professional engineering societies.[46] In both of these examples—the AIEE's role in the development of standards for the electrical industry and the negotiation of specifications for the durability of steel rails for the railroad tracks within the American Society for Testing Materials (ASTM, established in 1898)—the proponents of standardization believed that technical specifications would be most effective only through widespread (if not universal) use. To achieve such widespread adoption, engineers and corporate leaders needed to be convinced that their self-interest would be served through the adoption of these standards.

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[45] Sinclair, *A Centennial History of the ASME*, 46-60. See also James W. See, "Standards," *Transactions of the American Society of Mechanical Engineers* 10 (1889): 542-575.

[46] Beyond these two examples and Bruce Sinclair's work on mechanical engineering, the best analysis of the strategic importance of committee standardization in this era remains George V. Thompson, "Intercompany Technical Standardization in the Early American Automobile Industry," *The Journal of Economic History* 14 (1954): 1-20.

1.4.1 Elihu Thomson and the American Institute of Electrical Engineers

The need for standardization—of nomenclature, machinery, and measurement—had been firmly established since the initial stages of the electrical industry in the mid-nineteenth century. The appeal of standardization for engineers and executives in the American electrical industry stemmed from its potential to advance their respective technical and commercial interests. Where engineers such as Charles Proteus Steinmetz at General Electric advocated standardization because it facilitated greater coordination and systematization, executives such as Chicago Edison boss Samuel Insull favored standardization because it helped to simplify factory operations and to reduce costs.[47]

Much like standardization in other contexts in nineteenth century America, standardization in the American electrical industry could be a forum for conflict and rivalry. The most public conflict from this era was the "battle of the systems" waged between Thomas Edison and advocates of direct current (on the one hand), and George Westinghouse and advocates of alternating current (on the other). The battle took form in the late 1880s. Edison had established a dominant position in the young electrical industry by devising complex systems that used direct current to provide lighting and power for factory machinery. When Westinghouse challenged this position by introducing systems based on alternating current, Edison and his associates fought back with a nasty campaign of fear, uncertainty, and doubt that included the systematic execution of dogs as a supposedly "scientific" demonstration of the dangers of alternating

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[47] McMahon, *The Making of a Profession*, 88-98.

current.[48] By 1893, two developments—one technological, one organizational—helped to resolve the battle. The introduction of the rotary converter, a "gateway technology," facilitated the use of alternating and direct current within the same system. At the same time, Edison's single-minded assault on alternating current could not withstand the financial pressures that forced Edison Electric to merge with Thomson-Houston into a new firm, General Electric, in 1892. Having lost control of his electrical inventions, Edison subsequently followed his interests to newer inventive pursuits.[49]

By the mid-1890s, according to the historian Thomas P. Hughes, technical relationships in the industry were characterized by a "spirit of flexibility and compromise among the various utility interests, and especially among the manufacturers."[50] Further, standardization in the electrical lighting industry was enhanced by strong social ties between leading individuals in the industry, ties that were nurtured in trade associations such as the Association of Edison Illuminating Companies and the National Electric Light Association as well as the industry's leading technical society, the American Institute of Electrical Engineers (AIEE).[51] Although the "savage" aspects of the AC/DC standards war captured headlines—and still attracts the attention of journalists, Hollywood filmmakers, and even performance artists over a century later—the decisive

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[48] McNichol, *AC/DC: The Savage Tale of the First Standards War*, 77-142.

[49] Paul A. David and Julie Ann Bunn, "The Economics of Gateway Technologies and Network Evolution: Lessons from Electricity Supply History," *Information Economics and Policy* 3 (1988): 165-202.

[50] Thomas Parke Hughes, *Networks of Power: Electrification in Western Society, 1880-1930* (Baltimore: The Johns Hopkins University Press, 1983), 127. See also Paul A. David, "Heroes, Herds and Hysteresis in Technological History: Thomas Edison and 'The Battle of the Systems' Reconsidered," *Industrial and Corporate Change* 1 (1992): 129-180.

[51] Chi-nien Chung, "Networks and Governance in Trade Associations: AEIC and NELA in the Development of the American Electricity Industry, 1885-1910," *International Journal of Sociology and Social Policy* 17 (1997): 57-110.

factor leading to industry standardization was the concentrated nature of the industry, within which collegial relations and a "spirit of flexibility and compromise" could flourish.[52]

The creation of the AIEE and its standardization initiatives illustrate the cooperative character and professional ideology of the social networks that sustained the industry. The AIEE was created in 1884. With the International Electrical Exhibition scheduled to be held in Philadelphia later that year (hosted by the Franklin Institute), American electrical engineers wanted to have a formal body in place to receive the scores of prestigious foreign electrical scientists expected to visit. The founding members of the AIEE included the telegraph engineers Norvin Green (who was the society's first president), Elisha Gray and Franklin Pope; telephone engineer-managers Alexander Graham Bell and Theodore Vail; the power engineers Edwin Houston and Edward Weston; and the lighting engineers Charles Brush, Thomas Edison, and Elihu Thomson. This roster of founders hints at two enduring characteristics of the AIEE in its first decades: close contacts with the business community, and the technical sophistication and elite status of the growing American electrical profession.[53]

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[52] C. E. Skinner, "The Present Status of Standards in the Electrical Industry," *Annals of the American Academy of Political and Social Science* 137 (1928): 151-152. Recent journalistic accounts of the battle of the systems include McNichol, *AC/DC: The Savage Tale of the First Standards War*, and Surowiecki, "Standard-Bearers." Additionally, the AC/DC battle found its way into pop culture in Christopher Nolan's 2006 film *The Prestige* (featuring David Bowie as Nikola Tesla) and the performances of the self-described "monologuist" and author Mike Daisey. See Mike Daisey, "The Coil and I," in Brendan I. Koerner, ed., *The Best of Technology Writing 2006* (Ann Arbor, MI: The University of Michigan Press, 2006), 101-105.

[53] McMahon, *The Making of a Profession*, 28-9; Layton, *Revolt of the Engineers*, 38, 85. The founding objectives of the AIEE may be found in the AIEE *Transactions* 1 (May-October, 1884).

While the International Electrical Congresses and (after 1901) the National Bureau of Standards were concerned primarily with fundamental questions such as consistent international units, AIEE committees created standards that reflected the practical concerns of industry, such as ratings and test requirements for electrical machinery. AIEE committees also created an institutional basis for managing relationships with other institutions pursuing similar goals. For example, the AIEE's first standards activity began after an approach in 1885 from two trade associations, the National Telephone Exchange Association and National Electric Light Association, which sought support for their standard wire gauge. In 1889, the AIEE formed its own Committee on Units and Standards, with Edison Electric consulting engineer (and later Harvard and MIT Professor) Arthur Kennelly as chairman.[54]

In his history of professional electrical engineering, the historian A. Michal McMahon suggested that the AIEE's standards work "held special meaning for the first generation of professional electrical engineers… the standards process suggested a social standard as well as a technical one. It embodied the early electrical engineer's cherished social value: coordinated activity." Elihu Thomson's participation in electrical standardization amplifies this point. Thomson was a teacher, inventor, and entrepreneur who became famous in the 1870s and 1880s through his innovations in arc-lighting and electric power systems. Thomson and his friend Edwin Houston created Thomson-Houston, an electrical firm that began to thrive in the mid-1880s and became part of the General Electric Company when it was founded in 1892. Despite his commercial

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[54] McMahon, *The Making of a Profession*, 79-82; Skinner, "The Present Status of Standards in the Electrical Industry," 151-156.

successes, Thomson was at heart more interested in the worlds of invention and science than he was in the world of business. He demonstrated little patience for the commercial tensions that gripped the electrical industry at the height of the "battle of the systems." Rather than join in the public fracas surrounding direct and alternating current, Thomson instead dedicated himself to scientific and professional matters in the more urbane affairs of the AIEE and numerous other technical and scientific bodies. Within the AIEE, he served as president in 1889 and 1890, was a member of the Standards Committee from its creation in 1898 until 1906, and promoted safety measures for electric lighting systems. From the 1890s through the latter decades of his career, Thomson was concerned with reputation, not riches; with intellectual achievement, not commercial predominance.[55] As such, he was a vital figure in the AIEE's efforts to develop useful standards for the electrical industry, as well as in its campaign to establish its reputation in the eyes of the American and international scientific communities.

By 1906, the AIEE had achieved substantial success in its various standardization projects. These were not primarily technical achievements: the formative innovations for the electrical industry had already occurred within private firms in the late nineteenth century. Rather, the AIEE's successes were institutional and diplomatic: it established a dominant presence in the national engineering community, forged ties with a wide variety of American technical societies and trade associations, cooperated in the establishment of

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[55] W. Bernard Carlson, *Innovation as a Social Process: Elihu Thomson and the Rise of General Electric, 1870-1900* (New York: Cambridge University Press, 1991), 261-267, 340.

the National Bureau of Standards, and emerged as a powerful presence in international electrical standardization.[56]

We can take the AIEE's role in the organization of the 1893 and 1904 International Electrical Congresses—both held as part of the World's Fairs in those cities—as an indication of its rising institutional stature. Even though the AIEE was not the chief organizer of the 1893 Congress in Chicago, it was able to set several items on the agenda. AIEE representatives also won a symbolic victory for American engineers by securing international acceptance of "henry" (in honor of the American physicist Joseph Henry) as the international term for a unit of inductance. Where previous international units—such as the ohm, volt, and ampere—had been named after some of the great European electrical scientists, the henry was the first international unit named after an American. This and other successes in Chicago marked a "coming of age" for American electricians, and established the AIEE as a power bloc and peer with their colleagues (and rivals) from Britain, Germany, and France.[57] By 1904, when the International Electrical Congress met again in the United States, the AIEE was the chief organizer for the sessions in St. Louis. Its symbolic status in international electrical standardization was complete when Elihu Thomson, who was President of the 1904 St. Louis Congress, became the second President of the International Electrotechnical Commission upon the death of Lord Kelvin in 1908.

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[56] On the AIEE's contacts with the Bureau of Standards, see McMahon, *The Making of a Profession*, 90-91; and Cochrane, *Measures for Progress*. On the AIEE's role in the IEC, see Lagerstrom, "Constructing Uniformity," 131-141 and 160-170.

[57] Lagerstrom, "Constructing Uniformity," 160-189, 221-242 (quote on page 169).

The AIEE's standardization initiatives pushed it into an already crowded organizational field, where several other institutions were engaged in the cooperative and competitive social relations needed to establish uniform standards for nomenclature, designs, and components. Since leading engineers from the most powerful firms in the industry—such as Steinmetz at GE and Charles Skinner at Westinghouse—were also influential members in the AIEE standards committees, the combination of the prestige of the AIEE and market power of the large firms aided the AIEE's efforts to disseminate industry standards. In this sense, the AIEE served as venue to enhance the power and status of concentrated electrical industries, and AIEE standards helped the dominant firms maintain control and police the boundaries of the electrical industry.[58]

One of the AIEE's most significant contributions to industry standardization was its creation of institutional rules and norms that sustained cooperation among specialized portions of the electrical industry. The rules first appeared in a "Report of the Committee on Standardization" in the AIEE *Transactions* in 1899, and were subsequently revised in 1902, 1905-07, and 1910-1913. Comfort Adams, Arthur Kennelly, and Elihu Thomson were among the prominent electrical engineers who led this committee. In 1913, the work of the Standards Committee was reorganized into six sub-committees: ratings, telegraph and telephone standards, railway standards, nomenclature and symbols, wires and cables, and rating and testing of control apparatus. In 1916, in order to "crystalize [*sic*] the policy of the Standards Committee in its own activities, and in relation to similar committees of other engineering societies," the AIEE published by-laws of its Standards

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[58] Skinner, "The Present Status of Standards in the Electrical Industry," 151-156; Layton, *Revolt of the Engineers*, 80; and Noble, *America by Design*, 77-78.

Committee.[59] These by-laws were formulated through experience of the committee as well as through consultation with at least ten other societies including the British Engineering Standards Committee, whose secretary Charles le Maistre traveled from London to New York in May 1916 to assist the AIEE in revising its standardization rules.[60]

The by-laws of the AIEE declared that the "Standards Committee shall consider and investigate all matters relating to units and standards appertaining to or applicable in electrical engineering and in the allied arts and sciences."[61] Rather than attempting to establish sole authority over electrical standardization, the AIEE by-laws emphasized the desirability of cooperation with other standards committees, and included provisions to distribute reports of the meetings of its Standards Committee to all cooperating committees. Moreover, the AIEE welcomed objections from cooperating standards committees, and extended invitations to representatives of the objecting committees in order to discuss their differences. By 1916, then, electrical standardization was as much a manifestation of administrative cooperation between engineering elites as it was a technical or strategic pursuit. The AIEE Standardization Rules indicated a concerted

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59 "Standardization Rules of the A.I.E.E.," AIEE *Transactions* 35 (1916), 1551-1557.
60 See Charles le Maistre, "Standardization," AIEE *Transactions* 35 (1916), 489-500. In its 1916 publication of its "Standardization Rules," the AIEE noted the "helpful cooperation" of the following societies: American Society for Testing Materials (Committee B-1), Association of Edison Illuminating Companies (Committee on Meters), Illuminating Engineering Society (Committee on Nomenclature and Standards), Electric Power Club (Committee on Engineering Recommendations; Standardization Committee), National Electrical Light Association (Committee on Meters; Committee on Apparatus), Association of Railway Electrical Engineers (Committee on Wires and Cables), American Electric Railway Engineering Association (Committees on Equipment and Distribution), Institute of Radio Engineers (Committee on Standardization), Society of Automobile Engineers (Standards Committee). "Standardization Rules of the A.I.E.E.," 1554-1555.
61 "Standardization Rules of the A.I.E.E.," 1555.

effort to extend the spirit of cooperation beyond the circle of elite electrical engineers, thus broadening the social network of the standards community.

The AIEE quickly became the largest technical society in the United States, with 7000 members in 1910. In his study of a wide variety of engineering communities during this time period, Edwin Layton concluded that the AIEE was also the "most democratic and professional American engineering society."[62] McMahon also celebrated the AIEE's status as a model technical society and standard-setting body: "AIEE engineers would be able to declare on the eve of World War I that their standardization efforts provided an ideal model of the cooperative spirit in action."[63] Although such favorable interpretations highlight the ideological and practical successes of the AIEE to establish the trustworthiness of its early standardization efforts, these interpretations also can obscure the conflicts, desire for prestige in the domestic and international spheres, and the drive for efficiency and rationalization that were all persistent features in electrical standardization during the second industrial revolution.

1.4.2 Charles Dudley and the American Society for Testing Materials

Where the AIEE's standards activities illustrate how the values of professionalism helped to establish a new industry standards committee within a broader realm of powerful institutions, the creation of specifications for steel rails indicates the challenges inherent in finding common ground between rival firms in different industries. The latter example is particularly important because it shows the development of cooperative

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[62] McMahon, *The Making of a Profession*, xiii; Layton, *Revolt of the Engineers*, 38-9 and 93-4.
[63] McMahon, *The Making of a Profession*, 78-9.

procedures between the steel industry and the railroad industry, two iconic industries in the emergence of a national economy in the nineteenth century and the notorious realm of uncompromising capitalists.

Standardization was a necessary means for railroads to achieve regional and eventually transcontinental compatibility. Historians and economists have noted the development of *ad hoc* standards (and government regulations) that were vital for this national expansion, including agreements for a standard width for railroad tracks and standard time.[64] The wear and failure of steel and iron rails presented a different institutional problem for railroads, one that could not be solved by *ad hoc* agreements between different railroad carriers. The major difference was that steel companies, not railroad companies, manufactured rails. The quality of rails was a costly problem for American railroads and steel manufacturers in the latter decades of the nineteenth century. It also provides one of the earliest examples of institutional innovations—more sophisticated and formalized than the *ad hoc* standardization for rail gauges—that facilitated industry-wide consensus standards at the crossroads of science and industry. The two industries lacked common terminology and criteria for evaluating rails: where engineers in the steel industry thought in terms of the shape and wear of rails, railroad men adopted a more chemically-oriented approach beginning in the late 1870s and 1880s. These problems were compounded by the sometimes acrimonious and uncooperative

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[64] Douglas J. Puffert, "The Standardization of Track Gauge on North American Railways, 1830-1890," *The Journal of Economic History* 60 (2000): 933-960; Ian R. Bartky, "The Adoption of Standard Time," *Technology & Culture* 30 (1989): 25-56; Michael O'Malley, *Keeping Watch: A History of American Time* (New York: Viking, 1990).

relations between firms in the two industries, which were significantly less diplomatic and homogenous in comparison to the electrical engineers discussed above.[65]

Beginning in the late 1870s, a chemist for the Pennsylvania Railroad named Charles Benjamin Dudley presented a series of papers to the American Institute of Mining Engineers and the American Chemical Society on the results of his chemical analyses of steel rails. The main problem he addressed was an imbalance of information—in other words, the lack of reliable and consistent scientific basis upon which specifications for steel rails could be evaluated. Although we recognize Dudley today as a pioneer in industrial research,[66] his initial efforts to add scientific precision to these debates met with little success. Dudley faced substantial institutional resistance: steel manufacturers worried that specifications were an "unnecessary annoyance and interference with their works and processes," and railroad representatives were wary that the adoption of precise specifications would drive up the price of steel rails.[67] Moreover, Dudley's results, based on his laboratory tests, were highly problematic and caused much consternation among the professional engineers because they contradicted the operational experiences of railroad and steel firms.[68] These troubles were ironic, given the emphasis

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[65] On the market structure of steel industry, see Naomi R. Lamoreaux, *The Great Merger Movement in American Business, 1895-1904* (New York: Cambridge University Press, 1985), 76-86. See also Steven W. Usselman, *Regulating Railroad Innovation: Business, Technology, and Politics in America, 1840-1920* (New York: Cambridge University Press, 2002), 215-261.

[66] In David Hounshell's assessment, Dudley's chemical investigations at the Pennsylvania Railroad represent the establishment of the first industrial research laboratory in the United States. Hounshell, "The Evolution of Industrial Research in the United States," in Rosenbloom and Spencer, eds., *Engines of Innovation*.

[67] C. B. Dudley and F. N. Pease, "Chemistry Applied to Railroads. XXVI—How to Make Specifications," *The Railroad and Engineering Journal* 66 (1892): 160.

[68] Dudley's papers sparked unusually impassioned and lengthy debates among AIME members that filled hundreds of pages of the *AIME Transactions* between 1878 and 1883. See for example

that Dudley placed on the need for reliability and accuracy in measurement and testing. Like many other men who sought to create objective technical knowledge in the nineteenth century, Dudley emphasized the moral character, skill, experience, and "sincere disposition" that were prerequisites for arriving at trustworthy results for testing iron and steel.[69]

Dudley and several other chemical and metallurgical engineers continued their scientific investigations into the 1890s and beyond, but the eventual establishment of inter-industry specifications for steel rails owed more to the institutional innovations and diplomatic efforts of railroad engineers such as Dudley, Robert Hunt, and William R. Webster. The contentious relationships between the railroads and their suppliers in the steel industry continued into the early 1900s, when Dudley assumed the presidency of the newly-formed American Society for Testing Materials (ASTM). By appointing Dudley—a trusted scientist from the powerful Pennsylvania Railroad—as their president, the ASTM signaled a move away from dominance by steel manufacturers to a more balanced representation of interests. As Steven Usselman emphasized in his account of

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Charles B. Dudley, "The Chemical Composition and Physical Properties of Steel Rails," *AIME Transactions* 7 (May 1878-February 1879): 172-201; Charles B. Dudley, "Does the Wearing Power of Steel Rails Increase with the Hardness of the Steel?," *AIME Transactions* 7 (May 1878-February 1879): 202-205; and "Discussion of Dr. Charles B. Dudley's Papers on Steel Rails, Read at the Lake George Meeting, October 1878," *AIME Transactions* 7 (May 1878-February 1879): 357-413. See also Usselman, *Regulating Railroad Innovation*, 221-223.

[69] C. B. Dudley and F. N. Pease, "The Need of Standard Methods for the Analysis of Iron and Steel, with Some Proposed Standard Methods," *Journal of the American Chemical Society* 15 (1893): 510. As noted above, Dudley's emphasis on the moral dimensions of laboratory practice mirror the attitudes of electrical researchers. See Gooday, *The Morals of Measurement*.

these events, Dudley's professional standing and "unimpeachable reputation" helped to make ASTM a trusted forum for representatives from railroads and steel makers alike.[70]

Dudley's chief accomplishment, after many years of effort, was to bring together those who would be interested in industry standards to develop the standards jointly, even if the parties were rivals or had antagonistic relationships. Dudley characterized these parties as producers and consumers—in this case, the steel manufacturers and the railroad companies who purchased their products. In his 1903 presidential address to the ASTM, Dudley stated that the creation of specifications that would be accepted by both producers and consumers demanded that "all parties whose interests are affected by a specification should have a voice in its preparation."[71] Within two decades, this call for a representative process would become the foundational principle for American industrial standards.

By 1906, the ASTM reached agreement on industry standards for rails, which were subsequently adopted in private contracts and negotiations between engineers who used the industry specifications either as a normative standard or a baseline for customized orders. In Usselman's assessment, "an entirely new approach to innovation—one that emphasized cooperation, careful experiment by engineers, and controlled change that did not disrupt the economic equilibrium—had arrived."[72] The ASTM rapidly

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70 Later in Dudley's career, in the context of his role in the emergence of the American Chemical Society, Usselman notes the importance of Dudley's character, such as his "ability to fashion compromise" and his "scrupulous commitment to honest, open investigation" that "gave him an authority that few could match." Usselman, *Regulating Railroad Innovation*, 256-258.

71 C. B. Dudley, "The Making of Specifications for Materials," *Proceedings of the Annual Meeting – American Society for Testing Materials* 3 (1903): 30.

72 Usselman, *Regulating Railroad Innovation*, 240.

expanded its operations, and by 1910 it had 1,270 members in 17 countries, and had published 28 standards covering a variety of technologies, such as steel rails and wheels, locomotive cylinders, copper wire, cement, and structural timber.[73] Although the ASTM did not maintain its own laboratories, it served an important coordinating function for a variety of institutions—including private firms, academic laboratories, the National Bureau of Standards, and the United States Geological Survey—that conducted hundreds of thousands of tests on nearly all materials used by American companies and government agencies.[74] Materials testing was one of the most important aspects of the industrial age, and the ASTM, an independent organization that relied on consensus procedures and a broad membership, quickly became the linchpin of testing in the public and private sectors.[75]

Dudley was recognized by his contemporaries as the driving spirit behind this initial stage of growth. Upon his death in 1909, the ASTM convened a special session—unique in the early history of the ASTM—to memorialize Dudley and his contributions to the ASTM and to American industry more generally. The eulogies included tributes to Dudley as a railroad man, chemist, metallurgist, mentor, and citizen—"a diplomat of the heart, a nobleman of Nature's handiwork, a man of the broadest outlook and widest

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[73] *American Society for Testing Materials Year-Book, 1910* (Philadelphia: American Society for Testing Materials, 1910). A vast majority of the ASTM membership (1,193 out of 1,270) lived in the United States.

[74] Richard L. Humphrey, "The Structural Materials Testing Laboratories, United States Geological Survey: Progress During the Year Ending June 30, 1910," *ASTM Proceedings* 10 (1910): 631-650; C. L. Warwick, "The Work in the Field of Standardization of the American Society for Testing Materials," *Annals of the American Academy of Political and Social Science* 137 (May, 1928): 49-59.

[75] Slaton, *Reinforced Concrete and the Modernization of American Building*, 68-71.

perspective."[76] The fact that these plaudits came in the form of eulogies does not detract from the importance of Dudley's accomplishments. Instead, they reinforce the notion that individuals who were trusted and respected by their peers were essential to the establishment of trusted institutions that could set industry-wide standards. Indeed, Dudley deserves recognition as the architect of industry standardization's seminal institutional innovation—the "consensus principle"—in which businessmen with different needs and interests came together to work together and forge a mutually-agreeable solution.

Through these committees, industry standardization embodied a pragmatic approach in which the application of engineering values found widespread application within and between American industrial firms. According to Usselman, Dudley's success with the ASTM was an important example of how "engineers and engineering, as embodied in the process of negotiated specifications, acquired an almost mystical appeal."[77] Through the efforts of Dudley and his colleagues in the electrical standards community, we can see that this "mystical appeal" was hard earned. In the late nineteenth and early twentieth centuries, standards and specifications were created through a contested and power-laden process. The ability of men like Dudley to

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[76] Robert W. Lesley, "Introductory Remarks by the Vice-President," *ASTM Proceedings* 10 (1910): 21. The other eulogies appeared in *ASTM Proceedings* 10 (1910): 19-53. They were also reproduced in a commemorative volume, 269 pages in total, that included the papers from the memorial session as well as some of Dudley's published papers. *Memorial Volume Commemorative of the Life and Work of Charles Benjamin Dudley, Ph.D., Late President of the International Association for Testing Materials and the American Society for Testing Materials* (Philadelphia: American Society for Testing Materials, 1911).
[77] Usselman, *Regulating Railroad Innovation*, 241.

surmount the technical and organizational obstacles to shared specifications accounts for this ascension to mystical status.

Dudley's role in the creation of the ASTM also suggests something of a turning point in the history of precision measurement and standardization in industrial practice. Dudley, like the prestigious group of electrical engineers in Britain, established standards by virtue of their scientific approach and personal reputation—or, as Graeme Gooday has argued, their moral standing. In the context of American industry in the early twentieth century, moral standing was not by itself enough to obtain widespread agreement over standards and specifications. In a highly charged commercial environment, impartial bureaucratic institutions such as the ASTM and AIEE—more so than any one individual—became established as sources of trusted technical information. Standards were the clearest form of objective technical knowledge produced by these groups. Standards thus represented the institutionalization of trust, something that could be accomplished only after a consensus among professional scientists and engineers had been forged.

1.5 Conclusions

Standardization facilitated efficiencies and productivity gains across the boundaries of individual firms. The institutions that Americans created to advance the goals of industry standardization were not built by powerful, profit-minded, and unpopular capitalists such as John Rockefeller or Jay Gould. Instead, these institutions were led by elite engineers such as Elihu Thomson and Charles Dudley who were widely respected among their peers and loyal to the collaborative values of the nascent engineering professions. Our canonical histories of technology and business explain how standardization was pursued within firms though hierarchical management structures and, to a lesser extent, disseminated between firms through specifications articulated in procurement contracts by a dominant company. However, in industries that lacked such overwhelmingly dominant firms, common specifications were established not through market power but instead through trusted institutions that were created and maintained by men whose status stemmed from their status among their peers in science and industry. Elihu Thomson and Charles Dudley helped to create legitimate bodies where engineers could cooperate to exchange information and solve common technical problems. In this sense, we should remember Thomson and Dudley not only for their achievements in science and business, but also for their institutional entrepreneurship that facilitated collective action across the boundaries of science and industry.

The creation of standards in the AIEE and ASTM are but two examples of a broader pattern in which new institutions generated consensus standards for the core industries of the second industrial revolution. The different histories and foundations of the two institutions—the former a professional engineering society, the latter dedicated explicitly to producing technical specifications—indicate the diversity that existed among the dozens of standard-setting initiatives that took shape in the late nineteenth and early twentieth centuries. Within this diversity, however, there existed common threads: a respect for scientific and engineering talent and experience; the quest to devise orderly and rational solutions; the importance of cooperation, even in the midst of intense competition; and the need for trusted and impartial organizations.

The standard-setters of the American second industrial revolution primarily were professional engineers who were dedicated to working with their colleagues in a collaborative spirit. Through their activities in engineering societies and standards committees, their work reveals their divided loyalties to the cooperative values of engineering and the application of technical knowledge for profit. The characteristically American resistance of government control over industry in general, and technical standards in particular, led engineers to forge collaborative relationships in the private sector. By disseminating objective—or rather consensually produced—technical information, these groups helped to reduce inefficiencies in technical design and business transactions. These collaborations were vital tools that provided stability for the technological and economic advances that were at the core of the second industrial revolution.

Despite their successes, these new institutions found themselves duplicating work and even generating conflicting standards for the same technologies. The quest for stability in a technologically complex national economy soon led engineers to seek new organizational solutions where representatives from a variety of standard-setting institutions could negotiate inter-industry and national standards. These new solutions—born of a mix of efficiency-minded cooperation, commercial power dynamics, and leadership by trusted elites—are the subject of the next chapter.

Chapter 2: From Engineering Standards to American Standards, 1910-1930

2.1 Introduction

In the late nineteenth and early twentieth centuries, elite electrical, chemical, and mechanical engineers formed new institutions that slowly and painstakingly began to publish standards for a national industrial economy. Practical and ideological dimensions of standardization operated hand-in-hand. By the 1920s, the most prominent advocates of standardization were professional men whose careers spanned the boundaries of science, business, and politics: men such as Herbert Hoover, the famous mining engineer, Secretary of Commerce, and President of the American Institute of Mining Engineers who was elected President of the United States in 1928; and Albert Whitney, a safety advocate, insurance industry consultant, Caltech mathematics professor, pioneer in the field of actuarial science, and Chairman and longtime Executive Committee member of the American Engineering Standards Committee.

The ideas of these two men, both of whom were instrumental in the growth of industrial standardization in the United States, provide a good way to introduce the blend of values and beliefs at the core of the movement for industrial standards. Hoover personified the inspiration that this movement drew from the experience of World War I. Through the public-minded application of the principles of rational and scientific inquiry, Hoover believed that he and his fellow engineers could improve industrial performance and thus contribute to the creation of a more harmonious industrial and social order. To counter the wasteful tendencies of competitive industrial capitalism, Hoover used his political status to encourage professional engineers to eliminate unnecessary variety, to simplify industrial practice, and to pursue cooperative relations in the public and private sectors.[1]

In contrast to Hoover's political and engineering approach, Whitney sought to provide a sound philosophical basis for the standardization movement, most notably in a widely circulated 1924 essay entitled "The Place of Standardization in Modern Life." Whitney, like Hoover and other advocates of industrial standardization, defended standardization from critics who feared that it would produce a dull and mediocre world.[2] Whitney's outlook was more optimistic:

> 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.[3]

In Whitney's worldview, this liberatory essence of standardization could be generalized far beyond the realm of engineering. "In a very real sense," he continued,

> all the conservational forces of civilization are within the field of standardization, institutions, customs, laws, literature, and other forms of art, science—they all involve the fixation of advances which have been made into a better understanding of the world, and such advances are in turn points from which to make fresh advances.[4]

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[1] Herbert Hoover, *American Individualism* (Garden City, NY: Doubleday, Page & Co., 1922); Ellis W. Hawley, "Herbert Hoover, the Commerce Secretariat, and the Vision of an 'Associative State,' 1921-1928," *American Historical Review* 61 (1974): 116-140.

[2] One critic—an economist at the War Trade Board writing in 1919—objected to standardization on aesthetic as well as economic grounds. See Homer Hoyt, "Standardization and its Relation to Industrial Concentration," *Annals of the American Academy of Political and Social Science* 82 (1919): 271-277.

[3] Albert Whitney, *The Place of Standardization in Modern Life* (Washington, DC: Central Executive Council, Inter American High Commission, 1924), 5. This essay was reprinted in a 1928 special issue of the *Annals of the American Academy of Political and Social Science* 137 (1928). Dozens of articles—mostly but not unanimously supportive of standardization—also appeared in this volume.

[4] Whitney, *The Place of Standardization in Modern Life*, 5.

For Hoover and Whitney, standardization had clear potential for influencing the direction and character of society; but society first would have opportunities to direct the character of standardization. They agreed that the key to capturing the benefits of standardization while avoiding its pitfalls was a matter of control. The key questions, then, were: Who would control standardization? How would they do it? What would be the social and economic consequences?

In the United States, the most influential response to these questions came from professional engineers who were advocates of an ideology of voluntary cooperation. The leaders of the nation's largest and most influential engineering standards committees came together to create a national federation of standards organization in the wake of World War I. This federation, the American Engineering Standards Committee (AESC, founded in 1918) was the first institution dedicated explicitly to cooperation between industry standards bodies on a national scale. To accomplish such ambitious goals, the leaders of the AESC sought to establish the legitimacy and effectiveness of their organization through practical and rhetorical campaigns of cooperation with other organizations—including professional engineering societies, trade associations, and government bureaus—that also exercised jurisdiction over technical standards.[5] By the late 1920s, buoyed by the success of their efforts, the spokesmen of the AESC argued that their organization represented a form (and even a model) of industrial self-government. Theirs was not an implementation of a radical socialist or technocratic

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[5] In my use of the concept of "jurisdiction," I follow Andrew Abbott's discussion of jurisdiction as a process where different groups seek to exert control over work. Andrew Abbott, *The System of Professions: An Essay on the Division of Expert Labor* (Chicago: University of Chicago Press, 1988).

agenda; instead, it was an attempt to apply the principles of participatory democracy within a new sphere, in order to transcend the constraints and limitations of existing forms of state regulation.

2.2 Creation of the American Engineering Standards Committee, 1910-1922

In the United States, engineering standards committees were first formed in groups such as the American Institute for Electrical Engineers (AIEE, founded in 1884) and the American Society for Testing Materials (ASTM, founded in 1898), and multiplied quickly in the first decade of the twentieth century. By World War I, over 100 private organizations—including engineering societies, trade associations, and international bodies—were creating and disseminating standards that were intended for use in American industrial production. In several cases, however, this proliferation of standards committees ironically began to undermine their underlying purpose of providing greater cooperation and organization. This confusion was especially acute in technologies where four or five different committees issued different standards, for example in electrical machinery, screw threads, and pipe threads, without any systematic or formal channels of communication or coordination.[6]

Beginning in 1910, members of several engineering societies began to discuss how an alliance of standards work between the national engineering societies would be a

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[6] Comfort A. Adams, "Industrial Standardization," *Annals of the American Academy of Political and Social Science* 82, Industries in Readjustment (1919): 292-6; Bruce Sinclair, *A Centennial History of the American Society of Mechanical Engineers, 1880-1980* (Toronto: University of Toronto Press, 1980), 55.

"most desirable thing."[7] There was less agreement, however, on who would control the alliance and how much authority it would have. These discussions started when Henry Hess, an engineer active in mechanical and automotive standards work, met with the leaders of the British Engineering Standards Committee (BESC) in 1910. The BESC, founded in 1901, was a body designed to unify standardization efforts in British government and private industry. Convinced that Americans would benefit by following the British example, Hess initiated a series of discussions with representatives of the other major American engineering societies that would take eight full years before a national alliance of American standard-setters was formed. Throughout this period, American engineers looked to the BESC as a model and especially to Charles Le Maistre, the Secretary of the BESC, for advice for setting up a national standardization committee as the British had done.[8]

Hess first gained support for his initiative from Calvin Rice, Secretary of the American Society of Mechanical Engineers (ASME, founded in 1880). Hess—who in 1911 was appointed as Chairman of the ASME's committee on Joint Engineering Standards—then began to correspond early in 1912 with Comfort A. Adams, Secretary of the AIEE Standards Committee. He outlined an ambitious vision, calling for the creation of a "Joint Engineering Standards Committee" (similar to the British committee he

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[7] Henry Hess to Calvin W. Rice, quoted in Clifford B. LePage, "Twenty-Five Years—the American Standards Association (1. Origins)," *Industrial Standardization* (1943): 318.

[8] For an appraisal of the BESC (renamed British Engineering Standards Association in 1918), see Charles Le Maistre, "Summary of the Work of the British Engineering Standards Association," *Annals of the American Academy of Political and Social Science* 82 (1919): 247-252. On the career and influence of Le Maistre—who also served as the general secretary of the International Electrotechnical Commission—see JoAnne Yates and Craig Murphy, "Charles le Maistre: Entrepreneur in International Standardization," paper presented at the Business History Conference, June 2007.

discovered in 1910) that would transmit copies of ongoing standards work between the various member societies and, moreover, serve as a point of contact for an international committee to facilitate the exchange of information between national committees.[9] Adams was enthusiastic in his response, although he cautioned Hess about the administrative hurdles that would face such a comprehensive plan. Remarking on the troubles that the International Electrotechnical Commission faced, Adams warned that it would be "a very tedious and difficult matter to get such an international organization into successful operation."[10]

Despite widespread enthusiasm for an alliance of engineering standards committees, progress was slow. In 1916, Arthur Kennelly (Chairman of the AIEE Standards Committee and Professor of Electrical Engineering at Harvard University and the Massachusetts Institute of Technology) renewed the initiative. In a letter to Hess, Kennelly proposed that the four major national engineering societies (the AIEE, the ASME, the American Society for Civil Engineers (ASCE, founded in 1852), and the American Institute of Mining Engineers (AIME, founded in 1871)) send representatives from their respective Standards Committees to create a "standing federated Engineering Standards Committee," which would share equally in the meeting costs and rotate the chairmanship on an annual basis. Kennelly hoped that this institutional design would avoid rivalries and tensions between the four professional societies. "The main idea,"

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[9] Henry Hess to F. L. Hutchinson, quoted in Clifford B. LePage, "Twenty-Five Years—the American Standards Association (1. Origins)," 318.
[10] Comfort A. Adams to Henry Hess, quoted in Clifford B. LePage, "Twenty-Five Years—the American Standards Association (1. Origins)," 319.

Kennelly concluded, "is that no one society shall seek to dominate the situation, but that each should endeavor to assist all the others."[11]

By the end of the year, the idea finally began to bear fruit: the first meeting of the Joint Conference Committee on American Engineering Standards occurred on December 29, 1916, with Comfort Adams as chairman. Representatives from the four engineering societies asked a fifth society, the ASTM to join them to create a permanent American Engineering Standards Committee (AESC).[12] The Joint Committee immediately considered the advantages of asking American government officials to appoint representatives to the AESC, and authorized Comfort Adams, who had already spoken to government officials about the initiative, to continue his discussions with the Director of the Bureau of Standards and the Secretaries of War and Navy. Adams had already established collegial relations with Paul Agnew and Edward Rosa from the Bureau of Standards, and found his correspondents at the Departments of War and Navy—Colonel Warren R. Roberts and Franklin Delano Roosevelt, respectively—willing to follow the Bureau's lead.

With the five engineering societies and three government departments committed to collaboration, the main obstacles facing the newly-formed AESC were structural and procedural: what would be the constitution and by-laws of the new group? What about

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11 Arthur Kennelly to Henry Hess, quoted in Clifford B. LePage, "Twenty-Five Years—the American Standards Association (1. Origins)," 321. Charles le Maistre, "Standardization," *AIEE Transactions* 35 (1916): 489-500; and Comfort A. Adams, "National Standards Movement—its Evolution and Future," in Dickson Reck, ed. *National Standards in a Modern Economy* (New York: Harper and Brothers, 1956).

12 The AESC changed its name to the American Standards Association (ASA) in 1928, then to the United States of America Standards Institute (USASI) in 1966, and then to its present name, the American National Standards Institute (ANSI) in 1969.

its classifications for standards, and the form of its committees and subcommittees? Most importantly, what would be the relationship between these new procedures and the various existing procedures in place at the founder societies?

These questions took almost two years to settle. Adams later recalled, "What happened during those two years would be a long, but very interesting story, if it were related in full… fear and jealousy, as well as ignorance, were the chief obstacles which had to be overcome during two years of the hardest kind of work for the relatively small group that carried the load." Agnew commented wryly that the five societies engaged in "endless discussions" and "innumerable drafts of constitutions and methods of procedure" before they finally approved the AESC Constitution and Rules of Procedure in 1918.[13] The main problem was a fear—articulated most sharply by Edgar Marburg of the ASTM—that the new collective organization would usurp the prestige and authority of the member societies. The ASTM was especially sensitive to this fear because, unlike the other four founders, they were primarily a standards-setting organization, and not a professional engineering society. Even after two years, this jurisdictional conflict was not completely resolved, but instead, deferred and therefore destined to resurface time and again as a fundamental problem.

Although the tenuous balance of power would be a persistent problem for the AESC, it was clear from the start that this was not to be an endeavor led by the federal government. This was the fundamental difference between the United States and in European countries, whose industrial standardization efforts were financed and organized

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[13] P. G. Agnew, "Twenty Years of Standardization," *Industrial Standardization* (1938): 229; and Comfort A. Adams, "How the AESC Was Organized," *Industrial Standardization* (1938): 237-8.

by governments.[14] American government agencies were unwilling to lead, but were eager to join the enterprise as equal partners. The early involvement of the Departments of War and Navy highlights the importance of standardization during the nation's unprecedented mobilization for World War I. Working on behalf of the Naval Consulting Board (created in July, 1915) the automotive engineer Howard Coffin led the first efforts to enlist over twenty engineers from the leading professional societies to find the most efficient means for preparing American industry for war. Coffin and his fellow engineers sought to aid their country through the systematic application of scientific knowledge and bureaucratic expertise—an ideology that would achieve its most public expression through Bernard Baruch's War Industries Board and Herbert Hoover's oversight of the provision of food for eleven million Belgian refugees.[15]

Although Coffin used his time in Washington to bring together the leaders of the major American engineering societies—and even used the occasion to promote industrial standardization—the war only served to provide a boost for the initiative started by Hess, Kennelly, and Adams. Indeed, Paul Agnew later argued that the "British influence" was far more influential as an inspiration for the AESC than anything that "came out of Washington or even from civilian engineers' stays in Washington."[16] Rather than

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[14] Jay Tate, "National Varieties of Standardization," in Peter A. Hall and David Soskice, eds., *Varieties of Capitalism: The Institutional Foundations of Competitive Advantage* (New York: Oxford University Press, 2001), 442-473.
[15] Robert D. Cuff, *The War Industries Board: Business-Government Relations During World War I* (Baltimore: The Johns Hopkins University Press, 1973), 15-30. See also Ronald C. Tobey, *The American Ideology of National Science, 1919-1930* (Pittsburgh: University of Pittsburgh Press, 1971), xii, 3-96.
[16] Paul G. Agnew, "Historical Memoranda to H (for Mrs. Moffett), 9/3/48, in P. G. Agnew, *Historical and Policy Papers* (New York: American Standards Association, 1920-1952), 335. [My assumption is that "H" is Vice Admiral G. F. Hussey, Jr. (USN Ret.), who succeeded Agnew as

providing some sort of organizational or ideological template for industrial standardization, the lasting legacy of public-private cooperation during the war was that it demonstrated the benefits made possible by coordinated action and civic voluntarism to scientists, engineers, government officials and the general public.[17]

The first meeting of the AESC took place in New York on October 19, 1918. Comfort Adams was elected as Chairman, and the ASME volunteered the services of Clifford B. LePage as acting secretary. LePage stayed on until 1919, when Agnew began work as the AESC's full-time secretary. Agnew continued in that role until 1947, and his influence during this long tenure was the single most important factor in shaping the development of the AESC and American consensus standardization.

Given their formative roles in the AESC, the career paths of Adams and Agnew warrant a closer look. Comfort Avery Adams (b. 1868, d. 1958) was a talented scientist, respected teacher, and accomplished administrator. His career in science began with his undergraduate studies in mechanical engineering at Case Institute of Applied Science, where he was a laboratory assistant for Albert Michelson and helped design the apparatus used in the famous Michelson-Morely ether drift experiment. After graduating from

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Secretary of the American Standards Association in 1948.] Agnew's recollection is consistent with Henry May's insight that fundamental changes in American society were well under way before the beginning of the World War. Henry May, *The End of American Innocence: A Study of the First Years of Our Own Time, 1912-1917* (New York: Knopf, 1959).

[17] In contrast to the AESC, the National Research Council (NRC) was formed to respond to military needs during World War I. The NRC, focused more on research (As opposed to standardization), grew rapidly in the 1920s, but lost most of its funding in the 1930s. On the NRC, see Robert H. Kargon, "Introduction," in Robert H. Kargon, ed., *The Maturing of American Science* (Washington, DC: American Association for the Advancement of Science, 1974), 1-29. For a more general analysis, see Theda Skocpol, et al, "Patriotic Partnerships: Why Great Wars Nourished American Civic Voluntarism," in Ira Katznelson and Martin Shefter, eds., *Shaped by War and Trade: International Influences on American Political Development* (Princeton: Princeton University Press, 2002), 134-180.

Case in 1890, he worked as an engineer at Brush Electric Company before joining the engineering faculty at Harvard University in 1891. He was promoted to professor in 1906, served as Dean of the School of Engineering in 1919, and held prestigious chairs in Engineering from 1914 until his retirement from Harvard in 1936.

Additionally, Adams was active outside the academy in both the private and public sectors. Throughout his tenure at Harvard and for twenty years after his retirement, Adams kept in close touch with a broad cross-section of industry through consulting activities with over a dozen different private firms. His service in government began during World War I, when he was the chair of the Welding Committee of the Emergency Fleet Corporation and a member of the General Engineering Committee of the Council of National Defense. After the war he concentrated on facilitating cooperative action in the private sector, simultaneously serving as founder and first president (1919) of the American Welding Society, a twenty year member of the Boiler Code Committee of ASME, chairman of the AIEE Standards Committee (1910-1920), AIEE president in 1918, and, as noted above, first chairman of the AESC in 1918 and 1919. Later in his life he received tremendous acclaim from his peers, including election to the National Academy of Science (1930), lifetime achievement medals from the American Welding Society (1927) and AIEE (1944), and the prestigious Edison Medal in 1956. He was, in short, an archetype of the new professional engineer that emerged in the early twentieth century, one whose career spanned the boundaries of industry, academia, and, in times of need, government.[18]

Where Adams' career is remarkable for its breadth across distinct sectors of American society, Agnew's career is distinguished by the depth of his experiences and commitment to industrial standardization chiefly through one organization, the AESC. Agnew (b. 1881, d. 1954) earned a Master's degree from the University of Michigan in 1902, and, after teaching high school physics for three years, joined the staff of the Bureau of Standards in 1906. At the Bureau, he performed research and published several important papers on electrical instrumentation and measurement methods. His work was strong and original enough to earn him a Ph.D. from Johns Hopkins University in 1911.[19]

Agnew's interest in industrial standardization blossomed during World War I, when he was the technical assistant to the Bureau of Standards Chief Physicist Edward B. Rosa as well as a liaison between the Bureau of Standards and the War Industries Board.[20] (Agnew later provided important assistance for the federal government during the Second World War, as an emissary between the government, military, and industry in

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[18] Vannevar Bush, "Comfort Avery Adams," in *Biographical Memoirs* 38 (New York: Columbia University Press of the National Academy of Sciences, 1958), 1-16.

[19] P. G. Agnew, "A Study of the Current Transformer with Particular Reference to Iron Loss," *Bulletin of the Bureau of Standards*, Vol. 7, No. 3 (Washington, DC: Government Printing Office, 1911). Other publications included P. G. Agnew, "A Device for Measuring the Torque of Electrical Instruments," *Bulletin of the Bureau of Standards*, Vol. 7, No. 1 (Washington, DC: Government Printing Office, 1911); P. G. Agnew, W. H. Stannard, and J. L. Fearing, "A System of Remote Control for an Electric Testing Laboratory," *Scientific Papers of the Bureau of Standards*, No. 291 (Washington, DC: Government Printing Office, 1916); and P. G. Agnew, "A New Form of Vibration Galvanometer," *Scientific Papers of the Bureau of Standards*, No. 370 (Washington, DC: Government Printing Office, 1920).

[20] P. G. Agnew, "The Work of the Bureau of Standards," *Annals of the American Academy of Political and Social Science* 82 (1919): 278-288.

the development of American War Standards used by the armed services.) Agnew's involvement with the AESC began in 1919, when he represented the Bureau of Standards in discussions of the inclusion of government departments and trade organizations within the AESC. Agnew left the Bureau to join the AESC in 1919, probably tempted in part by a salary increase of at least $1,000.[21] His service as AESC Secretary spanned from 1919 to 1947, a period in which his staff grew from three to eighty-five people. After leaving this position, he continued to serve as a consultant for the organization until 1952. Given this outstanding commitment to standardization, it is easy to see why one author went so far as to call Agnew "Mr. Standards."[22]

Agnew maintained a personal interest and involvement in almost every aspect of the AESC's operations. Agnew served as the public face of the AESC by promoting the cause of standardization in business publications, academic conferences, and in testimony to Congress. At the same time, Agnew was deeply involved with a vast range of topics related to standardization, from the technical details of electrical, photography, and building standards to the philosophical, financial, and legal dimensions of industry, government, and international standardization. He also led the creation of ratings, certifications, and quality standards for consumer products such as clothing, bedding, and

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[21] At this time, restrictions on salaries severely impeded the Bureau's ability to attract and keep talented scientists. According to Rexmond Cochrane, "industry paid close to twice the Bureau salary at every level of training and experience." Agnew would have earned between $2,240 and $4,000 a year after over ten years at the Bureau; his 1921 salary at the AESC was $5,000. Rexmond C. Cochrane, *Measures for Progress: A History of the National Bureau of Standards* (Washington, D.C.: U. S. Department of Commerce, 1966), 223; and *Work of the American Engineering Standards Committee (Year Book)* (New York: American Engineering Standards Committee, 1921), 13.
[22] S. P. Kaidanovsky, "Personalia: Dr. P. G. Agnew," *Standards World* 1 (1949): 113-114. Kaidanovsky continued, "When speaking of standards one cannot help but think of P. G. Agnew."

food.[23] He represented Americans in efforts to create international alliances for standardization, including the International Standards Association in the late 1920s, a series of meetings with Latin American countries in the late 1920s, and was a "dominant figure" in the negotiations that led to the establishment of the International Organization for Standardization (ISO) in 1946.[24] With few exceptions, he was present at every meeting of the AESC main committee and, through his role as minute-taker, generated its documentary history and served as the scribe of its institutional memory. Agnew struggled with physical illness throughout his life, but, with the assistance of his wife Ethna M. Heebner and his staff at the AESC, functioned as the backbone and voice of American industrial standardization.[25] His colleagues recognized his decades of service with the first ASA Standards Medal in 1951.

Agnew's enduring contribution to industrial standardization came not only from his formidable technical and administrative accomplishments, but, most significantly, from the spirit in which he carried out his work. Agnew was deeply and sincerely committed to the cooperative vision embodied in multilateral standardization, and was one of the most articulate spokesmen for the social benefits and philosophical justifications for standardization.

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[23] The American Home Economics Association joined the AESC in 1929. See "Home Engineering," *The New York Times* (March 7, 1929), 17; "Standardized Bedding," *The New York Times* (April 1, 1929), 19; and P. G. Agnew, "The Movement for Standards for Consumer Goods," *Annals of the American Academy of Political and Social Science* 137 (1934): 60-69. For tributes to Agnew's formative role in standards for photographic equipment and consumer goods, see Paul Arnold, "American Standards in Complementary Industries," and Irwin D. Wolf, "Consumer Goods Standards—the Retailer's Viewpoint," both in Reck, ed., *National Standards in a Modern Economy*.

[24] Kaidanovsky, "Personalia: Dr. P. G. Agnew," 113-114.

[25] Agnew's ideas survive in accessible form thanks to the effort of his wife, who presented a collection of some of his papers to The Johns Hopkins University library as a gift in 1959.

Agnew argued that the AESC's cooperative method of developing standards, which he called the "consensus principle," compared favorably to the common law and statute law methods of establishing regulations: it was quicker and more flexible than the common law method, yet retained the authority of statue law without being burdened by its bureaucratized nature and autocratic tendencies. An illustration that accompanied Agnew's 1925 article "How Business is Policing Itself" revealed his cutting critique of existing forms of rulemaking. At one side of the illustration (credited to Emmett Watson), a bespectacled lawyer is reading from one of a mountain of legal books. His oratory is failing to hold the attention of the judge and a clerk, both of whom are asleep. In the middle of the illustration, a young, well-dressed businessman flees the courtroom, briefcase in hand, and moves toward a boardroom. He is joined there by two colleagues, one who is offering a match to light the young businessman's cigar, the other who is intently reading a document that the three men appear to share. The caption tells us that "The business man is turning from the courts with their numberless laws and intricate procedure to boards and reforms of his own choosing."[26]

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[26] P. G. Agnew, "How Business is Policing Itself," *The Nation's Business* (December, 1925), 41-43.

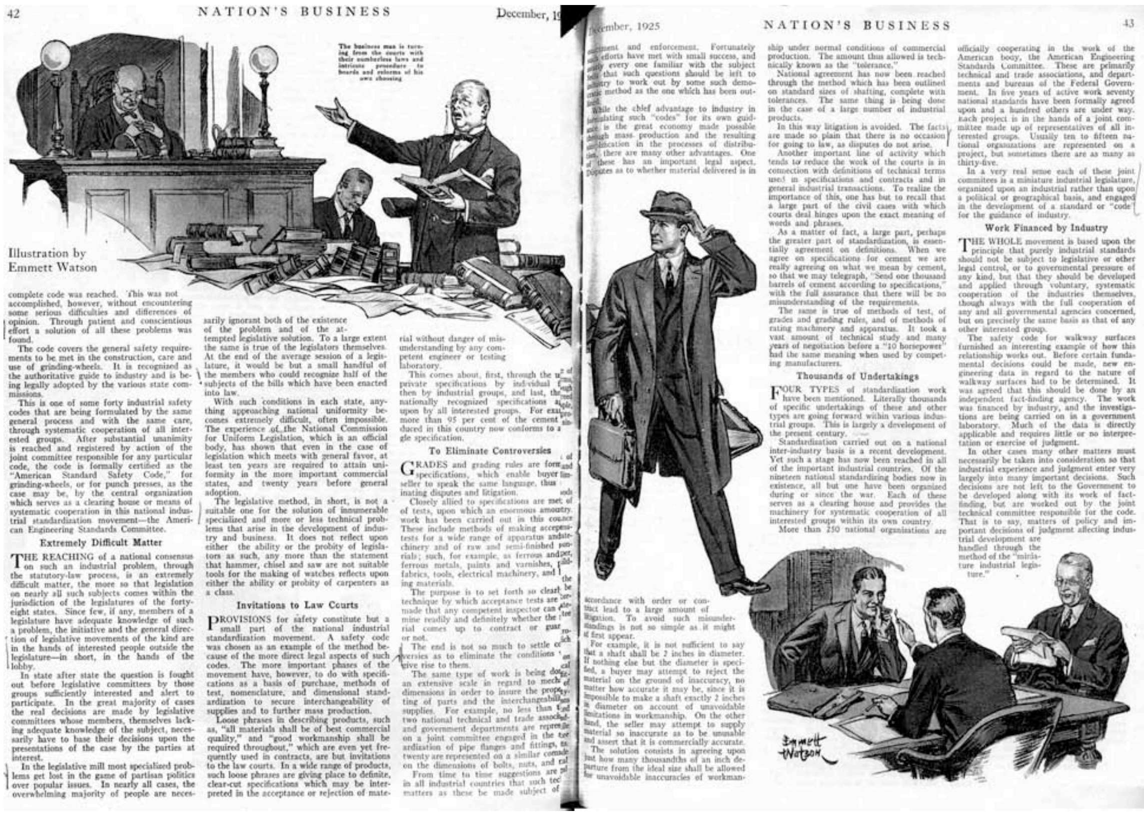

Figure 2.1: "…from the courts… to reforms of his own choosing."
Source: P. G. Agnew, "How Business is Policing Itself," *The Nation's Business*

As practiced in the technical realm of standardization, the consensus principle meant that "controversial matters usually are threshed out, often with the aid of research, until a *solution*, and not merely a *compromise*, is reached."[27] As such, Agnew recognized with apparent relish that, in the standards-setting process, "the human difficulties are usually much more serious than the technical ones."[28] If the work needed to ensure the

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27 P. G. Agnew, "Standardization," *Encyclopedia Britannica*, Fourteenth Edition (1940); reprinted as "Standards in Our Social Order," *Industrial Standardization* (1940), 7. Emphasis added. Agnew frequently drew this distinction between an adversarial compromise and an integrative solution, where *solutions* often were reached through the use of technical evidence.

28 P.G. Agnew, "Standards in Our Social Order," 6. One eulogy noted Agnew's strong feelings for this process: "To him the procedure which makes it possible for all groups to have a voice in the development of the standards under which they operate represented democracy in action… Dr. Agnew loved the standardization movement and the organization for which he worked. He also

creation of industry and national standards had more in common with diplomacy than it did with laboratory science or factory engineering, then Paul Gough Agnew was its most skilled and longest-serving diplomat.

2.2.1 Legitimacy Through Participation: the Growth of the AESC

Although the AESC consistently used terms such as "consensus," "compromise," and "cooperation," we should not interpret this rhetoric to mean that the growth of the AESC occurred in a frictionless or uncontested way. And although Adams and Agnew were two of the key figures in the "relatively small group that carried the load" during the early years of the AESC, their efforts could succeed only through the participation of other professionals who labored to create industrial and national standards. For the AESC, consensus and legitimacy were the consequences of a strategy to keep their organization intact and relevant to industrial practice. This strategy entailed countless hours of deliberation and debate among hundreds of engineers, managers, and executives, many of whom needed to be convinced of the benefits that could follow from cooperative standardization.

In the first meeting of the AESC, Chairman Comfort Adams suggested a radical increase in membership—from the five founders to, eventually, up to one thousand organizations—that would be necessary if the AESC was to achieve a truly national and

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loved a good fight on its behalf." Eulogy for Paul Gough Agnew prepared by the American Standards Association, 1954. MB6, American Institute of Physics, Niels Bohr Library, College Park, Maryland.

comprehensive scope.[29] Although this was at the time unimaginable for most participants, expansion began immediately and Adams' vision became reality within only a few decades. The first steps toward expansion took place after the first meeting, when the AESC invited the Departments of Commerce, Navy, and War to join the AESC.

By 1919, AESC leaders decided that the admission of additional technical societies, trade associations, and insurance groups was desirable for two reasons. First, given the absence of government financing, the AESC needed to generate more income so it could sustain its operations. Second, AESC leaders saw it could enhance its legitimacy through broader and more inclusive membership. The AESC reported an even balance in its first annual report in 1920, a positive balance of just over $1,000 on January 1, 1921, and a surplus of nearly $6,000 at the end of 1921. Despite this growth, the 1921 Annual Report warned that the group's current income was not sufficient for it to accomplish all the work before it. Forging industrial standards was labor-intensive and costly work, where thousands of dollars needed to be spent on travel, meetings, correspondence, and maintaining an office in New York. To meet these rising costs—costs that would surely increase as the organization endeavored to take on more work—the 1921 Annual Report noted the establishment of a committee on ways and means to

[29] AESC Minutes, 18 Jan. 1919, page 3. Plans for the AESC to play a part in international standardization (along the lines of Henry Hess's initial idea in 1910-11) were articulated in principle, but delayed in practice until an unsuccessful attempt to create an International Standards Association in 1926 and, more successfully, the International Organization for Standardization in 1946.

address the problem.[30] These fund-raising efforts show that, before technical proposals could even be discussed, standardization first required campaigns of persuasion to secure support for their work.

One fundraising tactic was introduced as an institutional innovation in 1922, when the AESC created a class for individual firms called "sustaining members." Sustaining members of the AESC agreed to pay a fee that was determined in proportion to the gross annual revenues of the firm. In exchange, the member would become a subscriber to an extensive AESC "information service" that included a full list of standards—over 2,000 in number—approved by standardization bodies both in the United States and abroad. This information was disseminated in periodic bulletins. The AESC believed that better and more complete information was not only "necessary as a basis of sound work," but also a vital "basis for that cooperation which is essential to real standardization." This was a good way for firms that lacked the personnel or funds to become full AESC members to benefit from AESC activities. The initiative met with immediate success: 228 companies joined as sustaining members in 1923. By the end of 1924, the AESC had received over $27,000 from sustaining memberships, making it the greatest single source of income for the organization (member dues generated $20,000).[31]

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30 Of the group's income in 1921, 70% (just over $17,000) came from dues, with the remainder coming from corporate and individual gifts. *Work of the American Engineering Standards Committee (Year Book)*, (New York: American Engineering Standards Committee, 1921), 11.

31 AESC Minutes, 14 May 1918, page 1; *American Engineering Standards Committee Year Book* (New York: American Engineering Standards Committee, 1924), 17-18, 56-57; *American Engineering Standards Committee Year Book* (New York: American Engineering Standards Committee, 1925), 62.

For the AESC to claim it was producing truly national standards, the second concern about the group's size and legitimacy was paramount. The links between inclusiveness and legitimacy became evident from the start. The AESC's first major project, initiated in December 1919, was to bring some order to industrial safety practices and regulations that sprang up in the 1910s out of a dizzying array of jurisdictions, including state regulatory bodies, manufacturers, insurance companies, and safety organizations. The task of developing safety standards within the AESC occurred after the Bureau of Standards, prompted by the National Safety Council, sponsored two conferences in 1919 on the standardization of safety codes. The Bureau of Standards did not see itself as an appropriate forum for the establishment of safety codes. Its budget—already insufficient for it to perform its core mission—was controlled by Congress, which was unwilling to allocate further funds for something that industry could accomplish by itself. Further, private firms viewed safety codes promulgated by the Bureau as unwelcome federal regulation, and had no enthusiasm for lending more power to the Bureau. Consequently, the Bureau handed the task to the AESC, which it perceived to be the only organization capable of fostering cooperation between representatives from industry and government. However, when the AESC began its work, it was immediately besieged by protests from industrial executives who complained that the organization was "entirely too undemocratic and narrow in its set-up to be entrusted with so important a program."[32]

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[32] Mark Aldrich, *Safety First: Technology, Labor, and Business in the Building of American Work Safety, 1870-1939* (Baltimore: The Johns Hopkins University Press, 1997), 103; P. G. Agnew, "Twenty-

The AESC's response to this critique was to continue to welcome participation from additional groups. By 1920, representatives from the five founding societies and three government departments had been joined by over a dozen trade associations, six technical professional societies, ten insurance or safety groups, and the Departments of Agriculture and the Interior. At this time, twenty-two projects were underway to create safety codes for such diverse areas as aviation, ladders, lightning protection, machine tools, mechanical refrigeration, and industrial sanitation.[33] To help manage the organizational complexity involved in the standardization of safety codes and other areas of industrial practice, particularly in areas where substantial effort to create standards already existed, the AESC established a National Safety Code Committee (chaired by Sidney J. Williams of the National Safety Council) as well as a General Correlating Committee for Mining Standardization (chaired by E. A. Holbrook from the Department of the Interior).[34] Agnew maintained personal involvement by serving as Secretary for both committees.

The AESC grew rapidly during its first few years. This rapid expansion testifies to the promotional abilities of AESC members and their allies, whose campaign for standards found widespread support throughout American industry. The adoption of dozens of AESC safety codes by state governments, insurance companies, and

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Five Years—the American Standards Association (2. Development of the ASA)," *Industrial Standardization* (1943): 322.

[33] For a list of the organizations participating in AESC projects, see *Annual Report of the American Engineering Standards Committee*, (New York: American Engineering Standards Committee, 1920), 11.

[34] For an assessment of mining standardization (including an address by Agnew), see *Proceedings of the Third National Standardization Conference of the American Mining Congress* (Washington, DC: American Mining Congress, 1923).

manufacturers further indicates the success of the these early efforts.[35] By 1921, representatives from 179 organizations and companies (or "cooperating bodies") were involved in 79 AESC projects, with another 70 companies providing additional financial support.[36]

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[35] See P. G. Agnew, "The National Safety Code Program," *Annals of the American Academy of Political and Social Science* 123 (1926): 51-54; P. G. Agnew, "Twenty Years of Standardization," 232-233; "States Curb Loss of Life by Using American Standard Safety Codes," *Industrial Standardization* 6 (1935): 266-270; and Leslie Peat, "The Place of Safety Codes in the Industries," *Safety Engineering* 70 (1935): 173-174.
[36] *Work of the AESC* (1921), 19-27.

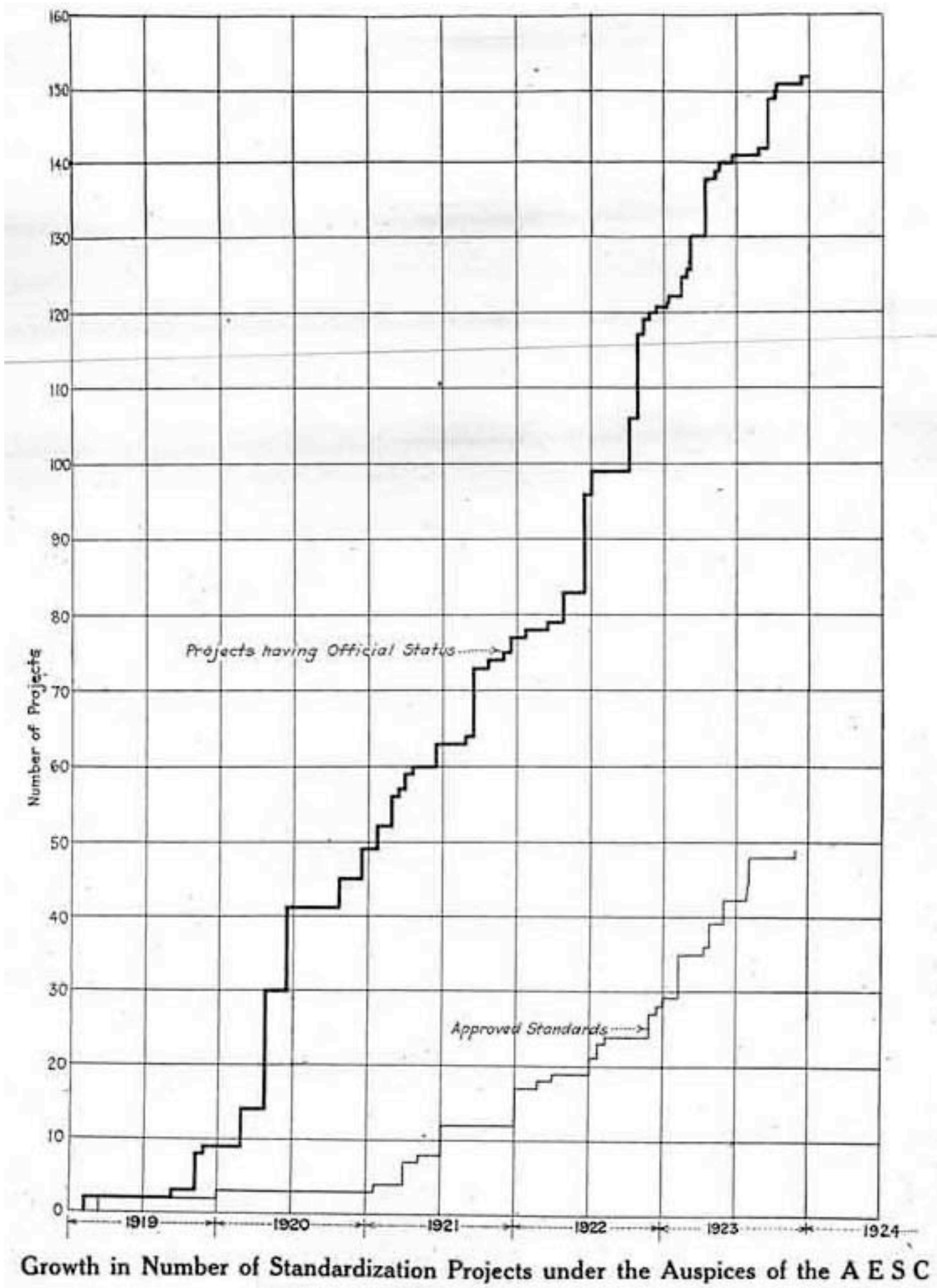

Figure 2.2: Number of AESC Standardization Projects, 1919-1924.
Source: *AESC Year Book*, 1924.

2.3 The AESC and Herbert Hoover's Associative State

The growth of the AESC and its establishment as a legitimate forum depended not only on its internal changes, but also on its external relationships, especially with the United States federal government. A consideration of these external relationships helps to establish the significance of the AESC within the broader context of American political and economic history. To accomplish this, we need look no further than "the engineering method personified," Herbert Hoover.[37] In general, historians regard Herbert Hoover's role in American economic history—epitomized by his inadequate response to the Great Depression that occurred during his presidential administration—as a "tragic failure." However, as revisionist accounts from historians such as Ellis Hawley and David Hart have shown, this caricature overlooks Hoover's ideological and organizational contributions during his tenure as Secretary of Commerce from 1921 to 1928.[38]

Hawley coined the term "associative state" in 1974 to refer to Hoover's broad cooperative program, but he noted that Hoover and his associates used labels such as "progressive democracy" or the "American system" to capture the social and political character and distinctiveness of their approach. Hoover's "associative vision" was

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[37] "Engineering method personified" is an accolade from Morris L. Cooke, quoted in Layton, *The Revolt of the Engineers*, 179.
[38] See Hawley, "Hoover and the Vision of an 'Associative State'"; and Ellis W. Hawley, "Three Facets of Hooverian Associationalism: Lumber, Aviation, and Movies, 1921-1930," in Thomas K. McCraw, ed., *Regulation in Perspective: Historical Essays* (Boston: Harvard University Press, 1981), 95-123. Hart's work is particularly attentive to the enduring institutional and ideological significance of Hoover's vision of cooperation between public officials and individuals in private industry. See David M. Hart, *Forged Consensus: Science, Technology, and Economic Policy in the United States, 1921-1953* (Princeton: Princeton University Press, 1998); and David M. Hart, "Herbert Hoover's Last Laugh: The Enduring Significance of the 'Associative State'" *Journal of Policy History* 10 (1998): 419-44.

nothing short of a comprehensive diagnosis of and response to the problems of American industrial society. Hoover advanced a sharp critique of the institutional superstructure of the American political economy in the first decades of the twentieth century, casting as villains the power-hungry trusts in private industry and inefficient bureaucrats in the government. Not content to fill the role of social critic, Hoover also pointed a way forward. His version of progressivism consisted of a social philosophy centered on a plan to harness "American individualism" to increase industrial efficiency, social harmony, and American power in the international arena.

Hoover, like his contemporaries in America and abroad, was deeply moved by the unprecedented mobilization of national resources during World War I. Hoover's personal experience in the reconstruction of post-war Europe established his public image as a compassionate and competent administrator, and convinced him of the benefits that could flow also from cooperation during peacetime. Moreover, the experience provided a clear indication that if such cooperation were to occur, it would have to draw on individuals and firms in the private sector. The opportunity to put these lessons into practice presented itself in the early 1920s, when Hoover and a group of like-minded associationalists opportunistically "moved into the policy vacuums opened by Warren Harding's willingness to recruit and defer to the nation's 'best minds.'"[39]

The new cooperative ethos was articulated clearly and prominently in the 1921 report *Waste in Industry*, composed by the Committee on Elimination of Waste in Industry that was appointed by Hoover in his capacity of President of the Federated

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[39] Hawley, "Three Facets of Hooverian Associationalism," in *Regulation in Perspective*, 99-100.

American Engineering Societies. The preface and Hoover's own foreword to *Waste in Industry* boasted that the report represented "the combined effort of about eighty engineers and their associates"—an exemplar of coordinated and applied expertise, "carefully planned and rapidly executed" in only five months. After identifying the sources and causes of waste, the report outlined recommendations for every branch of civil society: management, labor, owners, the public, trade associations, and government. Standardization in various guises—in factory equipment and production, through trade associations, and with the assistance of government—featured prominently in the recommendations. The report also spoke of "the duty of the engineer" to use his skills and social standing to overcome economic conflict and eliminate waste in industry. The report used a rhetorical strategy—which became increasingly common in the 1920s—that utilized estimates of millions and in some cases billions of dollars that could be saved through simplification, standardization, and the elimination of waste.[40] Although it did not fully accomplish its lofty goals, *Waste in Industry* was a landmark of engineering analysis and organizational prescriptions for American social problems.[41]

As the historian of engineering Edwin Layton has explained, Hoover, unlike many of his contemporary reform-minded engineers, did not view engineers as the vanguard of a new social order. Instead, Hoover believed that the engineer's civic orientation and skills in planning, organization, and rational thought made him an ideal

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[40] See for example Stuart Chase and F. J. Schlink, "A Few Billions for Consumers," *The New Republic* (December 20, 1925): 153-155; and Stuart Chase and F. J. Schlink, "A Few Billions for Consumers," *The New Republic* (January 6, 1926), 180-182; and Ray M. Hudson, "Organized Effort in Simplification," *Annals of the American Academy of Political and Social Science* 137 (1928): 1-8.
[41] Federated American Engineering Societies, *Waste in Industry* (New York: McGraw-Hill, 1921), vi, ix, 33. See also Layton, *Revolt of the Engineers*, 189-205.

candidate for working as a facilitator and prime mover within the associative machinery that would both celebrate and enhance his vision of "American individualism."[42]

Historians have sketched in great detail the associative machinery that Hoover built in pursuit of this vision during his tenure as Secretary of Commerce. For example, the Bureau of Standards more than doubled in size under his leadership and became the home of two new divisions—the Building and Housing Division and Division of Simplified Practice—whose purpose was to assist the "sick industries" identified in *Waste in Industry*. Hoover also made some headway with his vision beyond his own Department, and was able to bring the Patent Office and the Bureau of Mines under his influence. He also established associative programs in areas such as power and waterway development, aviation, transportation, unemployment planning, child welfare, and emergency health services. In all, Hoover's efforts reached nearly 400 committees and private associations.[43]

Cooperative institutions in general, and trade associations in particular, played a key role in Hoover's associative vision. In the early 1920s, a number of business professionals and regulators sought to establish the legitimacy of trade associations by drawing distinctions between legal trade association activities and the illegal and anticompetitive actions of trusts and cartels. Two studies published in the early 1920s—one in 1922 by Federal Trade Commission lawyer Franklin D. Jones and a second in 1925 by the National Industrial Conference Board (a group created by industry leaders in

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[42] Layton, *Revolt of the Engineers*, 192.
[43] Hawley, "Hoover and the Vision of an 'Associative State,'" 121-139.

1916)—described the historical, legal, and economic dimensions of trade associations.[44] Both of these books justified cooperation within trade associations by distancing these organizations from earlier incarnations of business associations, namely the trusts and cartels that had attracted the contempt of the public and the unwelcome scrutiny of government lawyers emboldened by the Sherman Act.

As with the rhetoric of "simplification" and "consensus" advanced by Hoover and the AESC (respectively), the importance of language in shaping public perceptions emerged as a primary concern for these proponents of trade associations. The books published by Jones and the National Industrial Conference Board both emphasized that "cooperation" in trade associations should not be conflated with the trusts, pools, cartels, monopolies, and the harmful collusive behavior of the vilified captains of industry. Rather than restricting production or fixing prices, the proponents of trade associations argued that they engaged in a variety of legal activities, including the dissemination of research on cost and accounting methods, the sharing of trade statistics and credit information, cooperative advertising, cooperative industrial research, and the standardization of products, nomenclature, and practice.

Advocates of trade associations could draw on a sound legal basis for this rhetorical distinction. Hoover was a key figure in this legal and public relations campaign. A 1922 exchange of letters between Secretary of Commerce Hoover and Attorney General Harry M. Daugherty, reprinted as an appendix in Franklin Jones's book

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[44] Franklin D. Jones, *Trade Association Activities and the Law: A Discussion of the Legal and Economic Aspects of Collective Action Through Trade Organizations* (New York: McGraw-Hill, 1922); National Industrial Conference Board, *Trade Associations, Their Economic Significance and Legal Status* (New York: National Industrial Conference Board, 1925).

Trade Association Activities and the Law, brought some clarity to the legal status of business cooperation in trade associations. The "informal" and "tentative" exchange clarified the legality of trade association activities that stopped short of suppressing competition or inflating prices, and encouraged the AESC and trade associations to "further and extend standardization activities."[45] In its 1924 Annual Report, the AESC happily noted the correspondence between Secretary Hoover and Attorney General Daugherty and declared, "Fortunately it is everywhere recognized that standardization is a legitimate and constructive association activity."[46]

In two cases decided in June 1925, the U. S. Supreme Court validated this shift toward a more favorable view of trade associations.[47] For the Taft Court, the issue boiled down to the need for businesses to collect, share, and analyze information in an increasingly complex world. In earlier eras, this accumulation of knowledge of prices, production, and stock was lumped together with price-fixing and, once the Department of Justice began to enforce the Sherman Act of 1890, considered to be in violation of antitrust laws. With the Supreme Court rulings of June 1925, standardization and other exchanges of statistics and economic data found new, legally stable, footing.[48]

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[45] *AESC Year Book* (1923), 6.

[46] *AESC Year Book* (1924), 18.

[47] Maple Flooring Mfrs. Assn. v. United States, 268 U.S. 563 (1925); Cement Mfrs. Protective Assn. v. United States, 268 U.S. 588 (1925).

[48] See William H. Becker, "American Wholesale Hardware Trade Associations, 1870-1900," *The Business History Review* 45 (1971): 179-200; Louis Galambos, *Cooperation and Competition: The Emergence of a National Trade Association* (Baltimore: The Johns Hopkins Press, 1966), 80-101; William J. Barber, *From New Era to New Deal: Herbert Hoover, the Economists, and American Economic Policy, 1921-1933* (New York: Cambridge University Press, 1985), 7-13; and M. Browning Carrott, "The Supreme Court and Trade Associations, 1921-1925," *Business History Review* 44 (1970): 320-338.

In drafting his opinions for the 6-3 majorities in both cases, Justice Harlan Fiske Stone asked his friend Herbert Hoover for help in examining the role that trade associations played in promoting economic stability.[49] Hoover must have been delighted to oblige and further establish his central role in the increasingly favorable view of business in the New Era. Stone's opinion in the Maple Flooring case denied that the exchange of information by itself constituted a price-fixing arrangement: "Competition does not become less free merely because the conduct of commercial operations becomes more intelligent through the free distribution of knowledge of all the essential factors entering into the commercial transaction."[50] As one contemporary assessment concluded, "Intelligence, the Supreme Court declared, is not necessarily a crime."[51]

Thus by 1925, we can see a harmonization between the Supreme Court's interpretation of antitrust law on the one hand, and, on the other, Hoover's vision of the importance of private sector cooperation in the reduction of industrial waste. The combined effect of Hoover's policy entrepreneurship and the Court's newly relaxed attitude settled the legal status of cooperation, provided the trade associations with a defense from allegations of anti-competitive conduct, and helped them to frame their actions in the cooperative ideology of industrial simplification, economic efficiency, and social stability. The only remaining legal questions surrounding trade associations concerned the fixing of prices. Since technical standardization in the AESC never

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[49] Carrott, "The Supreme Court and Trade Associations, 1921-1925," 335.
[50] Maple Flooring Mfrs. Assn. v. United States, 268 U.S. 563, 583.
[51] Gilbert H. Montague, "New Opportunities and Responsibilities of Trade Associations as a Result of Recent United States Supreme Court Decisions," *Proceedings of the Academy of Political Science in the City of New York* 11 (1926): 27.

broached the dangerous topic of prices, the process of setting standards remained safe from antitrust prosecution.[52] Agnew commented on this happy aspect of his organization's history in 1951: "In the 32 years in which ASA has been in existence, no question or suspicion of violation of anti-trust laws has been raised in connection with ASA operations, conferences, or committees."[53]

Despite the clear conceptual links between Hoover's engineering vision in the early 1920s and the consensus-building activities of engineers in the AESC at the same time, the extensive historical literature on Hoover and his associative initiatives completely neglects the AESC. This omission is surprising: not only did the AESC embody and advance Hoover's associative vision in a very clear way; Hoover also took a personal interest in the AESC, and maintained correspondence and personal relationships with AESC Chairmen and its Secretary Agnew. Secretary Hoover's personal involvement with the AESC illustrates his favorable view of the group's standardization work. Although Hoover did not appear to take a special interest in standardization when he was president of the American Institute of Mining Engineers in 1920 (when it was a founding member of the AESC), he was an important ally in the AESC's efforts to rationalize and coordinate industrial standardization.

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[52] Trade associations became the object of controversy once again during the National Recovery Administration; but collaborative standardization remained uncontroversial and has only rarely—and indirectly—been the focus of antitrust scrutiny. See Simon N. Whitney, *Trade Associations and Industrial Control: A Critique of the N. R. A.* (New York: Central Book Company, 1934), 32-60; American Society of Mechanical Engineers, Inc. v. Hydrolevel Corp., 102 S. Ct. 1935 (1982); and Richard H. Stern, "The Antitrust Ghost in the Standard-Setting Machine," *IEEE Micro* 25 (May-June, 2005), 7-9.

[53] P. G. Agnew, "Policy Questions Concerning the Proposed Congressional Charter for the American Standards Association, January 31, 1951 (Xxb1108), *Historical and Policy Papers*, 195.

The early stages of Hoover's relationship with the AESC indicates his clear sense for how the AESC would fit into his program of waste reduction through simplification and standardization. In March 1921, Agnew met with Hoover to discuss the possibility for government support of the AESC in an official yet "quasi-governmental" relationship with the Department of Commerce, to be administered through the Bureau of Standards. Following the meeting, Agnew optimistically drafted a Congressional joint resolution for Hoover's consideration. Through the draft resolution, Agnew hoped Congress would formally authorize representatives from government departments to participate in AESC committees, authorize appropriations from the Treasury Department to the AESC to support its standardization work, and mandate the use of AESC specifications as "the basis for Government purchases of materials, apparatus, and supplies," so long as such actions would not create disadvantages for the government.[54] It was a bold fundraising pitch and attempt at policy entrepreneurship on Agnew's part, but did not succeed as he had hoped. In his response, Hoover expressed appreciation for the sentiment behind this proposal and acknowledged the importance of the AESC's work. However, Hoover stated his characteristic preference to channel voluntary cooperation through a particular department—his department—instead of pursuing such a broad Congressional mandate.[55]

Acting on this ideological preference, Hoover discussed the AESC's role in subsequent months with the AESC Chairman, A.A. Stevenson. Records from AESC

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[54] P. G. Agnew to Herbert Hoover, March 31, 1921, Hoover Commerce Papers, AESC 1921 Folder, Box 23.

[55] Herbert Hoover to P. G. Agnew, April 12, 1921, Hoover Commerce Papers, AESC 1921 Folder, Box 23. See also William R. Tanner, "Secretary of Commerce Hoover's War on Waste, 1921-1928," in Carl E. Krog and William R. Tanner, eds., *Herbert Hoover and the Republican Era: A Reconsideration* (New York: University Press of America, 1984), 1-35.

meetings in 1922 document increasing levels of cooperation, starting with a meeting in Washington in early 1922 between AESC Chairman Stevenson, Chairman-elect Albert Whitney, Secretary Hoover, Bureau of Standards Director Samuel Stratton, and Chief of the Division of Simplified Practice A.W. Durgin. At the March 9, 1922 meeting of the AESC main committee, the AESC approved measures to appoint formal liaisons between the Division of Simplified Practice and the AESC in order to coordinate their efforts "as specific cases arise." Stevenson was appointed as the AESC's representative for work with the Department of Commerce. In turn, Durgin would work "as Mr. Hoover's representative" at the New York AESC offices as the Liaison Officer for the Bureau of Standards and Federal Specifications Board, an organization that was responsible for setting inter-agency specifications within the government.[56]

Secretary Hoover personally addressed his kindred spirits and admiring colleagues at the AESC main committee meeting of June 15, 1922. Hoover noted that the government "can lend a certain prestige" to help overcome the hesitancy of some manufacturers and trade associations in joining the work of collaborative standardization. He also urged the AESC to continue to move the engineering profession to reduce industrial waste through standardization and simplification, which were in his mind essential aspects to protect "the standards of living and wages in this country" from sliding back to pre-war levels. Following his brief address, he and the forty-odd engineers at the meeting discussed some responses to a survey that, at Hoover's request, had been sent to hundreds of organizations and companies to solicit ideas and targets for

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[56] AESC Minutes, March 9, 1922, pages 3-5, from Hoover Commerce Papers, Box 23, AESC Folder.

simplification and standardization—an example of the bottom-up style of work encouraged by the AESC.[57]

We can discern two important threads—one rhetorical, one practical—within the alliance between the AESC and Hoover's Department of Commerce as it developed throughout the 1920s. Hoover and the AESC shared compatible visions of the respective roles of engineers, private industrial firms, and government agencies. They also assumed that they, as engineers, were key players in a movement to increase industrial efficiency as a way of protecting their ideal of the American way of life. The legitimacy of this movement stemmed from its combination of grass-roots voluntarism with a sophisticated institution that could coordinate a wide range of private initiatives, manage disputes within their ranks, and provide the leadership necessary to convert this voluntarism into effective public policy.[58]

By the mid-1920s, AESC engineers, led by their Secretary Paul Agnew, promoted their organization in academic conferences and in the trade and popular press as a successful instance of industry self-governance and voluntary cooperation.[59] These publications demonstrate the ease with which AESC partisans could appropriate and

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[57] Minutes, Joint Meeting of the AESC and the Executive Committee, June 15, 1922, Hoover Commerce Papers, Box 23, AESC Folder.
[58] On legitimacy and interest groups during this period more generally, see Elizabeth Clemens, *The People's Lobby: Organizational Innovation and the Rise of Interest Group Politics in the United States, 1890-1925* (Chicago: The University of Chicago Press, 1997).
[59] Publications from AESC officers and staff included Whitney, "Place of Standardization in Modern Life," 1924; P. G. Agnew, "Results of Standardization of Supplies," *Annals of the American Academy of Political and Social Science* 133 (1924): 269-271; Chase and Schlink, "A Few Billions for Consumers"; P.G. Agnew, "The National Safety Code Program," *Annals of the American Academy of Political and Social Science* 123 (1926): 51-54; P. G. Agnew, "A Step Toward Industrial Self-Government," *The New Republic* (March 17, 1926), 92-95; and P. G. Agnew, "Can Industry Make its Own Law?," *Association Management* (December, 1926).

mobilize associationalist rhetoric to justify their organization's work. The AESC also used its annual reports (called *Year Books*) to publicize government involvement. Each *Year Book* contained a section on "Government Cooperation" that detailed projects and committees sponsored or co-sponsored by government departments and celebrated examples of AESC standards in use by various government departments.[60]

This rhetoric of cooperation also had a substantive basis in the work of the AESC. By 1922, the AESC main committee contained representatives from Departments of War, Navy, Agriculture, Interior, and Labor, while representatives from numerous other departments (including the Post Office and Department of the Treasury) participated in AESC projects. By 1926, the AESC reported that "one or more arms of the government are cooperating in nearly all projects." Significantly, however, Congress refused to authorize government departments to pay the customary $500 membership fee—an indication of Congress's continued reluctance to dedicate federal funds in support of industrial standardization.[61]

The most important—and contested—area of interaction between the AESC and the federal government was with the Bureau of Standards. On the surface, the respective missions of the AESC and Bureau of Standards appeared to be complementary: where the Bureau of Standards was concerned primarily with scientific research for fundamental standards and units for weights and measurement, the AESC worked to establish

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[60] See for example *Work of the AESC* (1921), 7-8, 32; and *AESC Year Book* (1923), 2.

[61] In 1924-25, representatives from the Bureau of Standards were involved in 67 of the AESC's 212 projects in progress; only the ASTM was involved in a comparable portion of the AESC's work. *AESC Year Book* (1925), 54; *AESC Year Book* (1926), 5-6. In its *Year Books*, the AESC consistently noted Congress's refusal to release membership fees for government participation. See for example *AESC Year Book* (1924), 17; and *Annual Report of the AESC* (1920), 6.

agreement around consistent standards for applications in industrial production. The co-existence of the two groups was facilitated by personal relationships in the shape of the formal liaisons and informal meetings and correspondence described above. To a great extent, both organizations benefited from mutual cooperation. The AESC provided an avenue for the Bureau to extend its influence beyond its modest size, and in return the AESC benefited from the technical expertise and political legitimacy carried under the banner of the Bureau and the Department of Commerce.[62]

These complementary missions were sustained by a rhetoric of cooperation, such as in Agnew's publications and in the AESC and ASA *Year Books* that emphasized productive and positive aspects of the relationship. The public rhetoric of cooperation, however, cleverly obscured the persistent tensions and jurisdictional conflicts at the boundaries of the AESC and the Bureau of Standards in the 1920s and beyond. "The two organizations engaged in a sometimes awkward but almost always outwardly civil dance of ostensible mutual support," summarized sociologist Marc Olshan. "But it was a dance in which the AESC increasingly took the lead."[63]

The establishment of the industrial safety code program within the AESC in the early 1920s illustrates how the AESC constructed itself as a more competent and—ironically—more legitimate authority in industrial standardization than the Bureau of Standards. Industrial safety codes were, at heart, an organizational and political problem. Like the situation with pipe fittings and ratings for electrical machinery in the early

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[62] For a broader account of the Bureau of Standards in the 1920s, see Cochrane, *Measures for Progress*, 220-298.
[63] Marc A. Olshan, "Standards-Making Organizations and the Rationalization of American Life," *The Sociological Quarterly* 34 (1993): 319-335.

1900s, a variety of organizations—including state commissions, safety groups such as Underwriters' Laboratories, the National Safety Council, the American Mining Congress, and federal authorities such as the Bureau of Standards—issued a variety conflicting and overlapping codes. The safety rules published by the Bureau of Standards in 1914 and 1915 were particularly irritating for industry executives, who resisted what they perceived as an unwarranted encroachment of federal regulators. Given this lack of support, and the lack of resources to enforce its safety codes, the Bureau of Standards realized by late 1919 that it had lost the jurisdictional struggle. The AESC was in a better position to gain the support of industry and, together with representatives from government, develop a set of consensual (rather than adversarial) safety codes.[64]

The victory of the AESC was a tacit acknowledgment of the AESC as a more suitable institutional mechanism for achieving public policy goals. Rather than struggle within the existing discourse of progressive regulation, where regulators sough to protect the public from the evils of industry through adversarial rules, the AESC safety code program is one indication of a broader shift toward an associative style of political economy. This new style featured an idealized method of rulemaking that followed from the participation and consent of all interested parties, including those that would be subject to regulations. Agnew's 1926 summary of the safety codes program captures this shift toward inclusivity: "Thus, the work of drawing up national safety codes is in the hands, jointly, of those who are responsible for the administrative and legal aspects of the problems involved, of those who have to face the technical, industrial and financial sides

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64 Cochrane, *Measures for Progress*, 121-2; M. G. Lloyd, "The Safety Code Work of the Bureau of Standards," *Industrial Standardization* (1933): 203-206.

of the problems, and of those who have to face the hazards to life and limb."[65] This cooperative style provided industry executives with the opportunity to dilute regulations that might otherwise have been difficult or costly to implement, but this was a palatable compromise for federal policymakers in business-friendly context of the 1920s.

Organized labor had a limited role in this process, even if the AESC was slightly more accommodating to labor than the typical industrial capitalist of the 1920s. Labor representatives did take part in the development of many safety codes, as evidenced by the participation of John P. Frey (who was vice president of the American Federation of Labor) on the Committee on the Foundry Code—despite the objection of the committee chair, W. H. Barr. By 1921, the objections of several executives to labor participation led the AESC Chairman A. A. Stevenson to craft a solution: union representatives would serve on safety code committees, not as representatives of a particular union but instead under the flag of the U. S. Department of Labor. According to Agnew, this compromise was tenable enough to allow the committee to proceed with its work while avoiding the greater underlying tensions between capital and labor. With this procedural compromise, Agnew recalled in 1949, "the union had the substance of representation but not the form." The Department of Labor joined the AESC as a Member Body the next year (in 1922), and the informal arrangement to allow labor participation remained intact until the late 1930s, when the ASA changed its rules to allow direct representation of labor interests in all sectional committees.[66] On the whole, the AESC's concern with labor was limited to

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65 Agnew, "The Safety Code Program," 52.

66 P. G. Agnew, "Labor Representation and Membership in ASA," XX 766, April 20, 1949, *Historical and Policy Papers*, 483-485.

a paternalistic concern with worker safety, and the safety code committees reveal the extent to which business interests dominated standardization in the AESC.[67] The social consequences of technical standardization for workers on site and on the factory floor seem to have been far beyond the concern of the elite engineers and executives in the AESC.[68]

2.4 The AESC: Structure, Process, and Ideology

The AESC, encouraged by the support of Hoover and the rulings of the Supreme Court, pursued a course of organizational expansion that brought trade associations into the group of engineering societies and government departments. Expansion meant a diffusion of power, which the AESC chose to organize along technological and professional lines. Amidst this diffusion of power, the affiliations of the men elected to lead the AESC may be taken as an indication of the group's nexus of power and prestige. Of the four AESC Chairmen elected in its first ten years, two were representatives from the AIEE (Comfort Adams in 1918-1919 and Charles Skinner in 1925-1927), one was from the ASTM (A.A. Stevenson in 1920-1922), and the other was from the National

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[67] In this sense, the AESC is a good example of Gabriel Kolko's conception of "political capitalism," which he defined as "the utilization of political outlets to attain conditions of stability, predictability, and security—to attain rationalization—in the economy." Gabriel Kolko, *The Triumph of Conservatism: A Reinterpretation of American History, 1900-1916* (Chicago: Quadrangle Books [1967], 1963), 3.

[68] For closer analyses of some of the implications of standardization for labor, see Amy Slaton, *Reinforced Concrete and the Modernization of American Building, 1900-1930* (Baltimore: The Johns Hopkins University Press, 2001); Gregory J. Downey, *Telegraph Messenger Boys: Labor, Technology, and Geography, 1850-1950* (New York: Routledge, 2002); and Amy Slaton and Janet Abbate, "The Hidden Lives of Standards: Technical Prescriptions and the Transformation of Work in America," in Michael Thad Allen and Gabrielle Hecht, eds., *Technologies of Power: Essays in Honor of Thomas Parke Hughes and Agatha Chipley Hughes* (Cambridge, MA: The MIT Press, 2001), 95-144.

Safety Council (Albert Whitney in 1922-1924). Beneath the political and symbolic power of chairmanship, however, the nitty-gritty work required to agree on standards occurred within specialized committees. A brief description of the organization's structure and process helps illustrate how power was distributed and exercised across the various units—the *member bodies*, *main committee*, *sectional committees*, and *sponsors*—of the organization. A closer look at the AESC also shows how its underlying ideological assumptions and aims fit well with Hoover's associative vision.

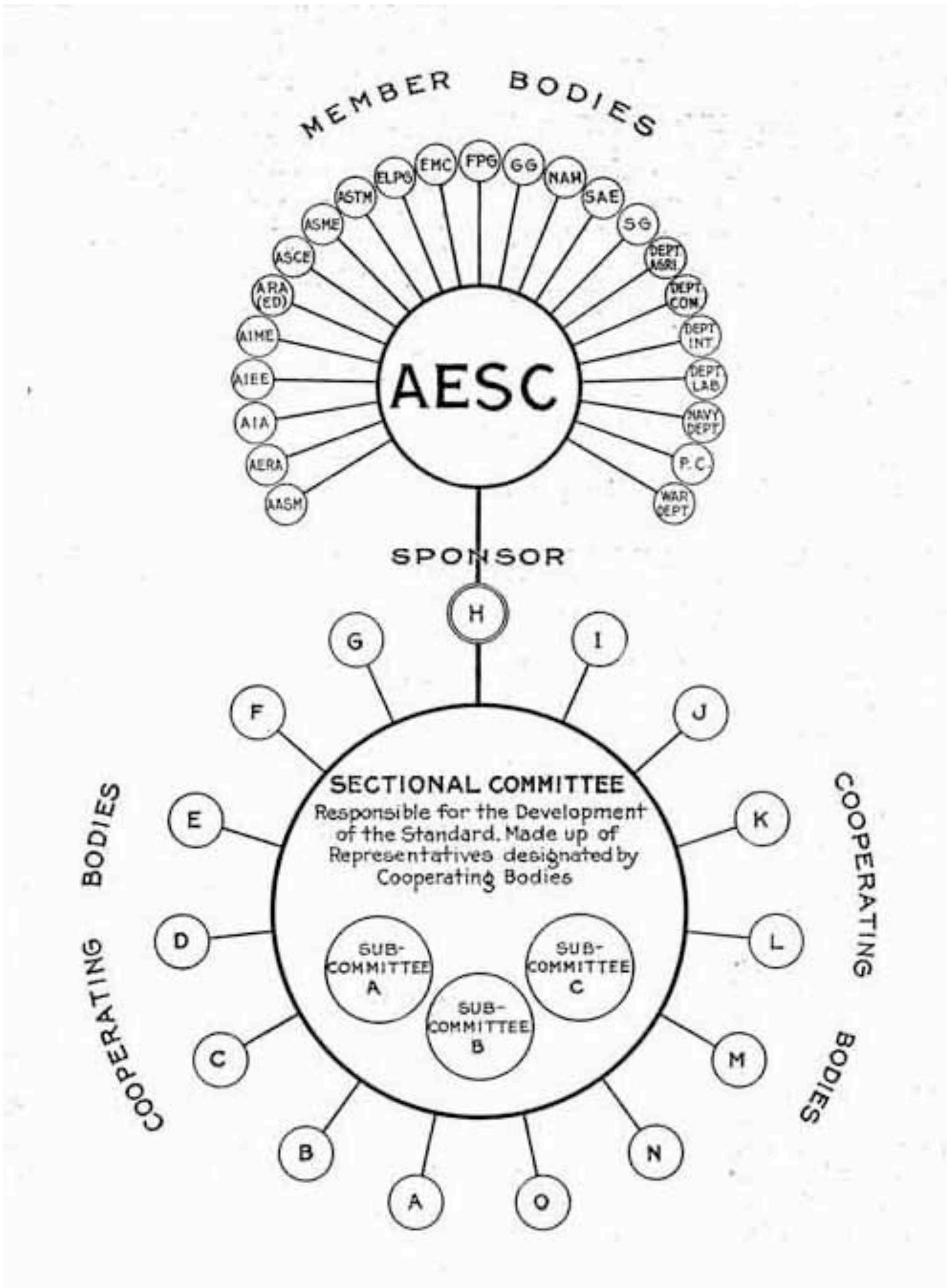

Figure 2.3: Structure of the AESC.
Source: *AESC Year Book*, 1923.

The original AESC *member bodies* were the five founding societies and, after the first meeting, the Departments of War, Navy, and Commerce. As noted above, membership grew from these original eight organizations to twenty-four in 1927.[69] Member bodies designated up to three representatives to serve on the *main committee*, which identified itself as "solely an administrative and policy-forming body, [which] does not concern itself with technical details."[70]

The actual work of creating standards began with a request from an organization or coalition of organizations (known as a *sponsors*) upon which the main committee would seek to ensure that all interested parties were aware of and invited to participate in the initiative.[71] Sponsorship entailed administrative duties, but, in this context, did not carry the financial obligations that we, in more recent times, have come to associate with the word sponsorship. Sponsors did not necessarily have to be one of the AESC member bodies—for example, the American Society of Refrigerating Engineers sponsored the safety code committee for Mechanical Refrigeration, but was not a member of the AESC.

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[69] These additional sixteen member bodies were: the American Electric Railway Association; the American Institute of Architects; the American Mining Congress; the American Railway Association—Engineering Division; the Association of Steel Manufacturers; the Electric Light and Power Group (consisting of the Association of Edison Illuminating Companies and the National Electric Light Association); the Fire Protection Group (consisting of the Associated Factory Mutual Fire Insurance Companies, the National Board of Fire Underwriters, the National Fire Protection Association, and Underwriters' Laboratories); the Gas Group (consisting of the American Gas Association, the Compressed Gas Manufacturers' Association, and International Acetylene Association); the National Electrical Manufacturers' Association; the Panama Canal; the Safety Group (consisting of the National Bureau of Casualty and Surety Underwriters and the National Safety Council); the Society of Automotive Engineers; the Telephone Group (consisting of the Bell Telephone System and the United States Independent Telephone Association); the U. S. Department of Agriculture; the U. S. Department of the Interior; and the U. S. Department of Labor.

[70] *Annual Report of the American Engineering Standards Committee* (1920), 5. A member body paid $500 for each representative it placed on the main committee.

[71] See "Rules of Procedure (Revised October, 1920)," *Annual Report of the American Engineering Standards Committee* (1920), 7-8.

The sponsor led the development of the standard within one of the AESC *sectional committees*, which were organized along industry lines.[72]

This delegation of technical work achieved two goals. First, it reduced complex discussions to manageable proportions and prevented the main committee of the AESC from becoming embroiled in technical disputes where they lacked experience. Second, it assigned technical discussions to qualified experts, and ensured that groups participated only in projects where they had a direct interest. Agnew used a political metaphor to describe this aspect of the process: "Each of these sectional committees… is essentially a miniature industrial legislature organized upon a subject basis instead of upon a geographical basis."[73]

This federation of "industrial legislatures" was an organizational strategy as well as a manifestation of an associative political philosophy. In a 1926 article published in *The New Republic* entitled "A Step Toward Industrial Self-Government," Agnew argued that this method of standardization had "all the directness and vitality of elementary local self-government." He continued,

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[72] In 1921, the sectional committees were organized into the following groups: A. Civil Engineering and Construction; B. Mechanical Engineering; C. Electrical Engineering; D. Automotive; E. Transportation; G. Ferrous Metals and Metallurgy; H. Non- Ferrous Metals and Metallurgy; K. Chemical Industry; L. Textile Industry; M. Mining; O. Wood Industry; P. Pulp and Paper Industry; X and Z. Miscellaneous (safety, symbols, general purpose combustion or testing, terminology, film).

[73] P. G. Agnew, "Work of the American Engineering Standards Committee," *Annals of the American Academy of Political and Social Science* 137 (1928): 13-16.

> We do not leave to Congress, or to the vote of 110,000,000 people, the decision whether a bridge shall be built in the city of Oshkosh. We leave it to the people of Oshkosh, who will walk over it and ride over it, and who will have to pay for it. Why should not the very limited groups directly interested in each of the innumerable industrial problems with which they are faced, themselves solve these problems through coöperative effort?[74]

The AESC put this principle of self-government to work through its sectional committees. Sectional committees were responsible for the detailed, technical work that went into the formulating of a particular standard. The makeup of particular sectional committees was at times controversial, since the main committee of the AESC reserved the right to approve the personnel of any given committee. In order to ensure that a sectional committee was "authoritative and adequately representative," the main committee required committees dealing with commercial standards to maintain a balance of "producers, consumers, and general interests." No one of these groups could form a majority on a sectional committee without the consent of the other two groups. Safety code committees required an even broader distribution of representatives, including manufacturers, employers, employees, governmental bodies, technical specialists (such as unaffiliated or academic experts), and insurance representatives.[75] This requirement would be lifted—in the name of greater flexibility and autonomy of sponsors and member-bodies—when the AESC was reconstituted as the ASA in 1928.

During the work of the sectional committee, a proposed standard was referred to as a "Recommended Practice" or "Tentative Standard." When a sectional committee

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[74] P. G. Agnew, "A Step Toward Industrial Self-Government," *The New Republic* (March 17, 1926), 95.

[75] "Rules of Procedure, Revised June 15, 1922," *American Engineering Standards Committee Year Book* (New York: American Engineering Standards Committee, 1923).

finished its work, it would submit the proposed standard to the AESC main committee. The main committee's role was judicial, not technical. The main committee did not examine the technical content of the proposed standard. Instead, it only checked to see if the sectional committee followed a fair and representative process that addressed the concerns of all interested parties—in short, to verify the legitimacy of the "industrial legislature." This separation of function was summarized in the "Method of Work" section of the 1920 Annual Report:

> Each industry, or branch of industry, is wholly autonomous in its standardization work, the function of the Main Committee being merely to assure that each body or group concerned in a standard shall have opportunity to participate in its formulation.[76]

Once a sectional committee reached consensus around a Tentative Standard, it submitted it to the main committee for a vote. If 90% of the votes were in favor, the specification would be published by the AESC as an "American Standard."[77] This division of technical and judicial labor was reinforced when the AESC Constitution and Procedure were redrafted in 1928. The revised Procedure began with these words:

> 101. A national standard implies a consensus of those substantially concerned with its scope and provisions. A chief function of the American

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[76] *Annual Report of the American Engineering Standards Committee, 1920* (New York: American Engineering Standards Committee, 1920), 5-6.

[77] In 1919, Comfort Adams summarized the entire process with admirable brevity: "Standard assigned by main committee to sponsor body. Sponsor body appoints a thoroughly representative sectional committee, subject to approval of main committee. Sectional committee prepares standard and submits to sponsor body which then submits the standard with its approval to the main committee. The standard is then published by the sponsor body and labeled 'American Standard.'" Adams, "Industrial Standardization," 298. In its "Rules of Procedure," the AESC "requested that cooperating bodies do not use the term 'American Standard' in their publications except in connection with a standard that has received approval of the Main Committee as such." *Work of the American Engineering Standards Committee (Year Book*), (New York: American Engineering Standards Committee, 1921), 17.

> Engineering Standards Committee is the judicial one of determining whether a national consensus has been reached.[78]

A qualitative political judgment—"the consensus of those substantially concerned"—thus became enshrined as the leading principle of the AESC. To become an "American Standard," a technical specification would first have to pass through this political process and judicial test. By creating separate spheres for the "technical" and the "judicial," the AESC tenuously charted a course that preserved the authority of members while simultaneously setting conditions that would ensure that the expert consensus would not be dominated by one powerful actor. This division of "technical" and "judicial" tasks was an important step in addressing the reservations of member societies, such as the ASTM, that were eager to preserve their own authority to set standards.

The AESC leaders also recognized that it needed to remain flexible in its methods and especially in the periodic revision of established standards. From the beginning, the AESC Constitution included provisions for the revision of American Standards. In the 1919 version of the Constitution, such revisions were not permitted until three years after the completion of the original standard. By 1922, however, the three-year requirement was dropped in favor of a clause that allowed revisions to standards on a case-by-case basis, "at such intervals as shall be agreed upon by the Main Committee and the Sponsor

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78 "Procedure (Revised to March 8, 1928)," *American Engineering Standards Committee Year Book* (New York: American Engineering Standards Committee, 1928), 68.

or joint Sponsors."[79] Agnew later compared this flexibility in the AESC procedures favorably to the "rigidity of legislative enactment." One of his dearest convictions was a philosophical and social assumption that was at the heart of the AESC enterprise: technical experts, once confronted with clear and objective evidence, could move quickly to make the right technical decisions, unencumbered by the bureaucratic weight of government regulation or the legislative process. He had no doubt that technical experts working in a collaborative process would not allow standardization to detract from the progress of technology. "The danger of stagnation lies," he concluded, "not in the use of standards, but in taking a fixed mental attitude, instead of keeping the mind receptive to new ideas."[80]

From the preliminary discussion that began in the early 1910s through the first decade of the AESC's existence, its most significant controversies grew out of conflicting visions over the strength of the AESC vis-à-vis its member societies. Agnew later referred to this tension as the "states' righters versus federalists" controversy. Adams, Agnew, and other AESC leaders advocated a strong central body with the power to resolve conflicts between members. Some representatives—particularly those from the ASTM—protested that the AESC should be a weak central body, thus preserving the authority of the member bodies and their standards committees. This tension was at the heart of persistent struggles within the AESC process, and became the key point of

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79 "Constitution of the American Engineering Standards Committee (Revised August 16, 1919)," *Annual Report of the AESC* (1920); "Rules of Procedure (Revised February 14, 1922)," *Work of the AESC (Year Book)* (1921).

80 Howard Coonley and P. G. Agnew, *The Role of Standards in the System of Free Enterprise: a study of voluntary standards as alternative to Legislative and Commission control. Prepared by Request of the Temporary National Economic Committee* (New York: American Standards Association, 1941).

contention as the AESC underwent significant reforms and reconstituted itself as the American Standards Association in 1928.[81]

2.4.1 The AESC Becomes the American Standards Association, 1928-1929

The momentous changes of 1928 were driven by three factors: the increased interest in standardization from industry executives, the rapid growth of standardization in trade associations, and the need to maintain flexible procedures in order to sustain the strength of the AESC in the face of organizational competitors. The AESC had already taken a step to bring more executives into the fold when, at the request of a 1925 Conference of Industrial Executives, the AESC formed an Advisory Committee of Industrial Executives.[82] Executives assumed an even greater role in 1928, during a fundamental reorganization of the management of the AESC that culminated in the reconstitution of the AESC as the American Standards Association (ASA).[83] As part of

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[81] See Agnew, "Twenty Years of Standardization," 230-232; Adams, "How the AESC Was Organized," 237-8; and AESC *Year Books* between 1920 and 1928. Resistance from the "states' righters" (led by ASTM representatives) continued at least into the late 1940s, as evidenced by a testy exchange of letters in 1947 over procedural matters between Agnew and his longtime colleague C.L. Warwick, Executive Secretary of the ASTM. P.G. Agnew, "Letter to ASTM, 9/10/47 – ASA Policy in the Initiation of Projects (BD 244)," in Paul Gough Agnew, *Historical and Policy Papers* (American Standards Association, Inc., 1920-1952), 564-573.

[82] This committee was composed of five executives, including a vice-president of New York Edison and the presidents of U.S. Steel, Consolidated Gas Company of New York, The Delaware & Hudson Company, and General Electric. *American Engineering Standards Committee Year Book* (New York: American Engineering Standards Committee, 1926), 4.

[83] In July 1928, the AESC main committee voted unanimously to support the proposed reforms. The proposal was then submitted to the thirty-seven Member Bodies, whose unanimous approval was announced in November 1928. "Scientific Events: The American Standards Association," *Science*, New Series, Vol. 68, No. 1751 (July 20, 1928), 53; and "The American Standards Association," *Science*, New Series, Vol. 68, No. 1768 (November 16, 1928), 473-474.

this reorganization, the AESC main committee was dissolved, with its functions divided into two new groups: a Board of Directors and the Standards Council.

This change was richly rewarded. The Board of Directors consisted of twelve executives who were selected by AESC member bodies to assume the administrative and financial responsibilities of the AESC main committee. The creation of the Board of Directors reflected a rising awareness of managers and executives of the importance of standardization, including "purchasing, production, accounting, inspection, service, sales, and in every other department of manufacturing organizations."[84] The ASA announced in 1929 the creation of an Underwriters' Fund to support the expanded scope of the organization. A finance committee, led by AT&T vice president Bancroft Gherardi and Bethlehem Steel vice president Quincy Bent, was appointed to solicit contributions from industrial firms. They found immediate success: in 1929 alone, this fund was responsible for adding $74,000 to the ASA's annual income of $54,000, and in 1930 announced that they had obtained the means to increase their budget by $500,000 over the next three years.[85]

The remaining procedural duties of the AESC main committee were assumed by the newly created Standards Council that, like the main committee it replaced, consisted

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[84] *American Standards Year Book* (New York: American Standards Association, 1929), 7.
[85] "Unity of Standards Sought by Industry," *The New York Times* (July 10, 1929), 50; "Plan to Enlarge Standards Work," *The New York Times* (January 5, 1930), N21; William J. Serrill, "President's Report," *American Standards Year Book* (New York: American Standards Association, 1930), 9-10. Serrill noted the contributions of the following companies in 1929, which funded the addition of several engineers to the ASA staff to support safety code work, electrical standardization, and mechanical standardization: Aluminum Company of America, American Telephone and Telegraph, 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, U.S. Steel, Westinghouse Electric and Manufacturing Company, and Youngstown Sheet and Tube Company.

of up to three representatives from each member body.[86] The new ASA Constitution enumerated the jurisdiction of the Standards Council:

> The functions of the Council shall be to formulate rules for the development of standards and for the constitution of committees; to approve, on behalf of the Association, such standards as it may find to be supported by a consensus, affirmatively expressed, of those substantially concerned with the standard; but not to formulate standards.[87]

With its functions divided between the new Board of Directors and Standards Council, the AESC Main Committee was dissolved.

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86 "Standards Group to Broaden Scope," *The New York Times* (July 8, 1928), 40; "Scientific Events: The American Standards Association," *Science*, New Series, Vol. 68, No. 1751 (July 20, 1928), 53-54.
87 "Constitution," *American Standards Year Book* (1929), 82.

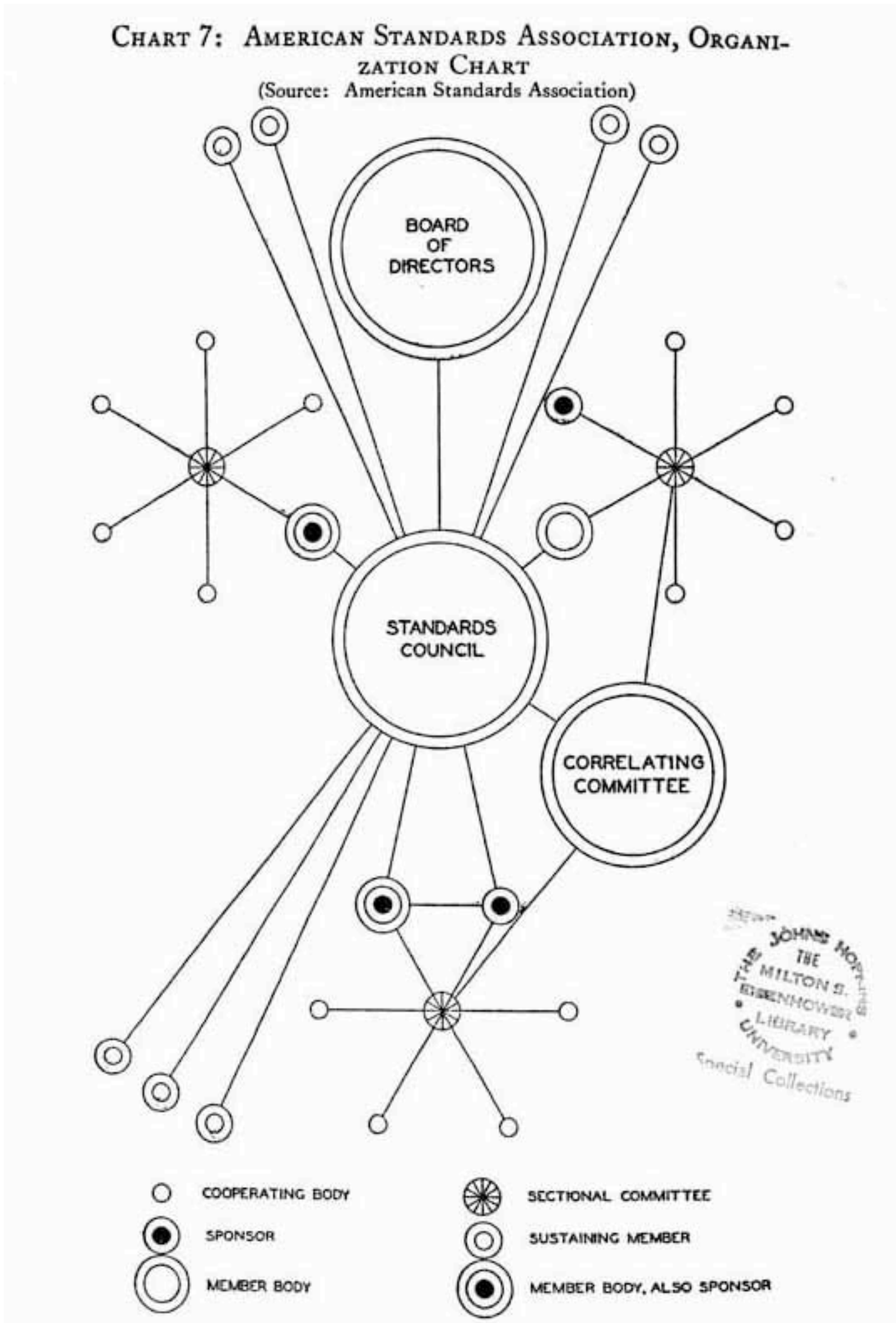

Figure 2.4: Structure of the ASA.
Source: National Industrial Conference Board, *Industrial Standardization*, 1929.

The 1928 reorganization also reflected recognition of the prominence of trade associations within the AESC and in industrial standardization more generally: of the 350 organizations participating in AESC activities in 1928, almost 300 were trade associations.[88] This shift in the composition of the AESC from technical and engineering societies toward trade associations indicates that standardization was not only an important technical concern; it was also widely recognized as a vital activity for running a successful business. One symbol of this shift came with the election of William J. Serrill, a representative of the Gas Group (a coalition of trade associations), as AESC Chairman in 1928. After the change from AESC to ASA, Serrill became ASA President and Standards Council Chairman until 1930.

The most visible symbol of the shifting membership of the organization was the group's new name, adopted in 1928: the American Standards Association (ASA). By removing "engineering" from the title of the organization, the ASA indicated a major step in its evolution, moving away from a committee to harmonize engineering standards toward a broader and more inclusive association of all industrial standardization in the United States. The 1929 *American Standards Year Book* noted that a good example of this change was the initiation of committees to set standards in areas such as household goods, although it hastened to add that the ASA "limits itself strictly to those fields in which engineering methods apply, not concerning itself in any way with questions of style or personal taste."[89] This and other forays into consumer standards made standards engineers a target for satire, as Herbert Hoover later recalled: "At that time [the 1920s],

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88 "Standards Group to Broaden Scope," *The New York Times* (July 8, 1928), 40.
89 *American Standards Year Book* (1929), 7.

the humorists sought to drown us in laughter over possible standardized women's hats. But in time we managed to sustain the conviction that we were wholly allergic to matters of style, for those vagaries were offspring of joy, not of engineering."[90]

Procedures for the development of American Standards also changed markedly in 1928, further reflecting the organization's flexibility and willingness to accommodate the needs of its member organizations. In 1928, the reconstituted ASA outlined four distinct methods that could be used to create American Standards: the Sectional Committee Method, Existing Standards Method, Proprietary Standards Method, and General Acceptance Method. Of these four, only the Sectional Committee Method was in use before 1928 in the AESC. The only change to this method under the ASA rules provided greater freedom for the sectional committee, which could choose either to retain its affiliation with a sponsor body or, instead, report directly to the Standards Council.

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[90] Herbert Hoover, "The Crusade for Standards," in Dickson Reck, ed., *National Standards in a Modern Economy* (New York: Harper and Brothers, 1956), 3. Hoover continued, "we even helped to cheapen some hats by way of simplifying and standardizing parts in the milliners' machinery."

Figure 2.5: ASA Sectional Committee Method After 1929.
Source: American Standards Association, *Voluntary Standards*, 1946.

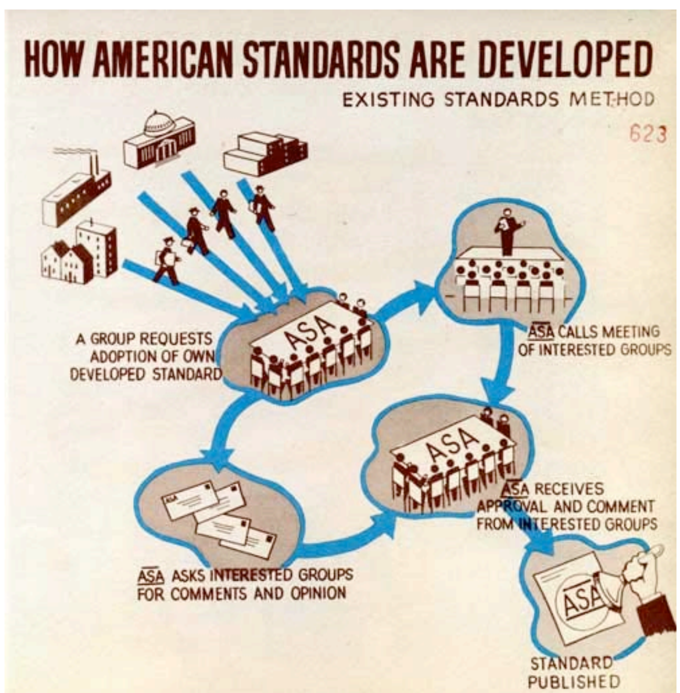

Figure 2.6: ASA Existing Standards Method After 1929.
Source: American Standards Association, *Voluntary Standards*, 1946.

The adoption of the Existing Standards Method was the most evident outcome of the power struggle between the AESC and its member bodies. The ASA would approve standards through the Existing Standards Method if the submitting body could demonstrate it had obtained an industry consensus on its own. Although not advertised as such, the adoption of the Existing Standards Method was an acknowledgment of the need to recognize the autonomy of powerful member societies, namely the ASTM, which had consistently opposed the construction of the AESC as a strong central body. By the late 1920s, the ASTM sponsored somewhere between one-third to one-half of the standards under development in the AESC, making it the most productive constituent in the AESC federation. The Existing Standards Method enabled the blessing of ASTM (or other standard-setting bodies deemed to be sufficiently representative) standards as American Standards, while avoiding the costs (and redundancies) of convening a sectional committee to gauge consensus. In other words, it was a political solution to a jurisdictional dispute, justified in the rational language of administrative efficiency.

The remaining two, less controversial, new methods were introduced to create other options for a more flexible and streamlined process. Standards developed through the Proprietary Method would be approved if its sponsor could demonstrate the support of "a consensus of those substantially concerned with its development and use." The General Acceptance Method for standards provided a venue for "simple projects" developed in the industry or academic conferences that became commonplace in the 1920s, or other non-exclusionary or *ad hoc* fora that did not merit the effort or cost required to organize a sectional committee. The new ASA rules also permitted greater flexibility in the revision of existing American Standards. Finally, the new ASA Procedure stated that the Standards Council was responsible for gauging the consensus obtained by a standard developed through each of the new methods of standardization. Any controversies over judicial decisions taken by the Standards Council could be appealed on a case-by-case basis, where each appeal would be presented by the ASA Secretary, Paul Agnew.[91]

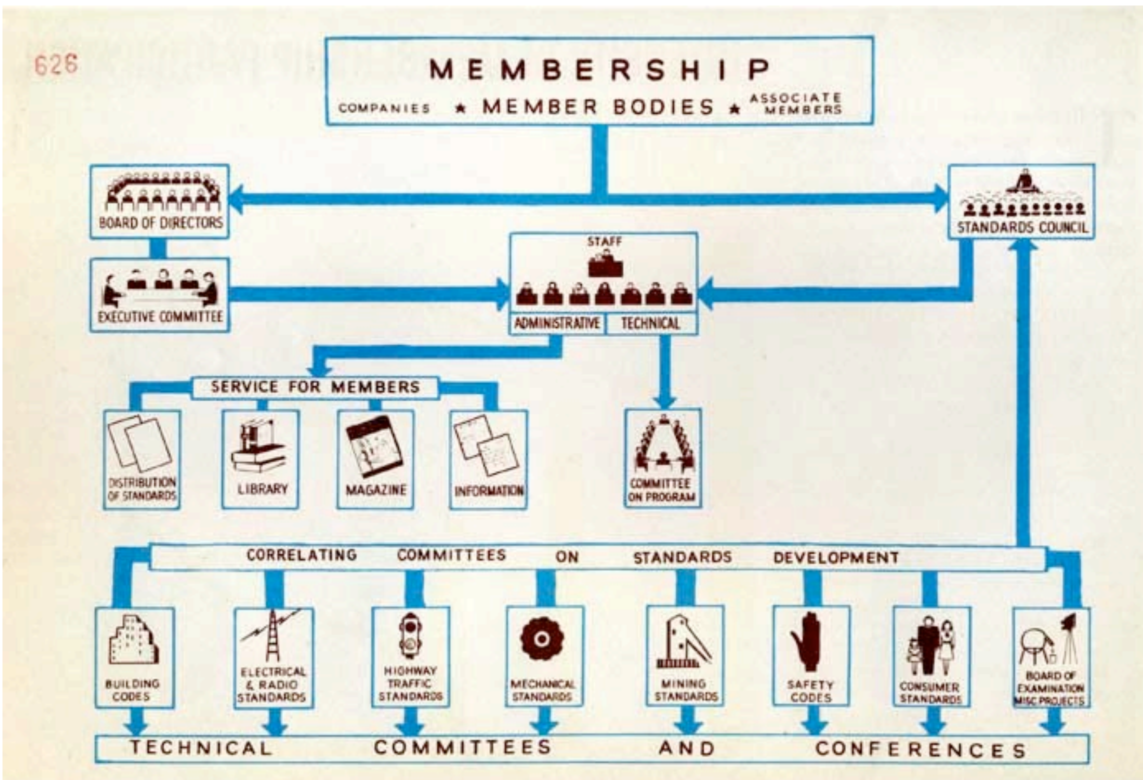

Figure 2.7: ASA Organization Chart, 1946. This representation of the ASA, taken from a 1946 promotional brochure, is essentially unchanged from 1929.
Source: American Standards Association, *Voluntary Standards*, 1946.

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91 *American Standards Year Book* (1929), 8, 83-87.

When the reorganized American Standards Association was announced in 1928, *Science* reported accurately that the changes were approved by unanimous votes, first of the AESC main committee and then of all thirty-seven member bodies.[92] Although this spectacle of unanimity was vital for advancing the cooperative goals of the group, it also reveals the extent to which the leaders of industrial standardization kept their dirty laundry out of the public view. Records from AESC and ASA meetings and some frank historical recollections from Agnew and other ASA officials indicate that the ASA's harmonious public self-representation intentionally obscured heated internal disputes. In 1938, Agnew recalled how J.A. Capp, longtime ASTM representative and head of the AESC Rules Committee from 1921-1925, declared at one point that the name "American Standards Association" would be "adopted only over his dead body." Capp later relented and in fact seconded the motion for adoption of the reorganization plan—which passed with the unanimous vote that was duly noted in *Science*, *The New York Times*, and the 1929 *American Standards Year Book*.[93]

The new Constitution and Procedure were not the result of effortless and harmonious consensus. Instead, they represented structural and procedural compromises that were forged to keep intact the power and prestige of member societies while at the same time establishing the legitimacy of the ASA. Confident in the flexibility and

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92 "Scientific Events: The American Standards Association," *Science*, New Series, Vol. 68, No. 1751 (July 20, 1928), 53; and "The American Standards Association," *Science*, New Series, Vol. 68, No. 1768 (November 16, 1928), 473-474.

93 Agnew, "Twenty Years of Standardization," 232. These sorts of public acknowledgments of controversy are unusual in professional engineering societies. As Edwin Layton noted in his history of the American engineering profession, "It is considered bad form to publicize the inner workings of engineering societies." Edwin T. Layton, *The Revolt of the Engineers: Social Responsibility and the American Engineering Profession* (Cleveland: Press of Case Western Reserve University, 1971), 15.

durability of the ASA federation, and ever reliant upon political metaphors to explain the significance of his cherished institution, Agnew drew a comparison to the increasing formality in the written rules created in the early decades of the American republic. He wrote, "the AESC corresponds to the government under the Articles of Confederation; the American Standards Association as reorganized in 1928 corresponds to our national government under its present constitution."[94] This comparison reveals as much about Agnew's perception of the organization's maturity as it does about Agnew's view of the role and characteristics of the American national government in the first half of the twentieth century.

These institutional and ideological changes provided the foundation for the ASA to succeed in its struggle with the National Bureau of Standards over jurisdiction of industrial standardization in the United States. Between the 1920s and the 1940s, many American policymakers thought that the National Bureau of Standards could promote technical innovation in small businesses by functioning as a clearinghouse for industrial research. This vision never came to pass. As the AESC (and later ASA) grew in size, power, and stature in the 1920s and 1930s, the Bureau of Standards, attacked by critics and crippled by the reduced budgets of the Depression years, never attained the prominence in industrial affairs that its advocates envisioned. By the 1950s, in the assessment of historian Thomas Lassman, this vision of a progressive and active Bureau

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[94] Agnew, "Twenty-Five Years—the American Standards Association," 323.

of Standards had failed to become reality, and the Bureau of Standards retreated from the realm of industrial standardization in order to serve military patrons.[95]

The ASA continued to grow during the Depression, even as circumstances took their toll on the members of the ASA and the money they could dedicate toward creating American Standards.[96] The ASA grew steadily throughout the 1930s and, by the early 1940s, emerged as an important source of cooperation and expertise for the coordinated mobilization of the military and American industry for World War II. In the years immediately following World War II, the ASA—and the consensus principle that it embodied and promoted—continued to flourish.[97]

Year	Member Bodies	Participating Organizations	American Standards
1923	23	235	48
1928	36	350	111
1945	96	650	1507

Table 2.1: Membership, Participation, and Products in the AESC and ASA.
Sources: American Engineering Standards Committee *Yearbook*, 1924; American Standards Association, "Voluntary Standards," 1946.

In response to yet another round of internal and external pressures to reform, the ASA reconstituted itself into the United States of America Standards Institute in 1966. This name was short-lived: in 1969 the group once again reformed itself and adopted its present name, the American National Standards Institute (ANSI). Beyond its new name, ANSI's reforms of 1969 also included structural and procedural changes, including the

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95 For assessments of the problems at the National Bureau of Standards in the 1930s, 40s, and 50s, see Thomas C. Lassman, "Government Science in Postwar America: Henry A. Wallace, Edward U. Condon, and the Transformation of the National Bureau of Standards, 1945-1951," *Isis* 96 (2005): 25-51; and Cochrane, *Measures for Progress*, 299-356.
96 "Group Hears of Gain in Standards Work," *The New York Times* (December 1, 1932), 38.
97 For assessments of the vitality of the ASA and affiliated industry standardization groups in the 1940s and 1950s, see Reck, ed., *National Standards in a Modern Economy*.

redefinition of processes for creating American National Standards. ANSI introduced a regime of accreditation, under which it would examine organizations to ensure that their procedures were in line with the core ANSI consensus principles and methods.[98] This system of accreditation, seen today as an obvious and natural way to distribute fairly the work of creating thousands of technical standards, should be recognized as the latest manifestation of the federalist tensions between the AESC and its member bodies that first surfaced in the "endless discussions" and "innumerable drafts of constitutions and methods of procedure" that Henry Hess, Comfort Adams, Paul Agnew, and their colleagues began to articulate in 1910.

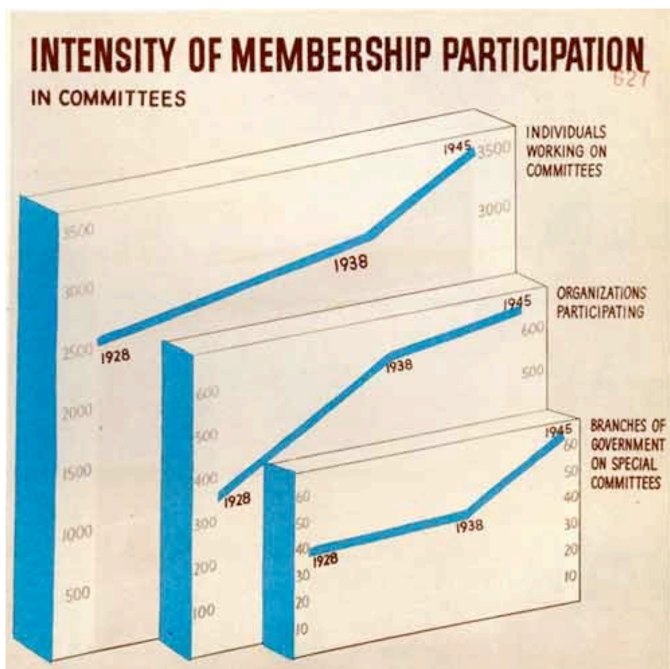

Figure 2.8: ASA Intensity of Participation, 1928-1945.
Source: American Standards Association, *Voluntary Standards*, 1946.

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98 Carl F. Cargill, *Open Systems Standardization: A Business Approach* (Upper Saddle River, NJ: Paladin Consulting, 1997), 159-167. The three methods used by ANSI—the canvass method, the Accredited Organization method, and the Accredited Standards Committee method, bear a close resemblance to three of the four methods articulated by ASA in its revised 1928 Constitution.

Figure 2.9: ASA Approved Standards and Safety Codes, 1928-1945.
Source: American Standards Association, *Voluntary Standards*, 1946.

2.5 Conclusions

Throughout the twentieth century, scientists, engineers, and technical professionals emerged as powerful players in American political, economic, and social affairs. In many cases, the increasing tendency for policymakers to defer to technical professionals has been imprecisely and anachronistically disparaged as "technocratic."[99] Historians often trace the origins of the so-called technocratic influence to the early twentieth century, specifically to Thorstein Veblen's advocacy of a "Soviet of technicians" and the radical reform agenda of engineers such as Morris L. Cooke who

99 Hugh Richard Slotten, *Radio and Television Regulation: Broadcast Technology in the United States, 1920-1960* (Baltimore: The Johns Hopkins University Press, 2000); and Barber, *From New Era to New Deal*, 13-15.

worked to apply the engineering method to realms such as education and government.[100] In this interpretation, Howard Scott's group "Technocracy, Inc." is treated as one of many manifestations of a broader technocratic trend that led to the predominance of technical judgments in political, economic, and social policy. Thus we are led to believe that *technocracy* is the polar opposite of *democracy*, and decisions made by technical experts must by definition violate principles of democratic participation.[101]

We should resist the impulse to view engineers in the standardization process as the heirs of Veblen or the foot soldiers of technocracy.[102] Far from being proponents of technocracy, AESC engineers—Agnew chief among them—articulated a distinctive vision of democratic control in a society increasingly defined by industrial technology and reliant on technical experts. Agnew not only envisioned and promoted a method for establishing industry consensus around technical specifications; he also advanced a critique of majority-rule democracy in the industrial age. Unlike radical reformist engineers such as Morris Cooke and Charles Steinmetz, and unlike the advocates of Technocracy, Agnew did not justify participation in the standardization process solely on the basis of *expertise*. Instead, he framed participation in the standardization process as a function of *interest*. This distinction helps us to understand the prevalence of democratic metaphors and analogies in his writing and in the formal procedures of the AESC.

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100 See Thorstein Veblen, *The Engineers and the Price System* (New York: B. W. Huebsch, 1921); and Layton, *Revolt of the Engineers*.
101 On technocracy, see William E. Akin, *Technocracy and the American Dream: The Technocrat Movement, 1900-1941* (Berkeley: University of California Press, 1977). For a sharp analysis of the inadequacies of this technocratic/democracy dichotomy, see Sheila Jasanoff, *The Fifth Branch: Science Advisors as Policymakers* (Cambridge: Harvard University Press, 1990), especially 15-18.
102 For one interpretation that builds upon Veblen to see standardization as "subversive to the old order," see Janet Knoedler and Anne Mayhew, "The Engineers and Standardization," *Business and Economic History* 23 (1994): 141-151.

Agnew believed that anyone with an interest or stake in a given technology should have a voice in the standardization process, even if he was not a dues-paying member of the AESC or ASA. For Agnew, participation in the standards process had more in common with local government—recall his discussion of the hypothetical bridge to be built in Oshkosh—than it did with an exclusive, rational, and efficiency-minded Soviet of technicians. His vision of democratic control over industrial technology included government officials, but the "industrial legislature" transcended the authority of those officials and the government interests they represented. They participated not as ultimate authorities, but rather as equal partners in a cooperative enterprise. Agnew's implicit claim, then, was that cooperative rulemaking in the AESC was, in its limited sphere, more democratic than control by elected legislatures.

This process valued the judgment of experts more than that of non-experts. Agnew openly acknowledged this fact, which was an essential component of claims to legitimacy and competence given the cooperative values of the 1920s. He also frankly admitted the limitations of the "coöperative method," such as a lack of organization that prevented important groups from participating fully in the consensus process, the "frequent short-sighted jockeying for immediate commercial advantage," and the "endless jealousies and bickerings" between competing interests. Agnew was nonetheless as enthusiastic about the cooperative method as he was critical of existing modes of democratic governance: "experience in diverse fields has amply shown that the [cooperative] method combines many of the advantages of the common-law and the statutory-law methods… while it avoids many of the limitations and abuses that have grown up about the legislative process."[103] Critics of the AESC, most notably Lyman Briggs (Director of the National Bureau of Standards from 1933-1945), lamented "the output in quantity [of the AESC and ASA] has not been all that some of its friends had hoped." These shortcomings stemmed from the diverse points of view that, because of the inclusive requirements in AESC procedures, sectional committees needed to reconcile before agreeing on a standard. Nevertheless, Briggs concluded "This procedure, while painful and sometimes slow, is nevertheless fundamentally sound."[104]

Agnew was aware of the radical "social engineering" proposals, such as Veblen's, that called on engineers to take a greater role in the control of industrial society. In his 1926 *New Republic* article, he addressed the suggestion whether "the standardization movement is a step toward the 'industrial parliament' which enthusiastic prophets proclaim is about to supplant, or at least to supplement, our existing legislative machinery." Agnew expressed interest in such speculation, but declared that "the movement must continue to develop along conservative lines… the movement is evolutionary and not revolutionary."[105]

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103 Agnew, "A Step Toward Industrial Self-Government," 95. Agnew and his colleagues persisted in this promotion of voluntary standards as a viable alternative to control by legislature and common law rule. See Howard Coonley and P. G. Agnew, "The Role of Standards in the System of Free Enterprise," *Industrial Standardization* (April, 1941): 1-12; and P. G. Agnew, "Standards in Our Social Order." Albert Whitney advanced a similar critique in his influential 1924 essay "The Place of Standardization in Modern Life."

104 Lyman J. Briggs, "The American Standards Association and The National Bureau of Standards," *Industrial Standardization* (1938): 239.

105 Agnew, "A Step Toward Industrial Self-Government," 95. I have not found any record of enthusiasm on the part of ASA officials for the industrial codes devised by the National Recovery Administration. Such sweeping plans for industrial control seem counter to ASA ideal of private sector autonomy with role of trade associations limited only to the establishment of voluntary consensus standards.

Agnew's comments provide two points of departure for evaluating his ideas in the context of 1920s America. First, advocates of industrial standardization explicitly linked their activities with the scientific authority and evolutionary theories that had become so influential among professionals in the early twentieth century. Agnew frequently situated the creation and growth of the AESC within an evolutionary trajectory. In the first stage, individual companies set standards. In the second stage, associations and government bureaus set group standards. The third stage consisted of standardization on a national scale; the fourth, standardization on an international scale. Agnew noted that the number of interested individuals and organizations increases from one stage to the next, as do the difficulties and importance of their work. In this classification, two or more stages develop simultaneously. The AESC, as a national organization, fit clearly into the third stage in the evolution of industrial standardization, following and building upon the first and second stages, and serving as a gateway and foundation to the fourth and final stage of international standardization.[106]

Second, the evolutionary path of industrial standardization could only occur through the work of professionals who strove to reconcile the needs and objectives of bureaucratic organizations. As such, the AESC was a typical example of the effort that went into building the "organizational society" that emerged in the early twentieth century.[107] The AESC's success stemmed in part from its compatibility with the vision

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[106] See for example P.G. Agnew, "Standards in Our Social Order," 3. This evolutionary classification also appeared in numerous editions of the AESC *Year Books*, which indicates that Agnew was a lead author (if not the sole author) of these annual reports.
[107] Louis Galambos, "Recasting the Organizational Synthesis: Structure and Process in the Twentieth and Twenty-First Centuries," *Business History Review* 79 (2005): 1-37.

of the most powerful American engineer and statesman of the 1920s, Herbert Hoover. The historian Edwin Layton nicely summarized Hoover's vision for the engineer in the new industrial society: "The engineer need not draw up a blueprint for the rebuilding of society, nor would he be its new ruler. His contribution, in Hoover's view, was to bring about cooperation between the great economic groups."[108] The evidence in this chapter shows how precisely Hoover's associative ideology aligned with the activities of the AESC, and how Hoover's policy entrepreneurship provided legal and ideological support for the AESC.

In the early twentieth century, standardization was not merely a technical challenge. It was also an organizational and ultimately political challenge—something that Agnew and his fellow engineers understood very clearly. It was a process of negotiations between a variety of powerful institutions, including private firms, government bureaus, and private groups such as professional engineering societies and trade associations. This history provides no support for the caricature of standardization as an uncontroversial or rational technocratic process. Instead, the AESC process—despite its prevailing rhetoric of "consensus"—was contested and labor-intensive at every step.

The legitimacy of American standards was function of the efforts of the AESC and ASA to make the standardization process open to all interested parties. Their emphasis on an inclusive and deliberative process foreshadowed the claims of critics such as Jürgen Habermas and Sheila Jasanoff in the latter decades of the twentieth century. In

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[108] Layton, *Revolt of the Engineers*, 192.

their theoretical and historical work, Habermas and Jasanoff emphasized the ways that the legitimacy of technical and political decisions could be achieved only through open and inclusive discursive procedures. In light of their work, we may sympathize with Agnew's claim that the AESC's "cooperative method" captured the essence of deliberative democracy in a technological age.[109]

We may also draw a significant historiographical lesson from this close look at engineers such as Comfort Adams and Paul Agnew and their activities in the AESC. An acknowledgment of the important activities of these engineers serves as a supplement to the historiography of industrial engineering that focuses on radical reformist engineers on one hand and loyal corporate engineers on the other.[110] Adams, Agnew, and the AESC help paint a richer picture of the connecting tissue of industrial development. The work of these engineers is significant because of their contributions to industry that were not restricted to one particular firm. In this sense, they fit into the tradition of mechanics and consulting engineers in the nineteenth century whose efforts and talents were felt across the boundaries of firms, government agencies, professional societies, and industry groups. Dedicated as they were to the cooperative development of technology, Adams,

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[109] See Jürgen Habermas, *Between Facts and Norms: Contributions to a Discourse Theory of Law and Democracy* (Cambridge, MA: The MIT Press, 1996); Jürgen Habermas, *Moral Consciousness and Communicative Action* (Cambridge, MA: The MIT Press, 1990); and Sheila Jasanoff, "Science, Politics, and the Renegotiation of Expertise at EPA," *Osiris* 7, 2nd Series (1992): 194-217. For a claim that a more recent consensus-based standardization process "conforms well to the requirements of Habermas's discourse ethics," see A. Michael Froomkin, "Habermas@Discourse.Net: Toward a Critical Theory of Cyberspace," *Harvard Law Review* 116 (2003): 751-873.

[110] On the radical reformists, see Layton, *Revolt of the Engineers*; and Ronald R. Kline, *Steinmetz: Engineer and Socialist* (Baltimore: The Johns Hopkins University Press, 1992). On corporate engineers, see David F. Noble, *America by Design: Science, Technology, and the Rise of Corporate Capitalism* (New York: Knopf, 1977).

Agnew, and their fellow standard-bearers are historically significant as institution-builders, administrators, liaisons, and consultants—in short, as agents of inter-organizational knowledge and expertise.[111] Scholarly appraisals of standardization frequently note that a successful standard is invisible: without much notice or controversy, successful standards seamlessly become a part of daily life. Judging from the lack of historical notice of the Adams, Agnew, and the institutions they built, it is fair to conclude that the same observation applies to standard-setters as well.

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[111] Business historians have recently begun to emphasize these inter-organizational themes with more clarity. See for example Christopher D. McKenna, *The World's Newest Profession: Management Consulting in the Twentieth Century* (New York: Cambridge University Press, 2006); and Naomi R. Lamoreaux, Daniel M. G. Raff, and Peter Temin, "Beyond Markets and Hierarchies: Toward a New Synthesis of American Business History," *American Historical Review* 108 (2003): 404-433.

Chapter 3: The "Engineering of the Present": Standardization in the Bell System, 1876-1956

3.1 Introduction

In the Second Industrial Revolution, standardization was more than a technical practice and an organizational strategy; it was an ideology, a way of extending rational control over a complex technological world. In the first two chapters, I showed how American engineers created collaborative institutions in the private sector—"industrial legislatures"—as alternatives to government control over industrial standardization. In some cases, however, industry standards did not emerge from the consensus process, but instead as a result of the market power of a single firm. The history of the Bell Telephone System provides the best example of this style of *de facto* standardization. Accordingly, this chapter examines the development the American telephone industry from its initial commercial stages to the emergence of AT&T as the parent company of the mature monopoly Bell System. Standardization was not simply a *consequence* of monopoly; instead, standardization first emerged as a strategy to create, justify, and sustain monopoly control.

"System architecture," a relatively recent concept that I borrow from computer science, illuminates the importance of standardization within the design and construction of the AT&T telephone network. According to a standard definition, system architecture refers to the "fundamental organization of a system embodied in its components, their relationships to each other and the environment, and the principles guiding its design and evolution."[1] In the American telephone industry, this "fundamental organization" emerged between the 1880s and the 1920s as the consequence of strategies implemented by four AT&T system architects: Edward J. Hall, Theodore N. Vail, John J. Carty, and Bancroft Gherardi.

The early history of the Bell System also serves as a starting point for the principal theme of the remaining chapters of this dissertation: the standardization of network architectures for telecommunications and computing in the Second and Third Industrial Revolutions. By reinterpreting the history of the Bell System from the vantage point of standardization, I argue that a single, interconnected American telecommunications network was the result of Bell strategies to exert complete control over the nation's telephone industry. By the early 20th century, Hall and Vail had overseen the creation of the monopoly Bell System that was led by a parent company, AT&T, and consisted of the manufacturing subsidiary Western Electric, the Long Lines long-distance department, and the dozens of regional operating companies.[2] As President of Southern Bell (1894-1909) and Vice-President of AT&T (1887-1914), Hall negotiated the extension of AT&T administrative and technical standards throughout regional and

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[1] This definition is literally a standard, issued jointly by the American National Standards Institute and the Institute for Electrical and Electronics Engineers, and therefore a product of the sort of cooperation described in the previous chapters. The standard is described in "Recommended Practice for Architectural Description of Software-Intensive Systems (ANSI/IEEE Standard 1471-2000)." See http://www.iso-architecture.org/ieee-1471; see also http://en.wikipedia.org/wiki/Systems_architecture.

[2] George David Smith, *The Anatomy of a Business Strategy: Bell, Western Electric, and the Origins of the American Telephone Industry* (Baltimore: The Johns Hopkins University Press, 1985); Robert W. Garnet, *The Telephone Enterprise: the Evolution of the Bell System's Horizontal Structure, 1876-1909* (Baltimore: The Johns Hopkins University Press, 1985); and Neil H. Wasserman, *From Invention to Innovation: Long-Distance Telephone Transmission at the Turn of the Century* (Baltimore: The Johns Hopkins University Press, 1985).

local systems.[3] Theodore Vail, in his second term as AT&T President (1907-1919), further extended Hall's vision on a national scale as he presided over the creation of a monopoly telephone system, which he famously described as "One System, One Policy, Universal Service." In short, the structure of the Bell System followed the strategy of a standardized network architecture.

Once this monopoly system architecture was firmly established by the mid-1910s, Carty and Gherardi took charge of the relations between the whole and the parts. As the only two men to hold the position of AT&T Chief Engineer between 1907 and 1938, Carty and Gherardi both oversaw engineering throughout the Bell System—the "engineering of the present" in AT&T President Henry B. Thayer's phrase.[4] In addition to the challenges they faced in the creation of an integrated Bell System, Hall, Vail, Carty, and Gherardi also faced critical system problems outside the boundaries of their company, including rivalries with competing firms and tensions with regulators in a variety of jurisdictions.[5] Standardization was also a most useful strategy for confronting these problems. Under Gherardi's leadership, AT&T engineers learned that they could effectively patrol the limits of AT&T's control in consensus standards committees described in the first two chapters, such as the American Institute for Electrical Engineers (AIEE) and the American Standards Association. By participating in these groups and

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3 Kenneth Lipartito, *The Bell System and Regional Business: The Telephone in the South, 1877-1920* (Baltimore: The Johns Hopkins University Press, 1989), 141-148.

4 Henry B. Thayer, "The Development of Development and Research," *Bell Telephone Quarterly* 4 (1925): 6. Carty was Chief Engineer from 1907-1919, at which point his deputy Gherardi assumed the title and held it until his retirement in 1938.

5 I follow Thomas Hughes' emphasis on "critical problems" as important sites for the historical study of large technological systems. See Thomas P. Hughes, *Networks of Power: Electrification in Western Society, 1880-1930* (Baltimore: The Johns Hopkins University Press, 1983), 14-17, 22, 79-80, 371-372.

influencing their standards, AT&T engineers found new ways to attack critical problems that they could not solve from within the Bell System.

It is my view that the strategy overseen by Hall, Vail, Carty, and Gherardi stands as the most successful execution of a standardization strategy in all of American history. For nearly a century, AT&T used standards to build a "universal" system architecture and maintain system momentum in the face of competition, regulation, and technological change. Momentum and monopoly, however, came at a cost: because of its scale and scope, AT&T developed a style of incremental innovation that made it difficult for the company to incorporate radical innovations into the system architecture. By the second half of the twentieth century, when the technological foundations of the telecommunications industry began to shift toward electronic components and new forms of transmission, this conservative strategy would prove to be fatal for the Bell System. By taking standardization as a primary vantage point, this chapter shows that the architecture of the Bell System did not only address internal technical and economic concerns; this network architecture also suited an explicitly *political* purpose, one in which standards defined the extent—and limits—of AT&T's control.[6]

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[6] For the general claim that choices in network architecture have significant social and political implications, see Dale N. Hatfield, "Architecture as Policy," in Sherrie Bolin, ed., *The Standards Edge: Dynamic Tension* (Ann Arbor, MI: Sheridan Books, 2004), 137-144; and Lawrence Lessig, *Code: And Other Laws of Cyberspace* (New York: Basic Books, 1999), 20.

3.2 Edward Hall and Theodore Vail: Standardizing the Bell System, 1877-1913

Between 1877 and 1913, Bell managers applied the principles of standardization in four different realms: technical and administrative control in their company, competition with independent phone companies, dealings with state and national regulators, and the image of their company as a member of civil society. In 1877, at the founding of the Bell Telephone Company,[7] there were no standards in any recognizable sense of the term. Telephone technology was in an early experimental phase, and telephone systems were administered by a handful of scattered entrepreneurs who licensed the Bell patents and were on their own to finance, build, and sell telephone service. This situation began to change in the 1880s, when Bell managers began to articulate and impose a vision of centralized control and interconnection.

Administrative standardization preceded and facilitated technical standardization. As Bell managers sought to establish the competitive and technical status of their company, they found that standardization could help them to define and redefine the scope of their control, and to integrate functions of manufacturing, engineering, and administration on a local and regional scale. Theodore Vail articulated the Bell ideology of centralized control most clearly with his slogan of "One System, One Policy, Universal Service." This slogan neatly captured the ideology of standardization that drove the company's technological and administrative strategy. By 1913, the Bell

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[7] The Bell Telephone Company was incorporated in 1877, and kept that name until 1879. From 1879 to 1880 it was the National Bell Telephone Company, which was reincorporated as the American Bell Telephone Company (1880-1899). The American Telephone and Telegraph Company was incorporated as a long-distance firm in 1885, and became the parent company for the Bell interests on December 31, 1899. See Garnet, *The Telephone Enterprise*.

System had developed into a regulated monopoly, in charge of a horizontally and vertically integrated telephone enterprise with a coast-to-coast scope.

The first American telephone networks were built by local entrepreneurs who licensed the telephone patents of the Bell Telephone Company. These systems were not interconnected: licenses were geographically exclusive, and it was initially impossible to place a call from one city to another.[8] One consequence of decentralization was considerable diversity in early telephone systems, particularly in complex components such as switchboards. Between 1877 and 1881, up to five different manufacturers supplied telephone equipment to Bell licensees. By 1880, in an effort to minimize the technical confusion that resulted from this diversity, the Bell Company hired salaried traveling agents who shared information about common problems between licensees. Although these efforts brought some uniformity to the various Bell licensees, there was at this point no overarching strategy to impose standardized equipment or procedures.[9]

Beginning in 1881, Bell managers led by Theodore N. Vail and Gardiner Hubbard took a significant step toward reducing this heterogeneity by consolidating manufacturing within one firm, Western Electric. The transition to a single manufacturer—a crucial first step in the creation of a "Bell System" (although it was not envisioned as such at the time)—was complete by 1883.[10] Still, this move toward vertical integration did not

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[8] Smith, *The Anatomy of a Business Strategy*, 12, 162; Garnet, *The Telephone Enterprise*, 15-17.
[9] Smith, *The Anatomy of a Business Strategy*, 47-48, 57-58, 69-71, 87; Garnet, *The Telephone Enterprise*, 22-23.
[10] Smith, *The Anatomy of a Business Strategy*, 5-7, 12; Richard John, "Recasting the Information Infrastructure for the Industrial Age," in Alfred D. Chandler, Jr. and James W. Cortada, eds., *A*

automatically guarantee the standardization of technical components. Even when standards did exist, they were difficult to enforce across the diffuse operating units of Western Electric and the Bell licensees.[11] However, as telephone switching and transmission technologies became increasingly sophisticated and complex, Bell managers found that the standardization of hardware and procedures was a vital means for maintaining their position in the industry. Accordingly, they took new steps to centralize the technical and administrative aspects of their sprawling company.[12]

Centralization occurred through the efforts of managers at American Telephone and Telegraph (AT&T). Founded in 1885, AT&T functioned as the unit responsible for long distance telephony before becoming the parent company for all the Bell interests in 1899. Historians have focused on the loading coil as a breakthrough technology for long distance transmission,[13] but they have also shown that the loading coil was one of a long line of administrative and technical efforts that had been underway since the 1880s to integrate local telephone systems into regional and national systems. Long-distance transmission, as historian Robert MacDougall argued, also served as a "symbol and

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Nation Transformed By Information: How Information Has Shaped the United States from Colonial Times to the Present (New York: Oxford University Press, 2000), 89-90.

[11] For example, Western Electric's reliance on the contract system—where specific jobs would be completed in different ways by different contracting foremen—inhibited the production of uniform components. See Smith, *The Anatomy of a Business Strategy*, 130-132.

[12] Smith, *The Anatomy of a Business Strategy*, 127-133.

[13] The loading coil raised the quality of voice calls by reducing attenuation and distortion on the line, thus providing cost savings and presenting new commercial possibilities. It also served as a focal point for the application of scientific theory to the telephone business, and encouraged Bell managers to pursue research and development in a more systematic and extensive manner. See Wasserman, *From Invention to Innovation*, especially 4-6; and Lillian Hoddeson, "The Emergence of Basic Research in the Bell Telephone System, 1875-1915," *Technology and Culture* 22 (1981): 512-544.

spectacle of integration and consolidation" that was more valuable for organizational and political purposes than it was for generating revenue or meeting consumer demand.[14]

Edward J. Hall and Theodore Vail—the founding general manager and president (respectively) of AT&T—are the two executives most closely associated with this trend toward interconnection that would as Hall argued "promote uniformity of methods" across the Bell licensees and throughout American telephony.[15] This promotion of uniformity was neither smooth nor simple. Hall, as President of Southern Bell (1894-1909) and AT&T Vice-President (1887-1914), believed that administrative integration and technical standardization were vehicles for simplifying the tasks of management while simultaneously pushing operators of local systems to adopt better technology. The social and technical aspects of Bell's enterprise, therefore, were two sides of the same coin—and, in Hall's eyes, both aspects of the business would benefit the centralization of authority through standardization.[16]

Many Bell operating companies resisted the Vail/Hall push for centralization and standardization, sometimes out of a desire to remain autonomous, other times due to concerns about the cost of standardization.[17] Anxious to avoid adversarial confrontations with the local companies—and lacking the financial power or administrative machinery

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[14] Robert MacDougall, "Long Lines: AT&T's Long-Distance Network as an Organizational and Political Strategy," *Business History Review* 80 (2006), 298.

[15] Edward J. Hall to Theodore N. Vail, 12 May 1885, quoted in Garnet, *The Telephone Enterprise*, 78. See also Smith, *The Anatomy of a Business Strategy*, 127-133. For a summary of Hall's vision and contributions, see Lipartito, *The Bell System and Regional Business*, 116-168; and Garnet, *The Telephone Enterprise*, 75-99.

[16] Garnet, *The Telephone Enterprise*, 37, 70-73, 87-89; Smith, *The Anatomy of a Business Strategy*, 57-60; and MacDougall, "Long Lines," 305-307.

[17] MacDougall, "Long Lines," 303-309. There was also a vigorous debate among Bell executives about the degree to which centralization and standardization should be imposed. See Garnet, *The Telephone Enterprise*, 83-99; and Lipartito, *The Bell System and Regional Business*, 116-124.

to enforce compliance with standards—Hall and telephone engineer John J. Carty sought out venues to establish standards through a cooperative process. During the 1880s and 1890s, engineers from a number of Bell licensees met under the auspices of the National Telephone Exchange Association in order to develop technical specifications that took into account the operational experiences culled from their everyday work. Managers and engineers used these conferences to blend local and regional approaches into a national style of telephone engineering. In these conferences, Bell engineers established baseline specifications which could then be adopted on a voluntary basis and adapted by companies who, if circumstances warranted, would adjust the specifications to meet local conditions.[18]

Hall and Carty pursued a similar cooperative strategy in the 1890s and early 1900s as they championed functional specialization in order to establish uniformity on a national scale. These reforms made it easier for employees with experience in particular tasks (such as switchboard equipment, network operations, accounting, and auditing), to undertake the slow and steady work of identifying and implementing standard practices across the Bell operating companies. One important example of this process was the introduction and gradual adoption of a new accounting system that generated more uniform financial information, which made analysis easier both for managers and investors.[19] Like the process of technical standardization, the introduction of accounting standards occurred not by dictate but instead through consultation and consensus with the

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[18] Garnet, *The Telephone Enterprise*, 92-99; Lipartito, *The Bell System and Regional Business*, 66-81, 162-3; and MacDougall, "Long Lines," 303-307.
[19] Garnet, *The Telephone Enterprise*, 96-103.

licensees. After all, the licensees would be forced to bear the costs of introducing new methods and retraining or recruiting people to manage it.[20]

It was in this methodical, iterative, and cooperative manner that the principles of standardization came to assume a central place in the creation of an integrated Bell system at the turn of the twentieth century. From manufacturing to long-distance to accounting, standardization had proven to be a flexible and dependable strategy for reforming and remaking the technological and business activities of Bell licensees in a way that suited the ideology of a unified national system. At the same time, leaders such as Hall and Vail used standards to protect their companiy from external threats. During the 1890s and early 1900s, the major threat came from the so-called "independent" telephone companies. After the original Bell patents expired in 1893 and 1894, entrepreneurs around the country began to build competing networks to compete with the Bell licensees. Their business strategies diverged substantially from the Bell companies: whereas the Bell companies tended to serve high-density populations (business customers or urban residential customers), many independents concentrated on smaller towns and rural areas, and were able to offer cheaper service than Bell. In several cases, the two networks occupied the same territory, but refused to exchange calls. This strategic impasse created a vivid symbol of this era of "dual service"—customers who were forced to keep two phones so that they could talk to subscribers of the different networks.[21]

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[20] Garnet, *The Telephone Enterprise*, 112-126.
[21] See Milton Mueller, *Universal Service: Competition, Interconnection, and Monopoly in the Making of the American Telephone System* (Cambridge, MA: The MIT Press, 1997), 54-96; and David Gabel, "Competition in a Network Industry: the Telephone Industry, 1894-1910," *The Journal of Economic History* 54 (1994): 543-572. On the independent companies, see Charles A. Pleasance, *The Spirit of*

At first, non-interconnection was a rational business strategy. Vail and the Bell executives already understood from their long-distance initiatives that interconnection (or "intercommunication," in the preferred terminology of Bell executives at the time[22]) was a key to control in the competitive telephone industry.[23] The Bell leadership recognized that by refusing to connect with independent networks, their competitors could not offer their customers the ability to place a call to any member of Bell's larger base of subscribers.[24] While many subscribers did not have the practical need or financial means to make long-distance calls, the potential to make long-distance calls was in many cases a decisive factor for consumers, thanks in large part to the efforts of AT&T engineer Thomas Doolittle and Edward Hall.[25]

Clearly, interconnection in itself was not undesirable; rather, for Bell's business model to work, it was essential that Bell managers controlled the terms of interconnection. As they recognized this basic fact of the competitive telephone industry,

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Independent Telephony (Johnson City, TN: Independent Telephone Books, 1989); and John Brooks, *Telephone: The First Hundred Years* (New York: Harper & Row, 1976), 102-126.

22 Instances of the rhetoric of "intercommunication" used by AT&T executives such as Vail and George Leverett may be found in Mueller, *Universal Service*, 96 and 98; and MacDougall, "Long Lines," 303, 309, and 313. See also AT&T Annual Reports for 1907, 1908, and 1909.

23 By the late twentieth century, economists coined the term "network externality" to define this strategic principle and describe how, in industries with competing systems, the larger network is more valuable to customers and more likely to succeed in the marketplace. Seminal papers include Jeffrey Rohlfs, "A Theory of Interdependent Demand for a Communications Service," *Bell Journal of Economics and Management Science* 5 (1974): 16-37; Paul A. David and W. Edward Steinmueller, "Economics of Compatibility Standards and Competition in Telecommunications Networks," *Information Economics and Policy* 6 (1994): 217-241; and Michael L. Katz and Carl Shapiro, "Systems Competition and Network Effects," *The Journal of Economic Perspectives* 8 (1994): 93-115.

24 Mueller, *Universal Service*, 44-45, 97.

25 For examples where Bell was successful with this strategy of non-interconnection, see Kenneth Lipartito, "System Building at the Margin: The Problem of Public Choice in the Telephone Industry," *The Journal of Economic History* 49 (1989): 329; and Lipartito, *The Bell System and Regional Business*, 116-130.

Bell and AT&T managers experimented with new ways to marginalize their competitors and leverage their subscriber base. Once again, Edward Hall was a leader in the effort to unify and systematize Bell control, and, once again, the logic of standardization featured prominently in several new tactics devised to extend Bell managerial control over American telephone networks in the face of independent competition.

Between 1895 and 1907, Bell executives used a variety of tactics to extend their control over the American telephone industry. One tactic was to continue to build out new portions of their network by adding toll lines and exchanges. A second tactic was the outright purchase of independent competing firms. Both tactics utilized existing technical standards to integrate new networks with existing Bell networks.[26] These tactics, however, were not in themselves enough to vanquish their competition: the growing demand for telephony meant that independent companies also continued to flourish: between 1902 and 1907, the independents operated more public exchanges than Bell companies, and Bell companies had marginally more subscribers than independent companies (51.2 percent and 48.8 percent, respectively).[27] Another tactic championed by Hall, sublicensing, proved to be more successful for compromising with the independents and extending Bell control. Sublicensing gave independent companies access to Bell technology, standards, and financial assistance, while simultaneously preventing them from competing directly against Bell networks or combining with other independents—

[26] Two additional tactics that attracted unfavorable contemporary and historical scrutiny were price competition and public relations campaigns against independent companies. See Mueller, Universal Service, 69-80; and Gabel, "Competition in a Network Industry."
[27] In 1902, there were 3,005 Bell exchanges, compared to 3,400 independent exchanges. By 1907, there were 4,889 Bell exchanges, compared to 5,400 independent exchanges. Mueller, *Universal Service*, 61. For subscriber statistics, see Lipartito, *The Bell System and Regional Business*, 114.

thus preserving the competitive advantage of AT&T's long-distance capabilities.[28] Finally, Hall also promoted Bell's high technical standards to municipal and state regulators, convincing them that quality of service was a more important regulatory concern than other issues such as rates, profits, and the presence of competition. By framing high-quality telephone service as an important public benefit, Hall and his colleagues used regulatory endorsement of Bell's technical standards as a competitive tactic and barrier to entry.[29]

Each of these tactics help us to recognize that a national, "universal" telephone system emerged in the early twentieth century as a compromise strategy between the totalizing goals of standardized control on the one hand, and the inescapable conditions of local variation and competition on the other. By 1907, the overall consequence of this strategy was that Bell technical standards gradually were implemented on a systematic and widespread basis, both in Bell networks as well as in independent sublicensee networks—but their creation and adoption occurred through a negotiated process where consensus was a dominant value.[30]

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28 Lipartito, "System Building at the Margin," 330-331; Lipartito, *The Bell System and Regional Business*, 133-137; Mueller, *Universal Service*, 76-79; John V. Langdale, "The Growth of Long-Distance Telephony in the Bell System, 1875-1907," *Journal of Historical Geography* 4 (1978): 145-159; and David F. Weiman and Richard C. Levin, "Preying for Monopoly? The Case of the Southern Bell Telephone Company, 1894-1912," *The Journal of Political Economy* 102 (1994): 117-120.

29 Lipartito, *The Bell System and Regional Business*, 176; John, "Recasting the Information Infrastructure," 95.

30 For discussions of the ways that competition forced Bell to improve its service, see Mueller, *Universal Service*, 94; and Kenneth Lipartito, "'Cutthroat' Competition, Corporate Strategy, and the Growth of Network Industries," *Research on Technological Innovation, Management and Policy* 6 (1997): 1-53.

Where Hall succeeded with his vision of standardization and control on a regional scale with Southern Bell, Theodore N. Vail, in his second term as president of AT&T from 1907 to 1919, extended Hall's vision throughout AT&T on a national scale.[31] By continuing the policy of sublicensing, Vail ensured that Bell's technical standards would be implemented on a broader scale, which put Bell managers in a better position to control the technological direction of the telephone industry.[32] Accordingly, we need to recognize that standardization was not simply a *consequence* of monopoly control; standards and standardization also were used as a competitive strategy to achieve this monopoly status.

To reap the efficiency gains promised by standardization and centralization—and under intense financial pressure to eliminate excessive diversity in equipment and personnel—Vail moved quickly to streamline the technical operations of the Bell System. In 1907, Vail named John J. Carty, previously chief engineer of New York Telephone (the largest operating company in the country) to be the AT&T's Chief Engineer. Carty closed down labs in Chicago and Boston and brought the Bell System technical operations under the centralized control of his Engineering Department, located in New York. The Engineering Department became the intermediary between the licensee

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[31] Vail's life and career has been chronicled by a number of biographers and historians. See for example Richard R. John, "Vail, Theodore Newton," *American National Biography Online* (February, 2000), http://www.anb.org/articles/10/10-01671.html; Albert Bigelow Paine, *In One Man's Life: Being Chapters from the Personal and Business Career of Theodore N. Vail* (New York: Harper and Brothers, 1921); John Brooks, *Telephone: The First Hundred Years* (New York: Harper & Row, 1976), 67-160; and Robert Sobel, "Theodore N. Vail: The Subtle Serendipidist," in *The Entrepreneurs*: *Explorations Within the American Business Tradition* (New York: Weybright and Talley, 1974), 195-246. For a more skeptical assessment of Vail's motives and legacy, see N. R. Danielian, *A. T. & T.: The Story of Industrial Conquest* (New York: The Vanguard Press, 1939).

[32] Lipartito, *The Bell System and Regional Business*, 137-139, 164-166; Mueller, *Universal Service*, 107-108; Garnet, *The Telephone Enterprise*, 125-126, 131.

companies and Western Electric, and the latter entity was designated as the sole site for the design and standardization of equipment. Like other efforts to create more uniformity and centralization throughout Bell's administrative and financial operations, Carty's consolidation of engineering departments built upon earlier initiatives that sought to reconcile the ideal of standardization with the realities of local control and variation.[33]

It is in this context that Vail introduced his slogan that defined the modern Bell System: "One System, One Policy, Universal Service."[34] Although "Universal Service" eventually became shorthand for government policies to extend telephone service to all Americans, the phrase originally drew the rhetorical distinction between the reality of "dual service" (or non-interconnection) in the competitive era and Vail's post-1907 ambition for Bell to assume complete control over American telephony.[35] Scholars have interpreted this slogan in a variety of ways, referring to it as the largest public relations campaign of its kind, a manifestation of Vail's civic values and administrative experience, a response to competition, and even an element of the Bell strategy of public indoctrination.[36]

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[33] Garnet, *The Telephone Enterprise*, 120-124. See also Smith, *The Anatomy of a Business Strategy*, 133; and Wasserman, *From Invention to Innovation*, 109-111.
[34] *Annual Report of the Directors of American Telephone and Telegraph Company to the Stockholders for the Year Ending December 31, 1909* (Boston: Geo. H. Ellis, Co., Printers, 1910), 18.
[35] In Lipartito's assessment, Vail's concept of Universal Service was "basically an extension of Hall's prescriptions for the South to the rest of the nation." Lipartito, *The Bell System and Regional Business*, 139.
[36] Roland Marchand, *Creating the Corporate Soul: The Rise of Public Relations and Corporate Imagery in American Big Business* (Berkeley: University of California Press, 1998), 48-87; Richard R. John, "Theodore N. Vail and the Civic Origins of Universal Service," *Business and Economic History* 28 (1999): 71-81; John, "Recasting the Information Infrastructure," 71-73, 99-100; Mueller, *Universal Service*, 92-135; and Federal Communications Commission, *Investigation of the Telephone Industry of the United States* (Washington, DC: Government Printing Office, 1939), 475-485.

We should add to this list that Universal Service was the most comprehensive and successful standardization strategy in the history of American telecommunications. It was a public articulation of the ideology of standardization that was cultivated in the 1880s and 1890s and, by the first decades of the twentieth century, resulted in the creation of the modern Bell System. This ideology of standardization suggested that the administrative, political, and technological aspects of the telephone business were inseparable—and the best way to oversee all three aspects was for AT&T to assume total control, free from competition and in consultation with national regulators. "Universal Service" was Vail's rhetorical masterstroke that folded the principles of standardization and centralization into the image and successful construction of AT&T as a regulated monopoly.

The notion of Universal Service provides the best example of how Vail and his colleagues persuaded regulators to appreciate the value of an interconnected monopoly telephone system, one that operated more like a common carrier or public utility than one of several firms in a competitive market. Torn between their desire to preserve competition and simultaneously promote interconnection, twenty six state regulatory commissions passed laws that mandated interconnection between Bell and independent networks between 1904 and 1913.[37] In 1913, Vail's public relations campaign finally succeeded on a national scale, when Nathan Kingsbury, AT&T's Vice President of Advertising and Publicity, came to an agreement with federal regulators that the best political solution was to endorse Bell control over a single interconnected telephone

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[37] Lipartito, "System Building at the Margin," 330-333; Mueller, *Universal Service*, 119-128.

network.[38] Federal regulation thus emerged as the preferred alternative to “cutthroat” competition on the one hand and to antitrust prosecution on the other. Cooperation, not competition, would provide the best way forward. This political settlement cemented the structure of the American telephone industry that would remain intact until the 1980s.

3.3 Bancroft Gherardi and Consensus Standardization in the Monopoly Bell System, 1913-1938

Standardization continued to be a sustaining ideology of the Bell System as it developed momentum as a regulated monopoly in the 1910s and 1920s. AT&T’s leading advocate of standardization during this period was its Vice President and Chief Engineer, Bancroft Gherardi. From the 1910s to his retirement in 1938, Gherardi was the premier architect of the AT&T standardization strategy. This approach had its basis in extensive technical studies of existing practice, and promoted common (if not universal) system-wide standards. Like his predecessors Hall and Carty, Gherardi struggled to reconcile the drive for uniformity with the technological and financial constraints faced by local licensees. And also like Hall and Carty, Gherardi drew on his reputation and technical abilities to persuade, cajole, and command engineers in the Bell System to continue to standardize the system.

Gherardi (1873-1941) began his career as a telephone engineer in 1895, testing and inspecting cables for the Metropolitan Telephone and Telegraph Company of New York. Gherardi, who earned a bachelor’s degree from Brooklyn Polytechnic Institute and

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[38] Mueller, *Universal Service*, 129-135. For examples of state-level regulation that enforced Bell standards, see Lipartito, *The Bell System and Regional Business*, 185-207.

two graduate engineering degrees from Cornell, quickly earned a strong reputation for his thorough technical investigations of cables and standards of transmission. In 1900 he was promoted to head the newly-formed Traffic Engineering Department of the New York Telephone Company, and continued his rise one year later when he was named Chief Engineer of the New York and New Jersey Telephone Company.[39]

Gherardi moved to New York during a period of rapid technological and organizational change for the New York and New Jersey Telephone Company, which grew from 30,000 telephones in 1901 to over 110,000 in 1906. Gherardi was particularly adept at working within the constraints of a large, complex, and relentlessly expanding technological system. He very quickly adapted to the systematic Bell approach to solving problems within this dynamic context, and demonstrated his abilities in a number of projects, including extensive studies of telephone traffic, the creation of new floor plans for central offices, experiments to test cable durability and safety, and the creation of technical standards for switchboard components and signal transmission.[40]

Through these efforts to enhance the efficiency of Bell operations, Gherardi earned the trust of his supervisor, John J. Carty. Gherardi proved his worth to Carty on a number of occasions, including the collaboration between the two men to supervise the first commercial application of Pupin's loading coils in New York in 1902. As Carty

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[39] Gherardi earned a B.S. in 1891 from the Brooklyn Polytechnic Institute, and an M.E. (1893) and M.M.E. (1894) from Cornell University. See Oliver E. Buckley, "Bancroft Gherardi, 1873-1941," *National Academy of Science Biographical Memoirs* (New York: Columbia University Press, 1957), 157-177; and "Bancroft Gherardi Dies; Phone Pioneer, 68," *The New York Times* (August 16, 1941).

[40] "Bancroft Gherardi," *The Sibley Journal of Engineering* 20 (1906): 241; and "List of Some Items of Scientific and Engineering Work Done by Mr. Bancroft Gherardi," July 20, 1932, Box 1133, "Gherardi, Bancroft – Biography – 1873-1941," AT&T Archives, Warren, New Jersey.

rose into the upper echelons of the Bell System, so did Gherardi.[41] When Vail reorganized the corporate structure of the Bell companies in 1907, he selected a new set of experienced and technically proficient executives, including Walter S. Gifford, Frank B. Jewett, and Henry B. Thayer, to lead the way forward. Vail's selection of Gherardi as Carty's right-hand man (with the title of Equipment Engineer of AT&T) has gone almost unnoticed by historians, but Gherardi's long and successful career as the overseer of standardization in the Bell System further confirms Vail's reputation for hiring the right men for the job.[42]

Gherardi was promoted in 1909 to AT&T Engineer of Plant Development and Standardization, responsible for these areas throughout the entire Bell System. In this capacity, Gherardi worked closely with Carty and Jewett, a Ph.D. physicist who Carty brought to New York to serve as a research manager in the consolidated Engineering Department of Western Electric in New York.[43] This triad formed an effective partnership as they guided the technological operations and trajectory of the Bell System over the next thirty years. As system architects, their major organizational challenge was to harmonize the ongoing efforts of the various technical departments in the Bell System, which included Long Lines, Western Electric's manufacturing and engineering

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[41] "Scientific and Engineering Work Done by Mr. Bancroft Gherardi," AT&T Archives; "Biographical Statement of Bancroft Gherardi [circa 1932]," Box 1133, "Gherardi, Bancroft – Biography – 1873-1941," AT&T Archives, Warren, New Jersey. In 1911, Gherardi reported to the scientific community on the introduction of loaded lines, Bancroft Gherardi, "The Commercial Loading of Telephone Circuits in the Bell System," *Transactions of the A.I.E.E.* 30 (1911): 1743-1773.
[42] In the immense literature on the leaders of the Bell System, only John Brooks gives the briefest of mentions to Gherardi as one of Vail's cadre of executives. Brooks, *Telephone*, 131.
[43] After 1907, the Manufacturing Department of Western Electric remained in Chicago, and the Engineering Departments of Western Electric and AT&T were consolidated in New York. Oliver E. Buckley, "Frank Baldwin Jewett," *National Academy of Science Biographical Memoirs* (New York: Columbia University Press, 1952), 239-264.

departments (the former in Chicago, the latter in New York), and the twenty-odd operating companies around the country.

Because of the technological and social difficulties in the standardization process, complete system-wide harmonization proved nearly impossible. For the manufacture of equipment to meet specific standards, the relationship between AT&T and Western Electric was more or less clear: AT&T gave the orders, Western Electric carried them out.[44] In contrast, AT&T management found it much more difficult to command the technical activities of the regional operating companies. Much to the frustration of Western Electric engineers, AT&T displayed more tolerance and understanding when the operating companies resisted the standard practices and equipment recommended by AT&T and manufactured by Western Electric. Western Electric engineers interpreted this treatment as a double standard, and resented the implication that their status was lower in comparison to the independence of the AT&T management in New York and the relative autonomy of the regional operating companies.

One example of this resentment was visible at a 1915 conference of Bell System engineers—the first such system-wide technical summit. A recurring point of controversy at this conference was the Bell System's use of condensers, devices used to store energy in the transmission process. Where the AT&T specifications (in 1915) called for Western Electric to manufacture condensers with a minimum capacity of five hundred volts, operating companies routinely used older equipment that was not up to

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[44] Western Electric acted with more autonomy in many other realms. See Stephen B. Adams and Orville Butler, *Manufacturing the Future: A History of Western Electric* (New York: Cambridge University Press, 1999). I thank Richard John for bringing this important distinction to my attention.

this standard. E. B. Craft, an engineer at Western Electric, complained that even though AT&T engineers were "making efforts to persuade the associate companies to live up to these requirements… the associate companies are not prepared at all times to meet with or agree with the A. T. & T. Company… especially when it touches their pocket-book as much as it does on this condenser proposition."[45]

For the operating companies, upgrading to the new standards was a costly and time-consuming process. Consequently, AT&T executives and engineers continued to prefer voluntary cooperation to outright dictate or coercion. As the Western Electric engineer J. L. McQuarrie summarized in 1915, "it is not the policy of the A. T. & T. Company to use force in compelling the associate companies to follow their standards. I think their policy is to set up their cases in such a manner that the associate companies will see for themselves that that is the thing they ought to do."[46] Gherardi had stated as much in 1912: "In applying transmission standards, it must be recognized that they cannot be considered as hard and fast rules which must be followed in all cases… in other words, to attain the standards might necessitate expenditures not warranted."[47] Carty, aware of these financial constraints on system-wide innovations, responded by pursuing low-cost solutions. In 1916, he boasted that the improvements to transmission—

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[45] E. B. Craft, "Discussion of Mr. McQuarrie's paper [page 20]," in Western Electric Company, *Manufacturing and Engineering Conference*, Chicago, Illinois, May 24-28, 1915.

[46] J. L. McQuarrie, "Discussion of Mr. McQuarrie's paper [page 45]," *Manufacturing and Engineering Conference*. This tension between centralized control and regional autonomy is the central theme of Lipartito, *The Bell System and Regional Business*. See especially Chapter 4, "Regional Change and Technological Conflict"; Chapter 7, "A Merging of Interests"; and Chapter 9, "Regional and Corporate Cultures."

[47] Bancroft Gherardi, "Discussion of Transmission—Cooperation of Departments," *Telephony* 62, No. 15 (1912): 468-70. The organization chart of the AT&T Engineering Department is instructive: see M. D. Fagen, ed., *A History of Engineering and Science in the Bell System: The Early Years (1875-1925)* (New York: Bell Telephone Laboratories, Inc., 1975), 48-49.

particularly the vacuum tube-powered repeater—would "be accomplished without requiring any Associated Company to spend one dollar—no, not one cent, in reconstructing any subscriber's station."[48]

On the other hand, Western Electric was required to follow AT&T standards more closely—thus producing a situation where their autonomy was circumscribed far more than that of the operating companies. This disparity fostered a simmering resentment among Chicago-based Western Electric engineers, a reaction to their subordinate status to the engineering executives in New York. At one point during the 1915 conference, one of the Chicago-based engineers went so far as to suggest that AT&T should move its headquarters to Chicago—a comment that drew applause from the audience. After the applause subsided, the conference's chairman H. F. Albright left no doubt about who was really in charge by noting their absence: "It looks as if we did not have enough conferees present," he responded meekly. "We should have Mr. Carty and Mr. Gherardi here."[49]

Changes in AT&T's corporate organization between 1918 and 1920 further consolidated the power of these two men, and propelled Gherardi in particular into a commanding role over standardization throughout the Bell System. During World War I,

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[48] Carty, "Universal Service," in American Telephone and Telegraph Company, *Telephone Transmission: Meeting of the Technical Representatives of the Bell System* (New York City: December 11-12, 1916), 13. On the repeater, see Leonard S. Reich, *The Making of American Industrial Research: Science and Business at GE and Bell, 1876-1926* (New York: Cambridge University Press, 1985), 157-160; Hoddeson, "The Emergence of Basic Research in the Bell Telephone System," 530-539; and Fagen, ed., *A History of Engineering and Science in the Bell System: The Early Years*. For a public report on these developments, see Bancroft Gherardi and Frank B. Jewett, "Telephone Repeaters," *Transactions of the American Institute of Electrical Engineers* 38 (1919): 1287-1345. See also Bancroft Gherardi, "Progress Through Research," *Bell Telephone Quarterly* 11 (1932): 7-9.

[49] H. F. Albright, "Discussion of Mr. McQuarrie's paper [page 33]," *Manufacturing and Engineering Conference*. Although Carty and Gherardi were not present in Chicago, they were, pointedly, the organizers of a two-day conference in New York in December, 1916 where technical representatives of the Bell System discussed recent developments in telephone transmission.

when Carty and Jewett directed their attention (and the research efforts of their subordinates) to the war effort, Gherardi stayed in New York as Acting Chief Engineer of AT&T. Vail retired as AT&T President on June 18, 1919 and was replaced by his protégé and close friend, Western Electric President Henry Thayer. Gherardi was named Chief Engineer of AT&T the same day. In 1920 Gherardi was promoted again, this time to Vice President of AT&T, and held both titles until his retirement in 1938.[50]

Gherardi took over as Chief Engineer just as the Engineering Department was split into two new departments—the Operations and Engineering Department and the Development and Research Department. The purpose of this reorganization, according to Thayer, was to allow Bell engineers to "differentiate in our work between the engineering of the present and the engineering of the future."[51] Under this new regime, Carty and Jewett turned to the engineering of the future, first in the Development and Research Department and later with Bell Labs, while Gherardi directed the engineering of the present within the Department of Operations and Engineering.[52] The breadth of Gherardi's responsibilities was staggering: he directed a staff of hundreds of engineers who were collectively responsible for developing engineering methods, operating plans,

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50 Buckley, "Bancroft Gherardi," 165-166; "Scientific and Engineering Work Done by Mr. Bancroft Gherardi," AT&T Archives. On Carty, Jewett, and AT&T research during World War I, see Reich, *The Making of American Industrial Research*, 180-1.

51 See Henry B. Thayer, "The Development of Development and Research," *Bell Telephone Quarterly* 4 (1925): 6; "Centralizing Bell System Researches," *Science*, New Series, Vol. 79, No. 2051 (April 20, 1934): 366-367; and "Notes on Recent Occurences: Bancroft Gherardi Retires as A.T.&T. Vice President and Chief Engineer after a Distinguished Career of 43 Years of Bell System Service," *Bell Telephone Quarterly* 17 (1938): 139-144.

52 Historians have paid much more attention to research and development in the Bell System, presumably due to the elite status of Bell Labs in American industrial research. See for example Reich, *The Making of American Industrial Research*; and Fagen, ed., *A History of Engineering and Science in the Bell System: The Early Years*.

and methods for analyzing and comparing different types of service. Further, Gherardi's staff was responsible for advising the technical staffs of the other units of the Bell System (including Western Electric, the regional operating companies, and the Long Lines division) as well as for the overall technical coordination of the System.

Standardization was Gherardi's primary means of managing complexity. In his view, standards were much more than simple technical prescriptions. They documented years of experimentation, and provided a record of the technical know-how and organizational capabilities of thousands of individuals who worked for the Bell System.[53] Many standards originated or matured through face-to-face discussions in system-wide conferences, an organizational innovation favored by Carty, Jewett, and Gherardi that were designed to overcome the coordination problems posed by distance and diversity.[54] The administrative consolidation of Bell local and regional operating companies under Vail and Thayer greatly facilitated communication among the system's engineering elite

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53 Once a technology or process was deemed to be a Bell System Standard (or "AT&T Standard"), it was promulgated through a publication series by the Department of Development and Research, commonly known as "D&R Bulletins." Along with General Engineering Circulars and other forms of communication, the D&R Bulletins distributed the latest technical information to engineering departments at all of the Bell operating companies. Fagen, ed., *A History of Engineering and Science in the Bell System: The Early Years*, 638 (especially note 159). See also Buckley, "Bancroft Gherardi," 166-167; and Harold S. Osborne, "Abstract of Discussion of Osborne Paper on Standardization in the Bell System," *American Standards Association Bulletin* (October, 1931), 27-28.

54 The proceedings of the first such conference are Western Electric Company, *Manufacturing and Engineering Conference*, Chicago, Illinois, May 24-28, 1915. I am grateful to Louis Galambos for bringing this rich source to my attention. For Galambos' own interpretation of some of this meetings, see Louis Galambos, "Theodore N. Vail and the Role of Innovation in the Modern Bell System," *Business History Review* 66 (1992): 114-117.

by reducing the number of engineering departments in the Bell System—further underlining the point that administrative centralization made it easier to set standards.[55]

These administrative strategies led to a healthy and diverse program of standardization throughout the 1920s. By 1929, AT&T had created standards for an astonishing variety of functions, including telephone plant design, underground cables, raw materials, manufacture, distribution, installation, inspection, and maintenance of new equipment, business and accounting methods, non-technical supplies (such as office furniture, appliance, janitors' supplies, cutlery, and china), and provisions for safety, health, and even sleet storms.[56]

As in the initial phase of his career in New York, Gherardi again excelled within the context of a rapidly expanding and evolving system. During his tenure as Chief Engineer between 1920 and 1938, the number of telephones in Bell System grew from 7.7 million to over 19 million. With the rapid expansion of telephone service, the explosive growth of radio transmission, and the introduction of television technology, the

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[55] See Garnet, *The Telephone Enterprise*, 137-144; and Brooks, *Telephone*, 133. Consolidation also made it easier for the Bell companies to create an "appearance of uniformity" in their advertising campaigns. See Marchand, *Creating the Corporate Soul*, 56, 86-7.

[56] 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—including Gherardi himself—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* 8 (1929): 9-28; Harold S. Osborne, "Standardization in the Bell System—II," *Bell Telephone Quarterly* 8 (1929): 132-152; Bancroft Gherardi and Frank B. Jewett, "Telephone Communication System of the United States," *Bell System Technical Journal* 9 (1930): 1-100; and Frank B. Jewett, "Some Fundamentals in Standardization," *Bell Telephone Quarterly* 17 (1938): 17-27.

1920s and 1930s were exciting times to be on the front lines of electrical communication. Gherardi thrived in the midst of this era of rapid change and was a key member of the AT&T technical community during this period. For example, he played a leading role in AT&T's opening of trans-Atlantic radio telephone service in January, 1927, served on the Board of Directors of Bell Labs, served on the editorial board of the *Bell System Technical Journal*, and co-authored essays on "Telephone Progress" for the annual editions of the *Encyclopedia Americana* between 1923 and 1936.[57]

During his tenure as Chief Engineer, Gherardi developed a characteristic style of implementing changes within the existing Bell System architecture. His first step was to carefully research and study existing operations. His second step was to design a comprehensive plan for change. His third step was to slowly introduce new methods and equipment—standardized, of course, to the greatest extent possible that local conditions would allow. His final step—one that could easily be blended with a first step of a new project—involved ongoing study to evaluate the system-wide impact of changes.

A brief discussion of the Bell System's transition from manual to mechanical switching—Gherardi's first and perhaps most significant project as Chief Engineer—illustrates his style of system architecture. The independent inventor Almon Strowger invented the first mechanical switch in 1891, but Bell experts did not see a way to integrate the device into their operations, and declined to buy or even license Strowger's patent. In the subsequent decades, Bell officials kept a close eye on Strowger's device

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[57] On the trans-Atlantic radio connection, see Bancroft Gherardi, "Voices Across the Sea," *North American Review* 224 (1927): 654-661. On Gherardi's role in AT&T's explorations of radio technology, see Reich, *The Making of American Industrial Research*, 170-238.

and developed their own "panel type" mechanical switch, but declined to introduce any sort of mechanical switching into the telephone network before 1920. In his study of AT&T's transition from manual to machine switching, Kenneth Lipartito explained this reluctance by pointing to the difficulties and uncertainties of introducing a new innovation in a system context. Many factors, including conflicts over the efficacy and economy of machine switching technology as well as AT&T's sunk cost in its existing "techno-labor system," convinced AT&T managers to pursue incremental innovations within the existing paradigm of manual switching. Only when they faced successive crises of system growth and labor shortages due to the American mobilization for World War I did Bell engineers decide to embrace machine switching and invest in the new technology.[58]

Gherardi, promoted to Chief Engineer in 1919, was the prime mover behind this deliberate transition to machine switching. Gherardi preferred the term "machine switching" to "automatic switching," given the misleading connotations of the latter term: the equipment and processes for switching telephone calls were anything but automatic.[59] Gherardi first presented to Carty a study on technological and human aspects of machine switching in 1917. Upon his promotion to Chief Engineer in 1919, Gherardi made a formal recommendation on the subject to the AT&T leadership. His recommendation

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[58] Kenneth Lipartito, "When Women Were Switches: Technology, Work, and Gender in the Telephone Industry, 1890-1920," *The American Historical Review* 99 (1994): 1074-1111; Venus Green, "Goodbye Central: Automation and the Decline of 'Personal Service' in the Bell System, 1878-1921," *Technology and Culture* 36 (1995): 912-949.

[59] Carty endorsed Gherardi's suggestion to use the term "machine switching" instead of "automatic switching" at a 1916 conference. Carty, "Universal Service," *Telephone Transmission*, 14.

called for the gradual replacement of manual switching, noting that significant obstacles needed to be overcome, including negotiating with the Automatic Electric Company to use the patents for the Strowger switch, engineering the production of panel switches at Western Electric, educating the engineers at regional operating companies, and convincing the general public to change their dialing habits.[60]

Gherardi's recommendation was approved, and, as Chief Engineer, he became personally responsible for implementing the plan. His emphasis on standardization made the technological basis for a transition to machine switching possible and affordable, as well as time consuming and labor intensive. The standardization and coordination of the various components of the machine switching system was a daunting task. As early as 1920, Western Electric had added five buildings to its Hawthorne Plant (with plans to add three more), and Gherardi and AT&T engineer Harry Charlesworth claimed that AT&T and Western Electric had combined to make "three thousand new piece parts involving some thirty-six thousand manufacturing and inspecting operations," including new working drawings, manufacturing methods, new tools and machinery, testing gauges, and the shipment of factory-assembled switch frames that would facilitate their installation throughout the Bell System. Thanks to sufficient planning and coordination, Gherardi and Charlesworth promised that the introduction of the new machine switching system would "be carried on in the usual Bell way, that is, in an economical and orderly manner,

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[60] See Bancroft Gherardi and Harry P. Charlesworth, "Machine Switching for the Bell System," *Telephone Review* 2, Supplement (April, 1920): 1-12; "Scientific and Engineering Work Done by Mr. Bancroft Gherardi," AT&T Archives; and Green, "Goodbye Central," 939-941.

without inconvenience to the subscriber, and without derangement or interruption of service."[61]

The first mechanical exchange opened in Omaha in December 1921. The signal event of this transition was the "cutover," the moment when manual switches were terminated and calls began to be routed through machine-operated switches. The transition to the new mechanical system demonstrated the soundness of Gherardi's extensive preparations: in addition to the new equipment installed in the central offices, Bell engineers updated 378 private branch exchange switchboards, and substituted thousands of new dial telephones for obsolete handsets.[62] In addition to the equipment, which cost around $2 million, the supervisors of the Omaha station retrained one hundred employees without, the district manager hastened to add, firing a single employee.[63]

AT&T engineer A. E. Van Hagen described in great detail the detailed operations of the cutover in an April 1929 article. He wrote, "Does a cutover have any drama? For the casual observer, no…. But to the men and women engaged in the work, there is all

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[61] Gherardi and Charlesworth, "Machine Switching for the Bell System," 11-12.
[62] On Gherardi's and AT&T's preparations for the transition to machine switching, see Bancroft Gherardi, "Remarks on Machine Switching Cutovers," R. F. Estabrook, "Machine Switching Service Observing," and W. E. Farnham, "The Preparation for a Machine Switching Cutover," all in AT&T, *Plant and Engineering Conference of the Bell System*, [1920], Section IV, pages 57-77.
[63] "Say it with Fingers to Get 'At' With Numbers," *Omaha World-Herald* (December 11, 1921). The massive human effort to change over to a new system—complete with new equipment and new standards—suggests the importance of human labor in communication networks. For fuller discussions of these issues, see Gregory J. Downey, "Virtual Webs, Physical Technologies, and Hidden Workers: The Spaces of Labor in Information Internetworks," *Technology and Culture* 42 (2001): 209-235; and Amy Slaton and Janet Abbate, "The Hidden Lives of Standards: Technical Prescriptions and the Transformation of Work in America," in Michael Thad Allen and Gabrielle Hecht, eds., *Technologies of Power: Essays in Honor of Thomas Parke Hughes and Agatha Chipley Hughes* (Cambridge, MA: The MIT Press, 2001), 95-144.

the thrill that a First Night at the theatre has for the cast—and more."[64] Because studies indicated that traffic was at its lightest point late on a Saturday night, the Omaha cutover occurred at the midnight hour. Van Hagen wrote, "one notices that every operator is dressed in her 'Sunday best.'" He continued,

> At the main frame downstairs, men are stationed at close intervals. Cords run behind the heat coils. At a word over the telephone from the Dispatcher, the man in charge signals to his lieutenants who in turn pass the word to the men to "PULL. TAKE IT EASY." As each man takes hold of the cord at the bottom of the bay and pulls, a barrage of heat coils comes flying from the frame. Goggles or a visor protect the eyes of each man… In all the years that they have worked in that office their problem has been to maintain service, but with a rip they have torn out all the heat coils and there are no subscribers connected with that office.[65]

In Omaha, Gherardi and Jewett personally gave the order to "cut em over" at 11:59 pm on the night of December 10. With this command, the Omaha exchange began to route calls through machine switching equipment that followed commands issued by subscriber dial telephones. The *Omaha World-Herald* reported that "for the first time since 1893, the operating room of the old telephone building was quiet and deserted."

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[64] A. E. Van Hagen, "The Dial Office 'Cutover,'" *Bell Telephone Quarterly* 8 (1929): 96.
[65] Van Hagen, "The Dial Office 'Cutover,'" 101-102.

Fig. 8—Private branch exchange—1600 stations, 148 lines to Central Office, 151 tie trunks to other private branch exchanges, 42 switchboard positions, 60 operators and 24 hour service.

Figure 3.1: Manual Switching Room and Personnel
Source: Bancroft Gherardi and Frank B. Jewett, "Telephone Communication System of the United States," *Bell System Technical Journal* 9 (1930): 14.
Courtesy of AT&T Archives and History Center.

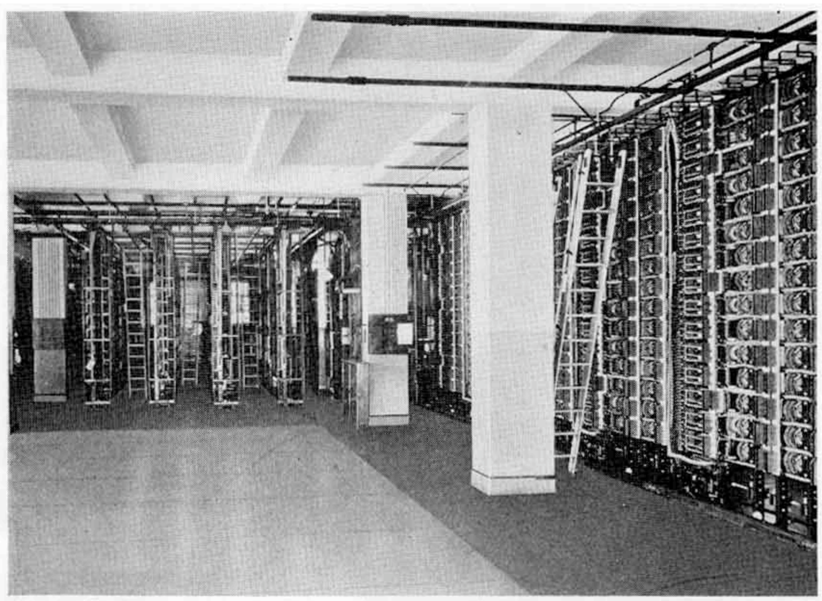

Fig. 20—Installation of panel dial equipment. The unused floor space is provided for future growth.

Figure 3.2: Machine Switching Room and Equipment.
Source: Bancroft Gherardi and Frank B. Jewett, "Telephone Communication System of the United States," *Bell System Technical Journal* 9 (1930): 26.
Courtesy of AT&T Archives and History Center.

With the Omaha exchange up and running, Gherardi, Carty, and Jewett conducted cost studies to estimate when the change to machine systems would be economical, the situations where it would not, and the amount of time it would take for machine systems to pay for themselves.[66] Based on these studies, Gherardi proceeded gradually and, characteristically, did not force change too quickly: by the time he retired in 1938, almost half of all American telephone subscribers were still relying on female operators to switch their calls manually.[67]

Insofar as it contained technical, economic, and social dimensions, the transition to machine switching demonstrates Gherardi's general attitude toward management. Throughout his career, Gherardi was a paradigmatic "organization man," a thoughtful professional who combined the tools of engineering and management and led American business into a thoroughly industrial and bureaucratic era.[68] Gherardi articulated this organizational worldview in his AIEE President's Address in 1928:

> The conquest of nature on a large scale must be done by those who can use organizations of men. The modern engineer should have as great a capacity for human management, cooperation and for dealing with others as the men in politics, religion and other professions which are devoted primarily to the study of man.[69]

Gherardi amply demonstrated his own "capacity for human management" as Chief Engineer of AT&T. Gherardi built his leadership style around clear and open lines

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[66] Bancroft Gherardi, "Engineering Considerations," in American Telephone and Telegraph Company, *Conference to Discuss Economy and Efficiency in Operation*, Shawnee, Pennsylvania, October 18-25, 1922, 200.
[67] Buckley, "Bancroft Gherardi," 169-70.
[68] Oliver Buckley was more effusive: "Bancroft Gherardi was a great engineer… one of the most eminent engineers of his time." Buckley, "Bancroft Gherardi," 157.
[69] Bancroft Gherardi, "Civilization and the Engineer," *Bell Telephone Quarterly* 47 (1928): 581.

of communication with engineers throughout the Bell System. In his first years as Chief Engineer, Gherardi held a number of conferences and meetings for technical representatives of all departments in the Bell System. Transcripts from these conferences show that Gherardi was one of the most charismatic, insightful, and vocal participants in discussions, always ready to exercise his moderator's prerogative to have the final word at the close of each session as well as at the conclusion of the conference.[70] Gherardi self-consciously nurtured the values of "morale and team-work," and consistently emphasized the importance of a "company-as-a-whole" attitude among AT&T employees. In accordance with this systematic outlook, Gherardi maintained close contact with the operating companies, and routinely canvassed their engineering staff for comments and criticisms on existing Bell standards.[71]

This collaborative leadership style seems to have won Gherardi nearly universal respect and trust, although there are hints of some displeasure at Gherardi's authoritative demeanor. In 1957, Gherardi's biographer (and Bell Labs president) Oliver Buckley wrote, "Some there were who considered him overcritical and even dictatorial, but others

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70 See for example AT&T, *Plant and Engineering Conference of the Bell System*, [1920]; AT&T, *Conference to Discuss Economy and Efficiency in Operation* [1922]; and Bancroft Gherardi, "Summary," in *Telephone Transmission*, 137-138.

71 See for example AT&T, *Conference to Discuss Economy and Efficiency in Operation* [1922], 121, 171, 194-5. Gherardi kept a close eye on ways to improve and maintain throughout the system, including measures that brought employee representatives into closer contact with management. Again, this process was greatly facilitated by Vail's initiatives to consolidate administration of local and regional systems.

close to him found beneath a somewhat austere exterior a warm, good-natured friend with a lively sense of humor and deep-seated human kindness."[72]

Gherardi advocated a more efficient approach to industrial production, and found a community of like-minded engineers and executives in technical societies and standards-setting organizations such as the AIEE and the American Standards Association. Gherardi and his fellow AT&T engineers participated tentatively in these groups before World War I, but increased their commitment as the industrial standardization movement gained strength in the 1920s and into the 1930s. Why? What did Gherardi and the AT&T engineers do in these committees, and why did they think industry standardization was important? To understand how efficiency concerns, power dynamics, and relations of trust informed Gherardi's and AT&T's attitudes toward standardization, we need to follow AT&T engineers beyond the boundaries of the Bell System and into these industry standards committees.

3.4 Standardization Across the Boundaries of the Bell System

As we learned in the previous chapter, the size and stature of the national movement for industrial standardization blossomed during the 1920s. Standards advocates such as Paul Gough Agnew and Herbert Hoover frequently pointed to the benefits of participation in standard-setting organizations, such as the American

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[72] Buckley, "Bancroft Gherardi," 172. Gherardi was a tall and athletic man who used his energy and stature to enhance his intellectual authority. One wonders if a comparison to the leadership style of Lyndon Johnson would be apt.

Engineering Standards Committee (AESC), that brought together engineers and representatives from different walks of industrial life.

Throughout its early history, AT&T was reluctant 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 World War I. One indication of changing attitudes may be seen in a speech at the 1915 conference of Bell System engineering and manufacturing personnel, where H. F. Albright asked the Western Electric and AT&T engineers to reconsider the potential benefits of professional activities outside the Bell System. 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.[73]

AT&T engineers quickly learned that "outside" cooperation had more than a social function. One prominent example of the technical benefits of cooperation may be seen in AT&T efforts to address electrical interference generated by the close proximity of other networks that utilized electrical current, such as electrical power lines, lighting systems, and railroad equipment. In the nineteenth century, information infrastructures

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[73] H. F. Albright, "The Business Activities and Relations of Members of Engineering and Manufacturing Departments Outside the Western Electric Company [page 2]," *Manufacturing and Engineering Conference* (1915).

such as the telegraph and railroad networks grew in a largely complementary manner.[74] The electrical infrastructures of the twentieth century, however, created new problems that engineers attacked by using both technical and organizational means.

AT&T 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.[75] By 1920, however, AT&T engineers were increasingly concerned with the electrical interference generated by the power companies. Although Gherardi and AT&T Chief Counsel N. T. Guernsey believed that AT&T held a strong legal position to avoid interference through litigation against the power and light companies, they preferred to settle the problems through negotiation among engineers of the respective industries.[76]

To accommodate a cooperative settlement to the problems of interfering infrastructures, Gherardi participated in the creation of new institutions to host direct negotiations with the powerful firms and industry groups in the railroad and electrical industries. Beginning in 1921, Gherardi led the Bell System's involvement in three separate Joint General Committees: one with the Edison Electrical Institute, a second with the Association of American Railroads, and a third with the National Electric Light

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74 John, "Recasting the Information Infrastructure," 55-106.

75 Fagen, ed., *A History of Engineering and Science in the Bell System: The Early Years*, 324-336.

76 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, pages 2-55.

Association.[77] These committees eventually formulated standards for safety and the shared use of poles, and established the foundations for creating standards for inductive coordination—a difficult technical problem that continues to vex telecommunications and electrical engineers in the early twenty-first century.[78] Because the negotiations between the telephone, power, railroad, and light companies had legal as well as technical dimensions, it would have been premature to bring such discussions into standard committees in groups such as the AIEE or the American Engineering Standards Committee. Instead, the telephone, electrical, and railway engineers first used the *ad hoc* Joint General Committees to establish a shared commitment to solving the problems of inductive interference through engineering cooperation instead of litigation. Once the problems were reduced to a set of technical problems that could be solved through standardization, the AIEE and American Standards Association provided ideal venues for ensuring widespread adoption of standards for inductive coordination.[79]

These Joint General Committees, oriented around collaborative research and data-gathering, left a lasting impression on Gherardi. Reflecting in 1928 on the Bell System's seven years of collaboration with the National Electric Light Association, Gherardi

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[77] By this time, Gherardi was an established figure within the broader community of electrical engineers. Gherardi became an AIEE Association member when he graduated from Cornell in 1895, served as Vice-President from 1908 to 1910, was named a Fellow in 1912, and served on many committees before being elected AIEE President for 1927-1928. He also served on a number of committees, and served on the Board of Managers from 1905-08 and 1914-17.
[78] Osborne, "Standardization in the Bell System—II," 151; "IEEE Starts Standard to Support Broadband Communications over Local Power Lines," July 20, 2004, available from http://standards.ieee.org/announcements/pr_p1675.html.
[79] See Fagen, ed., *A History of Engineering and Science in the Bell System: The Early Years*, 336-337; Lewis Coe, *The Telephone and its Several Inventors* (Jefferson, NC: McFarland & Company, 1995), 158-159; and "Bancroft Gherardi—Biographical Data," September, 1949, Box 1133, "Gherardi, Bancroft – Biography – 1873-1941," AT&T Archives, Warren, New Jersey.

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."[80]

Such experiences confirmed Gherardi's belief that cooperative organizations could help him solve technical problems. By the late 1920s, this belief, combined with Gherardi's longstanding interest in technical standardization, led him to get closely involved with the activities of the American Engineering Standards Committee (AESC). The AESC was formed in 1918 to solve the same types of inter-industry technical problems that Gherardi had been investigating through the bilateral and *ad hoc* Joint General Committees. The AESC, which began as a joint venture between electrical, mechanical, civil, mining, and materials testing engineers, 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.[81]

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[80] Bancroft Gherardi, "Discussion at Pacific Coast Convention," *Transactions of the American Institute of Electrical Engineers* 47 (1928): 50. Gherardi's observation about the relative insignificance of the technical aspects of the problem is confirmed by the nearly complete absence of the topic of interference in the pages of both the *Bell Telephone Quarterly* and the *Bell System Technical Journal* between 1922 and 1931. The only exception to this trend was a brief abstract in the October, 1928 issue of the *Bell Telephone Quarterly*, noting a paper by Charles J. Daly on the "Effect of Street Railway Mercury Arc Rectifiers on Communication Circuits" presented to the AIEE in June 1928.

[81] See the previous chapter, "From Industry Standards to National Standards: 1910-1930."

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."[82] 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 Member Body of the AESC.[83] By the end of 1927, Bell System engineers were involved in the work of twenty-one 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.[84] 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 it formed committees, the AESC was very careful not to tread on AT&T's technological 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

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[82] *Work of the American Engineering Standards Committee (Year Book*) (New York: American Engineering Standards Committee, 1921), 20, 25.

[83] *American Engineering Standards Committee Year Book* (New York: American Engineering Standards Committee, 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 9. *American Engineering Standards Committee Year Book* (New York: American Engineering Standards Committee, 1928), 57, 64.

[84] *American Engineering Standards Committee Year Book* (New York: American Engineering Standards Committee, 1923).

standards for insulated wires and cables illustrates the point clearly: "Wires and Cables, Insulated (Other than Telephone and Telegraph)."[85]

Gherardi became personally involved in the AESC as the consensus standardization movement 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.[86] 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."[87] Engineers and scientists remained in charge of the standards-setting process in the ASA Standards Council, while the industry executives formed a Board of Directors that assumed responsibility for the ASA's financial administration.[88] 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.[89]

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85 *AESC Year Book* (1928), 39.

86 "Standards Group to Broaden Scope," *The New York Times* (July 8, 1928), 40; "Scientific Events: The American Standards Association," *Science*, New Series, Vol. 68, No. 1751 (July 20, 1928), 53-54.

87 "Executives to Direct Standards Body," *The New York Times* (July 8, 1929), 36.

88 *American Standards Year Book* (New York: American Standards Association, 1929), 7.

89 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 group 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, U.S. Steel, Westinghouse Electric and Manufacturing Company, and Youngstown Sheet and Tube

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.[90] Despite the potentially crippling effects of economic depression, Gherardi could boast by the end of his term in 1932 that the ASA consensus standardization 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.[91] 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.

Company. In 1930, the ASA announced that they had obtained the means to increase their budget by $500,000 over the next three years. "Plan to Enlarge Standards Work," *The New York Times* (January 5, 1930), N21; William J. Serrill, "President's Report," *American Standards Year Book* (New York: American Standards Association, 1930), 9-10; and "Milestones of the ASA," *Industrial Standardization* (1943): 330.

[90] "Gherardi Heads Standards Group," *The New York Times* (December 12, 1930), 17.

[91] "Group Hears of Gain in Standards Work," *The New York Times* (December 1, 1932), 38; "Industrial Standardization," *The Wall Street Journal* (December 2, 1932), 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," *The New York Times* (December 12, 1932), 11; and "Award of the Edison Medal to Bancroft Gherardi," *Science*, New Series, Vol. 76, No. 1981 (December 16, 1932): 562.

3.4.1 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.[92]

For the Bell System, the major disadvantage of these coin-operated telephones was that 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. Slugs posed a costly problem for operating companies. 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.[93]

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

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[92] Fagen, ed., *A History of Engineering and Science in the Bell System: The Early Years*, 153-6, 160-162, 170-171.
[93] E. M. Gladden to L. B. Wilson, July 11, 1927, Location 482 07 03 08, "American Standards Association Committee on Washers, 1927-1934," AT&T Archives.

maintenance costs.[94] 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.[95]

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 with 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

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[94] George K. Thompson to C. J. Davidson, October 11, 1927, Location 482 07 03 08, "American Standards Association Committee on Washers, 1927-1934," AT&T Archives.

[95] [AT&T Outside Plant Development Engineer] to L. F. Morehouse, November 7, 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 illegal slugs.

quarters.[96] 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.[97]

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

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[96] E. M. Gladden to L. B. Wilson, July 11, 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, had businesses that used such equipment for legitimate business purposes.
[97] George K. Thompson to C. J. Davidson, October 11, 1927, AT&T Archives; F. J. Schlink to George K. Thompson, November 19, 1927, Location 482 07 03 08, "American Standards Association Committee on Washers, 1927-1934," AT&T Archives; George K. Thompson to W. F. Hosford, December 20, 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 thirty years, ever since he filed the first Bell patent for coin telephones back in 1895.

consumers—in this case, manufacturers and buyers of washers. With eighteen committee members designated as consumers and only eleven 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 Agnew's approval for this change. After these new members were approved, they needed several additional months to review the proposed specifications.[98]

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.[99]

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[98] C. B. LePage to E. W. Niles, June 9, 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," November, 1931; C. B. LePage to P. G. Agnew, July 12, 1932, Location 482 07 03 08, "American Standards Association Committee on Washers, 1927-1934," AT&T Archives.

[99] 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. E.M. Gladden to L. B. Wilson, July 11, 1927; "Fraudulent Use of Slugs in Coin Box Telephones (Confidential)," October 9, 1933, Location 482 07 03 08, "American Standards Association Committee on Washers, 1927-1934," AT&T Archives; [AT&T Outside Plant Development Engineer] to L. F. Morehouse, November 7, 1932.

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 committee B27 to completion. Upon discovering that washer dimensions specified in an Air Corps Standard contained the same specifications as some of the offending slugs, they 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 favored 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.[100]

The long-awaited victory was bittersweet. By itself, the new standard—a significant technical, organizational, and political achievement that took seven 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 seven 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.

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100 Harry H. Woodring to A. E. Van Hagen, October 13, 1933, Location 482 07 03 08, "American Standards Association Committee on Washers, 1927-1934," AT&T Archives; E. W. Niles to Z. Z. Hugus, December 22, 1933, Location 482 07 03 08, "American Standards Association Committee on Washers, 1927-1934," AT&T Archives.

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: 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 sixteen of them (including their "spearhead") were convicted by the end of June.[101] 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.[102]

Buoyed by public support for police action against the slug racket, AT&T and the

101 "Third Man Seized in Sale of Slugs," *The New York Times* (February 9, 1936), 24; "Merchant is Guilty in Fake Coin Racket," *The New York Times* (June 24, 1936), 19.
102 "The Slug Racket," *The Washington Post* (February 11, 1936), 8. Emphasis added.

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.'"[103] 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.[104]

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 much more harmonious and less controversial

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

[104] 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," The New York Times (May 6, 1941), 23; and "Slug Dropped In Phone Box Leads To Mobster's Arrest," The Hartford Courant (November 21, 1952). By the 1960s, however, the same technical practice—tricking network 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.

fashion.[105] 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.[106] 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 National Electric Light Association; other times it participated in larger and more bureaucratic bodies such as the ASA and the International Electrotechnical Commission.[107] 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 favored.

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 committee 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 realized that, over the long term, they could leverage standards

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[105] 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.
[106] 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: The Johns Hopkins University Press, 2000).
[107] Osborne, "Standardization in the Bell System—II," 150-151.

committees to extend their influence over separate, non-telephone lines of business. At the same time, AT&T managers learned that there were limits to the utility of the consensus standards process—and also limits to the willingness of antitrust regulators to let the telephone monopoly expand its reach.

3.5 Containing System Momentum Through Regulation, 1934-1956

Despite small problems (such as telephone slugs) and big problems (such as prolonged economic depression), by the end of the 1930s the Bell System was in good health—"sitting pretty" in the assessment of historian John Brooks. However, the reemergence of anti-monopoly sentiment in the 1930s led government officials to renew its efforts to regulate the Bell System. As part of the Communications Act of 1934, Congress gave a new independent regulatory body—the Federal Communications Commission (FCC)—the authority to regulate the telephone industry.[108] The Act represented the first in a series of regulatory initiatives, led by the FCC and the Department of Justice, that by 1956 had the cumulative effect of restricting the manufacturing and operations of the Bell System strictly to common-carrier telephone service and military contracting. These jurisdictional constraints, which AT&T executives viewed with satisfaction as a successful defense of their telephone monopoly, had the long term effect of containing AT&T's dominance to the telephone industry—ultimately leaving the commercial application of electronic technologies to other firms.

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[108] Brooks, *Telephone*, 206. On the FCC, see Robert W. McChesney, *Telecommunications, Mass Media, and Democracy: The Battle for the Control of U. S. Broadcasting, 1928-1935* (New York: Oxford University Press, 1994), 151-225; Richard H. K. Vietor, *Contrived Competition: Regulation and Deregulation in America* (Cambridge: Belknap Press, 1994), 176-178.

Soon after its creation, the FCC acted quickly to exercise its statutory authority to police the Bell System. In 1935, the FCC commenced a "Telephone Investigation" that culminated in a 661 page *Report on the Investigation of the Telephone Industry* in 1939.[109] Although the FCC staff believed that a cooperative relationship with AT&T would be much more productive (and in the public interest) than an adversarial one, the *Report* was nevertheless highly critical of the Bell System. An entire chapter of the FCC's *Report* focused on "engineering and standardization." The FCC showed no awareness of AT&T's involvement in industry standards organizations or on the potential for AT&T to manipulate these committees. Instead, the FCC's focus was exclusively on the internal workings of the System.

The FCC tacitly accepted AT&T's claims of the enormous savings that had been achieved through its standardization work, including $99 million from cable development, $50 million from the use of less expensive metals, and $5 million per year from improvements in switchboard cords. The FCC also acknowledged that standardization in the monopoly Bell System had generated substantial social benefits, such as the development of long-distance capabilities, service to rural areas, and increases in service quality through technological advances such as repeaters and telephone handsets. Moreover, the FCC recognized that centralized control and standardization had the benefit of providing "flexibility in the interchange of equipment and trained personnel" throughout the System, and helped to create a "uniformly high quality of

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[109] United States Congress, *Report of the Federal Communications Commission on the Investigation of the Telephone Industry in the United States* (Washington, DC: Government Printing Office, 1939). For some of the context of the FCC investigation, see Vietor, *Contrived Competition*, 178; and Brooks, *Telephone*, 196-200. See also Danielian, *A. T. & T.: The Story of Industrial Conquest*.

service."[110]

However, in keeping with the critical tone of the *Report*, the FCC concluded that "centralized control over engineering, standardization, and manufacturing" 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. Consequently, the FCC recommended continued regulatory scrutiny of AT&T's standardization activities—especially those that required large capital investment. Given the FCC's ultimate conclusion in this area ("the overall results of standardization by the American Co. are such as to justify a continuance of research and standardization"), this call for continued scrutiny sounded more like a justification or plea for the FCC's own existence, rather than any principled demonstration that such oversight would produce benefits to telephone subscribers and the general public.[111]

In any case, over three decades of advertising, public relations, and high-quality service had left AT&T with a positive public image that would have rendered ineffective any potential regulatory attacks.[112] AT&T's actions in the face of disasters—both natural and man-made—further established its reputation as a public servant. If AT&T's response to a devastating hurricane in 1938 cast it in a heroic role, as John Brooks suggested, then its wartime efforts confirmed this heroic status. The combined service of AT&T, Bell Labs, and Western Electric enhanced the American military and civilian

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[110] *Report of the FCC*, 247-255, 584

[111] *Report of the FCC*, 252, 281-2.

[112] Marchand, *Creating the Corporate Soul*, 48, 86.

communications infrastructure to meet heightened demand during World War II, and also contributed to the design and manufacture of decisive technologies such as radar and antiaircraft systems. After the war, officials in the Defense Department depended on Bell executives to manage efforts to build nuclear weapons, providing further confirmation that the Bell System was a vital asset for national security.[113]

Despite these good deeds, anti-monopoly sentiment in the federal government was rekindled after World War II. The mild complaints raised in the 1939 FCC *Report* fed a full-fledged antitrust suit filed in 1949. In *United States v. Western Electric Company and American Telephone and Telegraph Company*, the government repeated its claims that the exclusive ties between AT&T and Western Electric had stifled new technologies and generated excessive profits for AT&T. However, conflicts within the federal government—including a difference of opinion between the Departments of Defense and Justice as well as within the Justice Department itself—dulled the adversarial edge of the antitrust suit. With the election of Dwight D. Eisenhower in 1952, the Justice Department adopted a much more tolerant attitude toward big business, and Justice officials and AT&T executives pursued an amicable settlement that would keep intact the relationship between Western Electric and AT&T.[114]

As the government built its case, AT&T executives recognized that they would need to make concessions in order to attain their primary objective, which was continued

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[113] Brooks, *Telephone*, 199-200, 208-214.
[114] Brooks, *Telephone*, 233-8; Vietor, *Contrived Competition*, 184-185; and Gerald W. Brock, *The Telecommunications Industry: the Dynamics of Market Structure* (Cambridge: Harvard University Press, 1981), 187-197. See also David M. Hart, "Antitrust and Technological Innovation in the US: Ideas, Institutions, Decisions, and Impacts, 1890-2000," *Research Policy* 30 (2001), 923-936.

control over the American telephone industry. In January 1956, the antitrust suit was settled by a Consent Decree. The Consent Decree prevented both AT&T and Western Electric from entering markets outside of common carrier telephone service, thus restricting the Bell System's ability to control the interfaces and standards being developed in the nascent American electronics industry. Additionally, by forcing the Bell System to license its patents at reasonable rates, the Consent Decree forever ended the practice developed by earlier generations of Bell executives—notably Edward Hall and Theodore Vail—in which patents and technical standards functioned as strategic tools to marginalize competitors.[115]

Both parties claimed victory: the Justice Department, because it forced concessions from AT&T; and AT&T, because it kept intact the relationship between it and Western Electric.[116] In their haste to maintain the *status quo*, AT&T executives made the mistake of reaping what they had sown. Over the short term, AT&T maintained control over the telephone industry, but over the long term, technological change in American telecommunications markets moved swiftly past anything that AT&T could control. By ceding control over patents and accepting regulation as a condition of continued telephone monopoly, AT&T undermined its ability to influence standards committees in the same manner it did in the 1920s and 1930s. Rather than looking forward or beyond the Bell System toward new technologies and markets, AT&T

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115 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* (Westview Press, 1988), 145-148; Milton S. Goldberg, *The Consent Decree: Its Formulation and Use* (East Lansing, MI: Michigan State University, 1962), 37-48.
116 Goldberg, *The Consent Decree*, 44-47; and Brooks, *Telephone*, 251-256.

executives happily accepted federal regulation to protect what their company had already built.[117]

3.6 Conclusions

Monopoly, like standardization, was neither natural nor stable. In the context of the growth and development of the Bell System, monopoly and standardization were mutually causative and mutually reinforcing: standardization facilitated the drive for managerial integration and market superiority, which in turn facilitated further initiatives for standardization. Through this dynamic relationship, the Bell System gained momentum and matured as a large technological system—indeed, the largest such system in the history of American private enterprise.

Momentum brought stability to Bell System, but it also was accompanied by significant technological and organizational problems. The Bell System was powerful, but not omnipotent. Two factors—technological change and government regulation—were the primary challenges for AT&T managers as they struggled to control the direction and pace of change within the Bell monopoly between 1913 and 1956.

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[117] Subsequent events over the next three decades built on this pattern of AT&T domain restriction in exchange for its telephone monopoly. The major thrust of these interventions was to facilitate competition in markets for customer premises equipment, including devices such as telephones, network switches, and computer modems that users could attach to the telephone network. A series of hearings and decisions between 1968 and the mid-1980s (including the *Carterfone* decision, the FCC's Part 68 rules, and the FCC's *Computer Inquiries*) extended the FCC's control over interconnection standards for the telephone network, and allowed a flood of entrepreneurial competitors to enter markets that were previously dominated by AT&T and Western Electric. The next two chapters explore these changes in technology and regulation in more depth.

By the 1930s, AT&T executives and engineers had learned to use consensus standardization to achieve strategic goals, including system-wide problems that it found to be impossible to solve through its own isolated effort. Because consensus standards committees were oriented around problems that could be solved through technical expertise, these committees were well suited to AT&T's style of persuasion based on extensive research and technical data. When faced with critical system problems, such as inductive interference and illegal telephone slugs, AT&T engineers such as Bancroft Gherardi and George K. Thompson looked to standards committees to establish a unified, inter-industry front against problems that could not be solved within the boundaries of the Bell System.

Through consensus standards committees, AT&T executives and engineers used the power of the Bell System to pursue technological solutions that threatened the efficiency of the Bell System. In addition to these dimensions of power and efficiency, AT&T participation in industry standards committees also depended upon cultural notions of trust and reputation. The Western Electric engineer H. F. Albright stated the importance of these cultural aspects as early as 1915. Albright, framing AT&T's participation in industry bodies in civic terms, told his fellow engineers that Bell System support for the AIEE "is as much needed and is as much a duty as the support of local institutions for good government, the schools, and the churches."[118]

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[118] H. F. Albright, "The Business Activities and Relations of Members of Engineering and Manufacturing Departments Outside the Western Electric Company [page 2]," *Manufacturing and Engineering Conference* (1915).

The career of Bancroft Gherardi provides a good example of the ways that the cooperative ideology of standardization shaped technology and strategy in the monopoly Bell System. In addition to his duties as a traffic engineer and eventually Chief Engineer of AT&T, Gherardi devoted substantial effort to "industrial legislatures" such as the AIEE and American Standards Association. As AT&T engineers followed Gherardi's lead, they learned that they could mobilize these industry standards committees to help solve critical problems within the Bell System. Ultimately, however, AT&T executives needed to take additional steps—appeals to government authorities—to protect and preserve their control over telephone networks. By doing so, these executives voluntarily ceded control over new technologies, such as the transistor, that presented opportunities for radical innovation in telecommunications services.

Beginning as early as the 1890s AT&T had sacrificed the pursuit of radical or disruptive innovations in order to preserve incremental momentum. Thanks to the vision of the system architects Edward Hall, Theodore Vail, John Carty, and Bancroft Gherardi, the Bell System was thoroughly standardized and fully protected from competitive entry and regulatory control. Between the 1880s and the 1950s, standardization provided a smooth middle ground between innovation and stability, between the development of new technologies or methods and the diffusion of these innovations on a calculated and system-wide basis.

By looking at the creation and growth of the monopoly Bell System from the vantage point of standardization, we can see two different roles of standardization—dynamic and static. As Louis Galambos argued, many Bell standardization initiatives before 1907 "had an essentially static quality," and sought to stabilize and harmonize technologies and practices across local and regional Bell licensee companies. With monopoly achieved under Vail, Bell engineers shifted focus and emphasized the dynamic aspects of standardization.[119] At a 1915 conference, Frank Jewett felt the need to instruct his fellow engineers on the differences. Jewett suspected that many of his colleagues interpreted the term "standard" to mean something like the standard meter in the Archives of Paris that was "fixed as nearly as possible for all time." Standards in the Bell System, however, were more dynamic. "What we call a standard of to-day may not be the standard of tomorrow," Jewett explained, "because some condition in that operating field or some advance in manufacturing may have made it expedient to change that practice or that apparatus."[120] This dynamic conception of standardization was of vital importance in the "engineering of the present," such as the transition from manual to machine switching that Gherardi oversaw during the 1920s and 1930s. In the view of Jewett and Gherardi, standardization was an ally of innovation and change.

However, as the Bell System gained momentum and monopoly status and sought to protect that momentum between the 1930s and the 1950s, the tendency toward stasis became more pronounced in the Bell approach to standardization. For example, instead of absorbing the staggering costs associated with redesigning coin telephone boxes,

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[119] Galambos also suggests that, prior to 1907, many standardization initiatives "had an essentially static quality." Galambos, "Theodore N. Vail and the Role of Innovation," 106-107.
[120] Frank Jewett, "Discussion of Mr. McQuarrie's paper [pages 7-8]," *Manufacturing and Engineering Conference*. Jewett's recognition of this tension anticipated conceptions from the 1920s, articulated by standards advocates such as P. G. Agnew and Albert Whitney, that drew philosophical distinctions between the static and dynamic character of standardization. See Chapter 3, "From Industry Standards to American Standards, 1910-1930."

AT&T looked to standards committees—and eventually regulators and police—to eliminate washers that could be used to manipulate coin-operated telephones. In another example in the 1940s and 1950s, AT&T lawyers successfully convinced the FCC that even harmless a device like the "Hush-a-Phone" was illegal because it was a network attachment that was not furnished by AT&T.[121] In both of these examples, AT&T demanded end-to-end control over the telephone network, and struggled mightily to avoid changing their entrenched structures of control.

AT&T got what it wanted from the Consent Decree in 1956: total control over telephone technology and administration in exchange for all rights to enter new and dynamic markets. Although Bell Labs produced a steady stream of innovations, AT&T executives recognized that their company was not in a position to capitalize on them. With AT&T's power curtailed, a diverse set of institutions—including established firms such as IBM, a group of entrepreneurial ventures in California, government agencies such as the Department of Defense, and international standards-setting committees such as the International Organization for Standardization—would assume leading positions in the development of electronic forms of communication. This constellation of institutions, through cooperative and competitive relationships, would create new standards, new network architectures, and, ultimately, a new information infrastructure for the Third Industrial Revolution.

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121 Vietor, *Contrived Competition*, 190-191.

Chapter 4: "Rough Consensus and Running Code": The Political Economy of Network Architecture, 1956-1992

4.1 Introduction

In the second half of the twentieth century, fundamental changes in technology—including digital and microwave transmission techniques, as well as new solid-state electronic components—presented opportunities for the creation of new communications systems. Unlike the technological systems of the early twentieth century, these new systems were not developed by any single firm. Instead, the new system architects were leaders of consensus standards committees that integrated decentralized advances in computer hardware and software. As systems innovators such as AT&T and IBM were hindered by federal regulation and pursued proprietary, "one-size-fits-all" strategies during the 1960s and 1970s, entrepreneurs and small firms flourished by building products that conformed to consensus standards. By the 1990s, hundreds of firms around the globe competed within a segmented, diffuse, and highly specialized industry structure, industry leaders such as AT&T and IBM lost their dominant positions, and systems innovation gave way to modular innovation.[1] The combined effects of technological, economic, and political change led historians to conclude that global society was in the midst of a Third Industrial Revolution.[2]

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[1] Andrew S. Grove, *Only the Paranoid Survive: How to Exploit the Crisis Points That Challenge Every Company* (New York: Currency, 1999), 37-52; and Richard N. Langlois, "Organizing the Electronic Century," Paper for the conference "Has There Been a Third Industrial Revolution in Global Business?" November 16-18, 2006, Bocconi University, Milan, Italy.

[2] Thomas McCraw, ed., *Creating Modern Capitalism: How Entrepreneurs, Companies, and Countries Triumphed in Three Industrial Revolutions* (Cambridge: Harvard University Press, 1995); and Alfred D. Chandler, Jr., "The Information Age in Historical Perspective: Introduction," in Alfred D.

One of the most striking developments of the Third Industrial Revolution was the rise of "open systems" in the computer and electronics industries. In contrast to the proprietary systems developed by IBM and its imitators, open systems consisted of components with interfaces that were publicly available. Open systems appealed to users who valued the ability to mix and match components for technologies such as personal stereos and minicomputers. But, perhaps more importantly, they also appealed to regulators, engineers, and entrepreneurs who disapproved of IBM's dominance and wished to facilitate greater diversity and competition in markets for electronic components.[3]

The most significant developments in open systems occurred within computer networks designed between the late 1960s and the early 1990s. During this period, computer scientists and engineers in the United States and Europe began to experiment with electronic computers and digital transmission as the basis of new packet-switched networks. AT&T executives, hamstrung by the 1956 Consent Decree and fully committed to their analog, circuit-switched network, opted not to participate in these experiments in computer networking. In the absence of AT&T's commanding institutional presence, the designers of the new computer networks—supported by the

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Chandler, Jr. and James W. Cortada, eds., *A Nation Transformed By Information: How Information Has Shaped the United States from Colonial Times to the Present* (New York: Oxford University Press, 2000), 3-38.

[3] On open systems, see Richard N. Langlois and Paul L. Robertson, "Networks and Innovation in a Modular System: Lessons from the Microcomputer and Stereo Component Industries," *Research Policy* 21 (1992): 297-311; Carl Cargill, "Evolution and Revolution in Open Systems," *StandardView* 2 (1994): 3-13; Martin Libicki, *Information Technology Standards: Quest for the Common Byte* (Boston: Digital Press, 1995), 75-129; Garth Saloner, "Economic Issues in Computer Interface Standardization: the Case of UNIX," *Economics of Innovation and New Technology* 1 (1989): 135-156; and Sigram Schindler, "Open Systems, Today and Tomorrow – A Personal Perspective," *Computer Networks* 5 (1981): 167-176.

United States Department of Defense and national governments in Europe—created new standards to fit within their new concepts in network architecture.

Institutional innovation sustained and guided technological innovation. As researchers sponsored by the Defense Department's Advanced Research Projects Agency (ARPA)[4] created new protocols from scratch, they learned that regular meetings within informal settings greatly facilitated their collaborative technical work. Because their network—the Arpanet[5]—was sponsored by the Defense Department and was not part of commercial, for-profit activity, these researchers did not turn to existing committees—such as the American Standards Association or the Institute for Electrical and Electronics Engineers—that were dedicated to industrial standardization. Instead, they created a fluid group of informal institutions, such as the Network Working Group (1969), Internet Configuration Control Board (1979), and Internet Engineering Task Force (1986), to manage the development of standards for packet-switched networks. These informal institutions consisted of members from a wide range of academic institutions, government contractors, and, eventually, private companies. Participants in these institutions established a culture of free-wheeling technical discussions in which they would test and compare a number of protocols and specifications before coming to an agreement on a single standard. On January 1, 1983, ARPA forced all the administrators

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[4] ARPA was renamed DARPA (for Defense Advanced Research Projects Agency) in 1972; then ARPA again in 1993, before changing back to DARPA once again in 1996. For consistency, I will use "ARPA" throughout this chapter.
[5] The proper rendering of the network's name is ARPANET. For aesthetic purposes, I use "Arpanet" throughout this chapter.

of all computers on the Arpanet to convert to a new set of "Internetworking" protocols, TCP/IP, thus marking the birth of the Internet.

Although researchers in Europe also sought to create a new network architecture for packet-switched networks during the same time period, their standardization process followed a different path. After an initial phase of cooperation with ARPA researchers, in 1977 the leaders of the major European computer firms and telecommunications monopolies decided to create their own network architecture within the International Organization for Standardization (ISO). ISO was a federation of national standards-setting organizations that was created in 1947 under the auspices of the United Nations. This network architecture, Open Systems Interconnection (OSI), was an attempt to establish a framework to accommodate "anticipatory standards," or standards that had not yet been created. Between the late 1970s and the early 1990s, the OSI seven-layer model became enshrined in computer science curricula and was endorsed by governments around the world. Because OSI enjoyed such widespread support, most experts expected competing networks—including the TCP/IP Internet—to fade away once protocols within the OSI model were standardized and implemented by users and manufacturers.

As the Internet and OSI were under development, a tense rivalry emerged between advocates of the two competing network architectures. The rivalry—described in 1993 by the telecommunications analyst William Drake as "the Internet religious war"—highlighted divergent worldviews toward technology, system design, and political authority. He wrote,

> The debate is not merely about the comparative efficacy of two sets of standards, but it is rather between two competing visions of how international standardization processes and network development should be organized and controlled.[6]

Where OSI advocates favored an approach that was blessed by negotiations at the highest levels of international politics, Internet advocates insisted that their work should be immune from such political pressures. Their style of innovation, therefore, was an implicit—and at times explicit—rejection and critique of the existing political economy of standardization. In 1992, the Internet architect David D. Clark articulated the conventional wisdom of the Internet community in a memorable phrase that became the community's credo: "We reject: kings, presidents and voting. We believe in: rough consensus and running code."[7]

The Internet religious war was settled by the mid-1990s, as ISO's bureaucratic and politicized standardization process failed to keep up with the Internet's informal approach that was more effective at coordinating diffuse and rapid technological innovation. An examination of the competition between the two network architectures reveals the ways that Internet engineers embedded their cultural values into specific Internet standards as well as the organizations responsible for creating and maintaining these standards.[8] As we strive to understand these technological, organizational, and

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[6] William Drake, "The Internet Religious War," *Telecommunications Policy* 17 (1993): 643.
[7] David D. Clark, "A Cloudy Crystal Ball: Visions of the Future," (plenary presentation at 24th meeting of the Internet Engineering Task Force, Cambridge, MA, July 13-17, 1992). Available from http://ietf20.isoc.org/videos/future_ietf_92.pdf.
[8] According to one history, the Internet's architectural principles "embody some value judgments and reflect the fundamental political and ethical beliefs of the scientists and engineers who designed the Internet." National Research Council, *The Internet's Coming of Age* (Washington, DC: National Academy Press, 2000), 35. See also Helen Nissenbaum, "How Computer Systems Embody Values," *Computer* (2001): 118-120.

cultural choices, it is helpful to keep in mind the forms of consensus standardization pioneered in the early twentieth century (and described in Chapter 2). Internet researchers may not have seen themselves as operators within an "industrial legislature," but much like Paul Gough Agnew in the 1920s, they did view their collaborations as a demonstration of the failures of existing power structures. In both the Second and the Third Industrial Revolutions, creating consensus standards was as much an act of inclusion as it was an act of exclusion; as much a creation of new institutions as it was a critique of existing power structures.

4.2 Computer Systems and Networks, 1956-1969

IBM dominated the early years of the electronic computer industry. The demand for computers rose dramatically in the late 1940s and early 1950s, as the American military searched for the means to process large amounts of data for ballistics firing tables, radar systems, and command and control systems. Based in large part on its ability to partner with the military and research projects at MIT, IBM became a world leader in computing technology, and leveraged its organizational capabilities to become the dominant force in the domestic and international computer industry by the mid-1950s. IBM manufactured different electronic computers—six models in total—that could be programmed to meet the needs of almost every type of user in scientific, government, military, and business settings.[9] However, the incompatibilities between IBM's different

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[9] Kenneth Flamm reported that over half of IBM's research budget in the 1950s and 1960s came from government contracts. Kenneth Flamm, *Creating the Computer: Government, Industry, and High Technology* (Washington: The Brookings Institutions, 1988), 94. See also Steven W. Usselman,

models created problems that the firm found difficult to manage, such as tensions between divisions and excessive diversity in components. In 1964, IBM executives responded to these problems with a strategy that replaced all existing models of IBM machines with a series of computers designed around a single system architecture: System/360.

The chief architectural innovation of System/360 was the establishment of standard interfaces for different components of the system, including peripherals (such as storage devices, printers, and terminals) and software. By creating standardized components that fit within a modular design, IBM ensured that different customers and users could customize the system in order to meet their individual needs. On the supply side, IBM achieved new economies of scale and scope in production by reducing variety in components, further adding to the company's bottom line. The System/360 was a "bet the company" strategy that paid spectacular dividends: the company received over one thousand orders within a month of the System/360 announcement in April 1964, and IBM's gross income more than doubled between 1965 and 1970.[10] Altogether, System/360 was a brilliant strategy because it consolidated existing market power into a standardized system that was under IBM's exclusive control.

"IBM and its Imitators: Organizational Capabilities and the Emergence of the International Computer Industry," *Business and Economic History* 22 (1993): 1-35; Alfred D. Chandler, *Inventing the Electronic Century: The Epic Story of the Consumer Electronics and Computer Industries* (New York: The Free Press, 2001), 7-9, 85-176; and Thomas P. Hughes, *Rescuing Prometheus* (New York: Pantheon Books, 1998), 15-68.

[10] Paul E. Ceruzzi, *A History of Modern Computing* (Cambridge: The MIT Press, 1998), 145; Emerson W. Pugh, *Memories That Shaped an Industry: Decisions Leading to IBM System/360* (Cambridge: The MIT Press, 1984); Emerson W. Pugh, *Building IBM: Shaping an Industry and its Technology* (Cambridge: The MIT Press, 1995); Flamm, *Creating the Computer*, 96-102.

IBM executives, much like their counterparts at AT&T in the early twentieth century, used standardization as a strategy and a practice when their company faced organizational and technological complexity. Standards simplified intra-company coordination and, when imposed by dominant firms such as AT&T or IBM, created higher barriers to entry. Just as Edward Hall and Theodore Vail devised AT&T's corporate strategy in order to control the terms of telephone interconnection, so too did Gene Amdahl and Fred Brooks (two of the lead architects of System/360) design the System/360 so that IBM could define and control the standardization of interfaces between computer components. For both firms, complete control over system architecture reinforced and extended existing dominance in their respective industries.

Like AT&T in the era of "Universal Service," IBM faced a number of smaller competitors. Most of the competitors, including Sperry Rand, National Cash Register, Burroughs, Honeywell, RCA, and General Electric responded to the System/360 by introducing their own proprietary alternatives, but ultimately failed to take much of IBM's market share. Two of the notable successes in this era, Control Data Corporation and Digital Electronics Corporation ("Digital"), survived by focusing on niche markets. Control Data found some success with a strategy that focused on making high-performance "supercomputers" for scientific uses at the high end of the market. Digital, on the other hand, created a line of "minicomputers" in the early 1960s that appealed to users who wanted to modify and experiment with machines for their own specialized purposes. In stark contrast to IBM's policy of leasing computers to customers, Digital sold their computers outright and provided customers with detailed specifications for tinkering with the machine. This strategic decision fed a growing appetite among users—including communities of "hackers" at MIT—who resented the IBM approach that kept its computers out of reach in sealed rooms.[11]

The above examples—IBM's success with the System/360 as well as the niche strategies of Control Data and Digital—show how computer manufacturers in the 1960s designed system architectures to meet a wide variety of customer needs. Recent studies by James Cortada indicate the breadth and diversity of computer users in almost every conceivable industry, including firms in the manufacturing, retail, transportation, financial, media, and entertainment sectors.[12] However, in one case in the late 1960s, an important community of computer users in the United States Defense Department found that neither IBM nor its competitors could meet its needs. This community responded to the market's failure to provide an appropriate commercial solution by building a new system architecture for connecting computers, known as the Arpanet.

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[11] Timothy F. Bresnahan and Franco Malerba, "Industrial Dynamics and the Evolution of Firms' and Nations' Competitive Capabilities in the World Computer Industry," in David C. Mowery and Richard R. Nelson, *Sources of Industrial Leadership: Studies of Seven Industries* (New York: Cambridge University Press, 1999), 95-96; Chandler, *Inventing the Electronic Century*, 94-106; Ceruzzi, *A History of Modern Computing*, 128-143, 161-173; and Steven Levy, *Hackers: Heroes of the Computer Revolution* (New York: Doubleday, 1984).
[12] James W. Cortada, *The Digital Hand Volume I: How Computers Changed the Work of the American Manufacturing, Transportation, and Retail Industries* (New York: Oxford University Press, 2003); and James W. Cortada, *The Digital Hand Volume II: How Computers Changed the Work of American Financial, Telecommunications, Media, and Entertainment Industries* (New York: Oxford University Press, 2006). For an emphasis on commercial firms as users, see JoAnne Yates, *Structuring the Information Age: Life Insurance and Technology in the Twentieth Century* (Baltimore: The Johns Hopkins University Press, 2005).

4.2.1 JCR Licklider, Interactive Computing, and the Arpanet

The visionary behind the creation of the Arpanet was a psychologist from MIT, J.C.R. Licklider. Licklider was the leader of a nascent community of computer researchers funded by the Department of Defense during the 1960s. Licklider had a longstanding interest with computers that began after his research in psychoacoustics convinced him that computers could help humans think and work in more sophisticated ways, resulting in a partnership of humans and electronic computers that, by the early 1960s, he called "interactive computing."[13] Licklider's vision of interactive computing differed from the prevailing notion of computing at IBM, in which users submitted stacks of cards to a uniformed operator who was the only person authorized to run programs on the computer. In the vision of interactive computing shared by Licklider and others at MIT, the tremendous social potential of computers could be tapped only when individual users could interact directly with the machine.[14]

Broader developments in national security provided Licklider with a chance to pursue his vision on a large scale.[15] After the "Sputnik shock" of 1957, President Dwight D. Eisenhower created the Advanced Research Projects Agency (ARPA) within the U. S. Defense Department, with the expectation that it would help the American military keep

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13 J.C.R. Licklider, "Man-Computer Symbiosis," *IRE Transactions on Human Factors in Electronics* Vol. HFE-1 (March, 1960), 4-11.

14 M. Mitchell Waldrop, *The Dream Machine: J. C. R. Licklider and the Revolution That Made Computing Personal* (New York: Viking, 2001); and Howard Rheingold, *Tools for Thought: The History and Future of Mind-Expanding Technology* (Cambridge: The MIT Press, 2000 [1985]), 132-151.

15 I explore these issues in depth in Andrew L. Russell, "Ideological and Policy Origins of the Internet, 1957-1969," paper presented to TPRC 2001, the 29th Research Conference on Communication, Information, and Internet Policy, Washington, DC, October 28, 2001. Available from http://www.arxiv.org/abs/cs.CY/0109056.

up with the technological capabilities of the Soviets. This basic course of action—heavy government investment in science and technology, in the hopes that American scientists would be able to win another war—was one of the core assumptions of the science policy consensus that Americans forged in the early Cold War.[16]

In 1961, Defense Department officials Jack Ruina and Eugene Fubini decided to centralize the DoD's research on computing technology into one program, and asked Licklider to lead it.[17] Licklider, known to Ruina as a "man of some distinction," had previous experience in military science through acoustic research for the Navy during World War II and as an advisor to Air Force scientific studies since 1952.[18] Licklider immediately seized the opportunity to advance what he often referred to as an evangelical mission, his "religious conversion to interactive computing."[19] His primary strategy was to link his vision of interactive computing to ARPA's overarching need to find new ways to use computers in military communications (known at the time as command and control). "Every time I had the chance to talk," Licklider recalled of his first days at

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16 On the science policy consensus and Cold War consensus, see David Hart, *Forged Consensus: Science, Technology, and Public Policy in the United States, 1921-1953* (Princeton, NJ: Princeton University Press, 1998); Bruce L. R. Smith, *American Science Policy since World War II* (Washington, DC: The Brookings Institution, 1990); and Robert Griffith, "Dwight D. Eisenhower and the Corporate Commonwealth," *The American Historical Review* 87, Supplement (1982): 87-122.
17 Fubini was Director of Defense Research and Engineering (DDR&E). The DDR&E was the only step in the chain of command between the director of ARPA and the Secretary of Defense. Ruina was ARPA director between February 1961 and September 1963.
18 Jack Ruina, OH 163. Oral History interview by William Aspray, 20 April 1989, Cambridge, Massachusetts. Charles Babbage Institute, University of Minnesota, Minneapolis.
19 Howard Rheingold, *Tools for Thought*, 138. The evocative language of "religious conversion" also appears in J. C. R. Licklider, OH 150. Oral History interview by William Aspray and Arthur L. Norberg, 28 October 1988, Cambridge, Massachusetts. Charles Babbage Institute, University of Minnesota, Minneapolis; and John A. N. Lee and Robert Rosin, "The Project MAC Interviews," *IEEE Annals of the History of Computing* 14 (April-June, 1992): 16-17.

ARPA, "I said that the mission is interactive computing." He convinced his colleagues that

> the problems of command and control were essentially problems of man computer interaction… Fubini essentially agreed 100% with that and so did Ruina… Why didn't we develop an interactive computing? If the Defense Department's need for that was to provide an underpinning for command and control, fine. But it was probably necessary in intelligence and other parts of the military too. So, we essentially found that there was a great consonance of interest here, despite the fact that we were using different terms we were talking about the same thing.[20]

Once he convinced his Pentagon bosses of the utility of his work, Licklider operated freely under conditions that he referred to as "benign neglect." With Ruina and Fubini concentrating on the agency's much larger programs for ballistic missile defense and nuclear test detection, Licklider was able to direct the program with a great deal of autonomy. Throughout the mid-1960s, Licklider and his successors at ARPA's Information Processing Techniques Office (IPTO) funded research projects in pursuit of their shared vision of interactive computing, such as time sharing, networking, graphics, and artificial intelligence. These types of projects—especially time-sharing, where different users could use a single computer simultaneously—were not priorities in the "one-size-fits-all" design of IBM's System/360.[21]

Licklider left IPTO in 1964 and was succeeded at first by Ivan Sutherland (1964-1966) and then Robert W. Taylor. In 1966 and 1967, Taylor and his deputy Lawrence Roberts initiated a series of conversations among IPTO-supported researchers about the

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[20] Licklider interview, Charles Babbage Institute.
[21] Licklider interview, Charles Babbage Institute. On IPTO, See Arthur L. Norberg and Judy E. O'Neill, *Transforming Computer Technology: Information Processing for the Pentagon, 1962-1986* (Baltimore: The Johns Hopkins University Press, 1996). On time-sharing and IBM, Ceruzzi, *A History of Modern Computing*, 154-156.

possibility of building a network to connect the seventeen ARPA-funded computer centers around the country. Such a network—dubbed the Arpanet—could simultaneously address IPTO's administrative and research goals: IPTO would be able to conserve its computing budget by facilitating remote access to expensive computers; researchers at different sites could swap data and programs developed remotely and on incompatible systems (such as the IBM System/360 and Digital's PDP-8); and the network itself would be an exciting new research focus for the time-sharing community.[22] Since every major computer manufacturer was following a proprietary strategy designed to prevent connections between dissimilar systems, the Arpanet represented a government-funded project that sought to compensate for this market failure.

The chief innovation in the Arpanet's system architecture was its reliance on packet-switching. Packet-switching was developed independently in the mid-1960s by two researchers, Paul Baran at RAND in the United States and Donald Davies at the National Physical Laboratory in England. Packet-switching breaks data into discrete chunks (or packets) that contain basic information about their places of origin and destination. The packets are then sent throughout nodes in the network and eventually arrive at their destination, where they are reassembled into their original form. Unlike the circuit-switched networks used by AT&T, packet-switched networks did not require a constant connection. Instead, a packet-switched network could send individual packets

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[22] The origins of the Arpanet have been explored at length in a number of books and articles. The best include Janet Abbate, *Inventing the Internet* (Cambridge, MA: The MIT Press, 1999); Norberg and O'Neill, *Transforming Computer Technology*; Katie Hafner and Matthew Lyon, *Where Wizards Stay Up Late: The Origins of the Internet* (New York: Simon & Schuster, 1996); and Janet Abbate, "Government, Business, and the Making of the Internet," *Business History Review* 75 (2001): 147-176.

along any number of routes to their final destination—a feature that made packet-switched networks more robust and, according to Baran, more likely than circuit-switched networks to survive a catastrophic event.[23]

Although AT&T provided the leased-line infrastructure for the Arpanet, AT&T played a curious—and ultimately negligible—role in the design of packet-switched networks. When Baran approached AT&T with his ideas in the mid-1960s, AT&T executives dismissed the notion that their analog network was inadequate. Despite some support for Baran's ideas within Bell Labs, Baran and AT&T could not get past what he called a "cultural impasse": AT&T engineers were fully enmeshed in an analog mindset, and could not understand how a digital, packet-switched network would be more reliable than the Bell System. AT&T also displayed an arrogance toward Baran's innovative ideas. Baran recalled in a 1999 interview that an irritated AT&T official told him, "It isn't going to work, and even if it did, damned if we are going to put anybody in competition to ourselves."[24] Baran continued,

> I suspect the major reason for the difficulty in accommodating packet switching at the digital transmission level was that it would violate a basic ground rule of the Bell System—everything added to the telephone system had to work with all previous equipment presently installed. Everything had to fit into the existing plan.[25]

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[23] Paul Baran, "On Distributed Communications Networks," *IEEE Transactions on Communications* 12 (March, 1964): 1-9. Baran published more detailed analyses in twelve volumes entitled *On Distributed Communications*, published by RAND Corporation in 1964. For an analysis of packet-switching in its Cold War context, see Abbate, *Inventing the Internet*, 7-42.
[24] Paul Baran, Electrical Engineer, an oral history conducted in 1999 by David Hochfelder, IEEE History Center, Rutgers University, New Brunswick, NJ, USA. See also Paul Baran, OH 182. Oral history interview by Judy O'Neill, 5 March 1990, Menlo Park, California. Charles Babbage Institute, University of Minnesota, Minneapolis.
[25] Baran interview, IEEE.

AT&T's greatest technological strength—thorough standardization into a permanent, "universal" network architecture—was also a great impediment to new ideas, which meant that a digital, packet-switched communications system would require new institutions to create and maintain it. Lawrence Roberts, who replaced Taylor as IPTO Director in March 1969, gathered several ARPA researchers into the Network Working Group, the first such institutional effort to design a packet-switched network. At first, the Network Working Group was led by Steve Crocker, a graduate student at UCLA, and consisted mostly of graduate students at other ARPA-funded sites at UCLA, the University of California at Santa Barbara, the University of Utah, and the Massachusetts Institute of Technology. The group also included representatives from ARPA contractors such as Bolt, Beranek and Newman, Rand, and the Stanford Research Institute.

The main technical objective of the Network Working Group was to create technical specifications to connect ARPA mainframes—known as "host" computers—to the network. Each mainframe would be connected to a small computer, designed by engineers from Bolt, Beranek and Newman, called an IMP ("interface message processor").[26] Because IMPs were the common gateways to the Arpanet, their software for communicating with hosts—known as the Network Control Protocol (NCP)—would be the defining point of interconnection. The most important design principal behind NCP was simplicity, which greatly facilitated the implementation of protocols on different, incompatible computers at ARPA sites. By August 1971, the Network Working Group had developed and implemented additional network applications on a

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[26] In this era, a "small" computer was about the size of a refrigerator.

number of host computers, including the now-familiar programs for remote login (telnet), file transfer (ftp), and electronic mail.[27]

The social dynamics of the Network Working Group also reinforced the logic of simplicity in the Arpanet's design. Roberts extended Licklider's effort to develop a social network alongside a computer network, and sought to develop shared goals and values through frequent site visits, contractor meetings, and retreats. However, tensions simmered among members of the group, mostly centered around the role of Bolt, Beranek and Newman. The company—the leading contractor for the Arpanet—viewed the Arpanet experience as an opportunity to develop a strong position in a growing niche of the computer industry, and sought to protect this strategic advantage by taking a secretive approach and sometimes resisting the release of the IMPs' technical details to other ARPA researchers.[28]

These tensions, though significant, did not derail the group's promising work. They did, however, inform the style of collaboration that took shape within the Network Working Group. In 1969, Crocker initiated a document series—Request for Comments (RFCs)—whose name and structure perfectly captured this work style. In 1987, Crocker recalled "Most of us were graduate students… we kept expecting that an official protocol design team would announce itself." No such team arrived—a fact that Crocker was slow to realize. In the meantime, he was overcome by a

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[27] Abbate, *Inventing the Internet*, 59-69.
[28] Abbate, *Inventing the Internet*, 69-74.

> great fear that we would offend whomever the official protocol designers were, and I spent a sleepless night composing humble words for our notes. The basic ground rules were that anyone could say anything and that nothing was official. And to emphasize the point, I labeled the notes "Request for Comments."[29]

The RFCs soon became the vehicle for the Network Working Group to publish consensus statements and technical standards for the Arpanet.[30] Over three years of planning culminated with the installation of the first node on the Arpanet at UCLA in September 1969. By December, computers at three additional sites were connected via IMPs to the Arpanet and, hence, one another. The Arpanet grew quickly in subsequent years: from four hosts at the end of 1969, to 23 hosts in 1971, to almost 50 by the end of 1973—including one in England.

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[29] Stephen D. Crocker, "The Origins of RFCs," in Joyce Reynolds and Jon Postel, eds. (1987), "The Request for Comments Reference Guide," RFC 1000, http://www.ietf.org/rfc/rfc1000.txt.

[30] Steve Crocker, OH 233. Oral history interview by Judy E. O'Neill, 24 October 1991, Glenwood, Maryland. Charles Babbage Institute, University of Minnesota, Minneapolis. See also Reynolds and Postel, eds., RFC 1000; and RFC Editor, et al. (1999), "30 Years of RFCs, RFC 2555, http://www.ietf.org/rfc/rfc2555.txt.

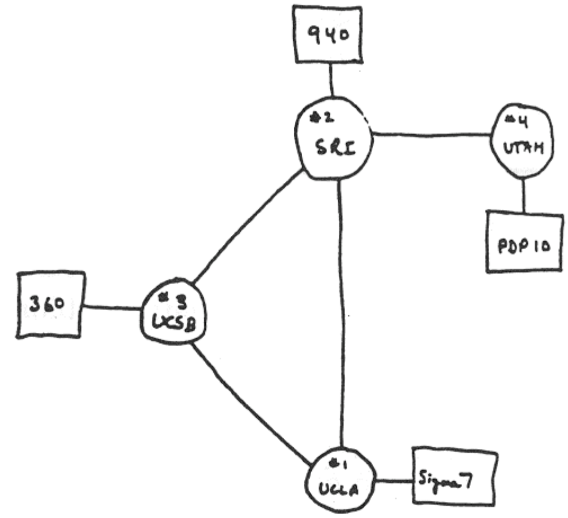

Figure 4.1: Arpanet, December 1969.

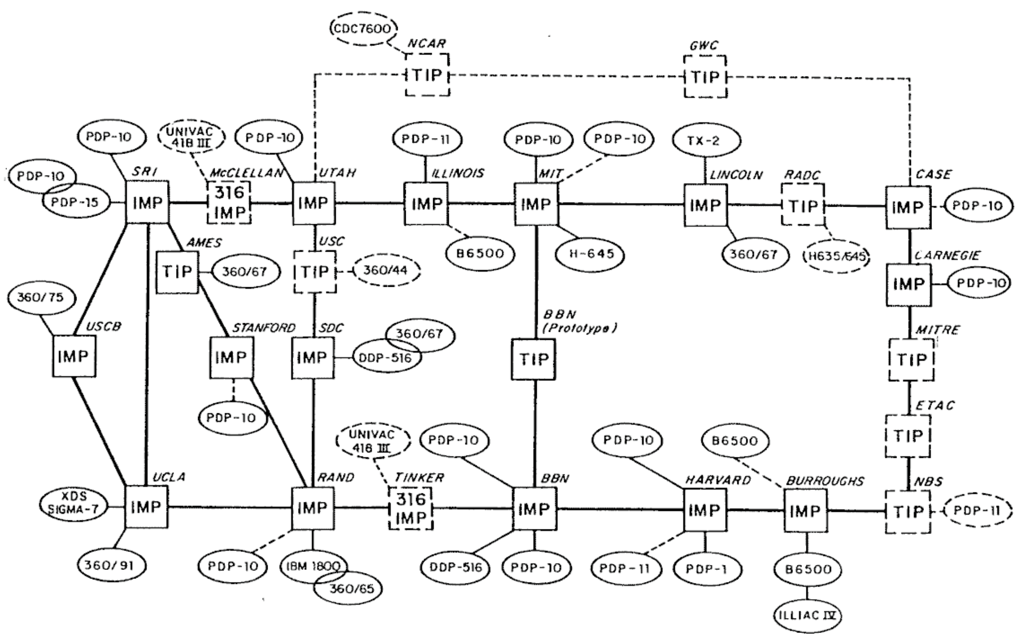

Figure 4.2: Arpanet, August 1971.

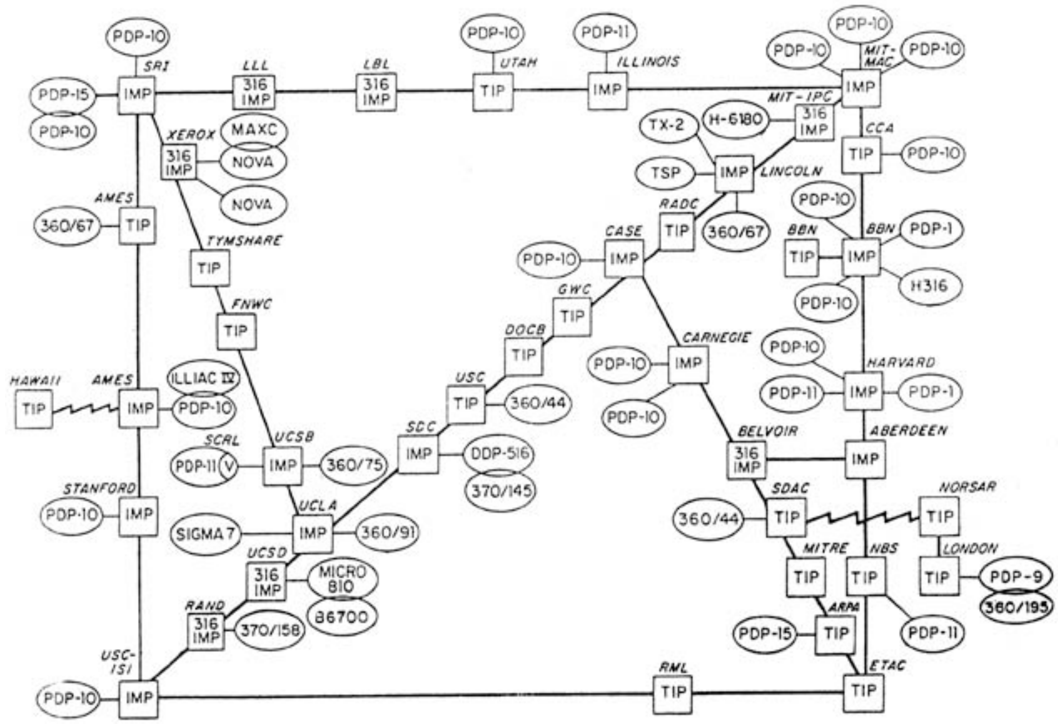

Figure 4.3: Arpanet, September 1973.

As it grew, the Arpanet was an important research project in its own right as well as an infrastructure for other ARPA-sponsored projects and experiments in computer networking. The network continued to grow as more and more users wrote, tested, and implemented protocols. In sum, the standards-setting process in the early Arpanet was both a forum for debate as well as a means for arriving at a consensus and moving the community forward together. This tension between competition and cooperation in the Network Working Group provided a taste of the standards wars to come.

4.3 Internetworking in the United States and Europe

After their initial networking experiments with the Arpanet, ARPA researchers, led by Robert Kahn and Vint Cerf, continued to explore networking concepts for satellite and radio technologies. The problem of network interconnection—how to enable communication between technically disparate computer networks—was a challenging research problem, one with significant implications for mobile military communications. In the early 1970s, ARPA developed a packet radio network (known as PRnet) based on the same packet-switching technology being tested in the Arpanet. The PRnet project was led by Kahn, an engineer at Bolt, Beranek and Newman who moved to ARPA in 1972 and became head of the Arpanet program from 1973-1976. Kahn hoped to connect packet radio networks to large computers in the continental U. S. via the Arpanet (PRnet was developed in Hawaii), but faced a problem of trying to connect what he later called "two radically different networks" with different network capacities, protocols, and routing systems.[31] ARPA's concurrent development of satellite packet switching in SATnet further compounded this problem, leading Kahn to conclude that network interconnection could not be achieved on an *ad hoc*, network-to-network level.

To overcome this problem, in 1973 Kahn rekindled an effective partnership with Cerf that began when the two worked together on the first node of the Arpanet at UCLA (where Cerf was a graduate student) in 1969. Cerf graduated in 1972, and joined the

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[31] Robert Kahn, OH 192. Oral history interview by Judy E. O'Neill, 24 April 1990, Reston, Virginia. Charles Babbage Institute, University of Minnesota, Minneapolis. Kahn continued, "… all the details were different. I don't mean conceptually they were different. They were sort of the same genre. Just like, say, Chinese and Americans are of the same genre except one speaks Chinese and one speaks English, one lives on one side of the world, they go to sleep during your daytime, etc."

faculty of computer science at Stanford the same year. To overcome the problem of network interconnection, Kahn and Cerf created a new mechanism to transport data packets. This mechanism was a simple technical protocol (transmission control protocol, or TCP) and system of gateways (now known as routers) between networks.[32] Their underlying goal was to make the network invisible to users, including their military patrons, who would be more interested in accessing information over the network instead of the operation of the network itself.

In July 1977, they ran a successful demonstration of a network that consisted of the three networks, SATnet, PRnet, and Arpanet. This was the first public demonstration of internetworking, and the ARPA networks would soon be known as one entity—the Internet. In 1978, Cerf and two other ARPA-funded researchers, Danny Cohen and Jon Postel, split the functions of TCP into two protocols, TCP and the Internet Protocol (IP), that worked together and became known as TCP/IP.[33]

Three basic design principles lay behind the Internet's architecture as it emerged in the late 1970s. The first—interconnection via common protocols—was a principle that had been explicitly recognized since the earliest days of the Arpanet. The second principle became known as the "end-to-end" principle. End-to-end design only required the network to send packets back and forth, and left the complex tasks of decoding and

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32 Vinton G. Cerf and Robert E. Kahn, "A Protocol for Packet Network Intercommunication," *IEEE Transactions on Communications* Com-22 (1974): 637-648.

33 Cerf, Cohen, and Postel split the protocol into TCP and IP in order to reduce the requirements on network gateways and leave complex tasks such as tracking reliable packet delivery to the computers at the ends of the network. See Abbate, *Inventing the Internet*, 129-30; Vinton G. Cerf, "Protocols for Interconnected Packet Networks," *Computer Communication Review* 18 (October, 1980): 10-11; and Jon Postel, ed. (1980), "DOD Standard Internet Protocol," RFC 760, http://www.ietf.org/rfc/rfc760.txt. For records of discussions leading up to the TCP/IP split, see the series of "Internet Engineering Notes" at ftp://ftp.rfc-editor.org-1/ien-index.html.

processing packets to host computers at the edges of the network. This design stood in stark contrast to the circuit-switched telephone network, in which AT&T designed a stunning amount of intelligence (including human operators) in the middle of the network.[34] The Arpanet's designers recognized the importance of the third principle—layering—as early as 1967.[35] A layered network separates various network functions from one another, so that a change at one layer of the network does not necessitate changes at another. Layered design thus created both a technical and a social division of labor: by relying on a system architecture consisting of common interfaces, researchers could focus their efforts narrowly on innovations that fit within one particular layer and not concern themselves with how their new application or protocol would interact with other innovations.[36]

These three basic principles—standard protocols, end-to-end design, and layering—became centrally important as the Internet protocols attracted the attention of a researchers in England, France, and other countries who were experimenting with packet-switched networks. International collaboration was an important feature of the growth of computer networks in the mid-1970s. The opening act of this collaboration was the First International Conference of Computer Communications held in Washington, DC in October 1972. After months of preparations orchestrated by Kahn, the Arpanet went on

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[34] Jerome H. Saltzer, David P. Reed, and David D. Clark, "End-To-End Arguments in System Design," *ACM Transactions on Computer Systems*, Vol. 2, No. 4 (November, 1984), 277-288; and David D. Clark, "The Design Philosophy of the DARPA Internet Protocols," *Proc. SIGCOMM '88, Computer Communication Review* 18 (1988), 106-114.

[35] M. A. Padlipsky, *The Elements of Networking Style, And Other Animadversions on the Art of Intercomputer Networking* (Lincoln, NE: iUniverse, 2000, first edition Prentice-Hall, 1985), 89-115.

[36] Abbate, *Inventing the Internet*, 50-53.

public display, stunning the audience with demonstrations of applications such as interactive graphics, methods of reading Associated Press reports over the network, and several chess programs. It was a resounding success—even if utterly baffling to the ten AT&T executives who attended, and declined ARPA's offer to operate the Arpanet or even purchase it outright.[37]

The 1972 meeting was a morale boost for the Arpanet community as well as an opportunity to formalize international cooperation. At the Washington meeting, Vint Cerf from UCLA chaired the first meeting of the International Network Working Group (INWG), created to bring Arpanet researchers in closer contact with their European counterparts. Cerf chaired the group until 1976. It was a formative experience for Cerf, both in a technical sense and in a political sense. Technically speaking, Cerf's own ideas about networking—which would eventually be incorporated in the design of TCP/IP—were influenced strongly by his interactions with French researchers in the INWG, especially Louis Pouzin and Gerald Lelann. Pouzin was the head of the Cyclades packet-switched network in France that was built in 1972 and supported by government funds. Lelann, in addition to his active participation in Cyclades and in INWG meetings, also spent a year in Cerf's lab at Stanford, and was active in the discussions leading up to the specification of TCP.[38]

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[37] Robert Kahn (1972), "Demonstration at International Computer Communications Conference," RFC 371, http://www.ietf.org/rfc/rfc371.txt; Hafner and Lyon, *Where Wizards Stay Up Late*, 176-186; Abbate, *Inventing the Internet*, 123-127.

[38] Vinton Cerf, OH 191. Oral history interview by Judy E. O'Neill, 24 April 1990, Reston, Virginia. Charles Babbage Institute, University of Minnesota, Minneapolis. See also Abbate, *Inventing the Internet*, 123-133; and Louis Pouzin, *The Cyclades Computer Network: Towards Layered Network Architectures* (New York: North-Holland Publishing Company, 1982).

Apart from these important technical collaborations, Cerf also obtained a first-hand look at the politics of European standards-setting—a vast and complex subject which has been explored in a number of books and articles.[39] Beginning in 1974-5, the European telephone monopolies recognized the potential value of packet-switched networks and commenced their own standards effort (called X.25) through the International Telecommunications Union, which consisted of representatives from national governments around the world. Representatives from Japan and Canada soon joined the group. Where AT&T had been barred from computer markets by the 1956 Consent Decree and subsequent rulings from the Federal Communications Commission, no such regulations prevented the European telephone monopolies from attempting to bring computer communications under their own jurisdiction. Because the X.25 committee was dominated by the telephone monopolies, European computer firms—as well as IBM, which introduced its own proprietary networking system in 1974—looked for other venues to create their own standards.[40]

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[39] Robin Cowan, ed., *Information Technology Standards: the Economic Dimension* (Paris: Organisation for Economic Co-operation and Development, 1991), 23-30; Susanne K. Schmidt and Raymund Werle, *Coordinating Technology: Studies in the International Standardization of Telecommunications* (Cambridge: The MIT Press, 1998); Abbate, *Inventing the Internet*, 147-180; Paul A. David and Mark Shurmer, "Formal Standards-Setting for Global Telecommunications and Information Services," *Telecommunications Policy* 20 (1996): 789-815; and William J. Drake, "The Transformation of International Telecommunications Standardization: European and Global Dimensions," in Charles Steinfield, Johannes M. Bauer and Laurence Caby, eds., *Telecommunications in Transition: Policies, Services, and Technologies in the European Community* (Thousand Oaks, CA: Sage Publications, 1994), 71-96.

[40] Abbate, *Inventing the Internet*, 152-155; Robert Cannon, "The Legacy of the Federal Communication Commission's Computer Inquiries," *Federal Communications Law Journal* 55 (2003): 167-206; and Jason Oxman, "The FCC and the Unregulation of the Internet," Federal Communications Commission Office of Plans and Policy Working Paper No. 31 (July, 1999).

As this controversy was brewing, Cerf and the INWG were trying to establish a consensus around their own standards for packet-switched networks.[41] Cerf attempted to convince the group to adopt TCP as the consensus transport protocol; but, in January 1978, the group instead chose a protocol developed within the Cyclades network. This was a turning point in a previously collaborative effort. Members of the INWG immediately moved their work to a more established standards body, the International Organization for Standardization (ISO), which would be in a better position to advance their interests and resist the competing initiative led by the telephone monopolies. Cerf, who became the director of the Internet program at ARPA in 1976, became frustrated with the politics of the European situation, rededicated his efforts to the TCP/IP Internet and, according to one participant, subsequently denied funding for ARPA contractors to participate in ISO meetings.[42] By the late 1970s, then, three competing communities of researchers—ARPA contractors, telecommunications professionals in the ITU, and European computer professionals—were seeking to establish their own design as the definitive architecture for packet-switched networks.

4.3.1 The Political Economy of Open Systems Interconnection (OSI)

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[41] In 1972, the group had become affiliated with the International Federation for Information Processing (IFIP), a non-governmental organization of computer professionals that was established under the auspices of UNESCO in 1960. See Alex Curran and Vinton Cerf, "The Work of IFIP Group 6.1," *ACM SIGCOMM Computer Communication Review* 6 (April, 1975): 18-27.

[42] John Day, conversation with author, November 8, 2006. Day worked on the Arpanet and Internet protocols, first at Bolt, Beranek and Newman, and later in several other small networking companies. An extensive set of materials related to the INWG are available from the Charles Babbage Institute. See Alex McKenzie Collection of Computer Networking Development Records (CBI 123), Charles Babbage Institute, University of Minnesota, Minneapolis.

The late 1970s was a dynamic and uncertain period for international computer networking. In addition to the three efforts described above, both IBM and Digital introduced their own proprietary networking products: IBM's System Network Architecture (1974) and the Digital Network Architecture (1975). For many customers, these proprietary solutions were adequate; but for users who were technically advanced—and for regulators and competing firms who did not want to see one or two firms dominate the industry—proprietary networks threatened their own visions of the future.[43]

During the same period, a movement for "open systems" emerged as a technical, economic, and political response to the proprietary network architectures. An open system consisted of interfaces that were non-proprietary and available to any interested firm (instead of controlled by a single firm or group of firms). The emergence of many types of open systems in the 1970s and 1980s (such as for microcomputers and personal stereos) helped smaller producers and consumers who did not want to be locked in to proprietary products from a single manufacturer.[44]

The political economy of the European computer industry made open systems an especially attractive option for computer networking in the late 1970s. First, although individual European nations pursued industrial policies that favored "national champion" firms, this approach flew in the face of the movement to unify European markets.

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[43] Paul E. Green, Jr., ed., *Network Interconnection and Protocol Conversion* (New York: IEEE Press, 1988); R.J. Cypser, *Communicating for Cooperating Systems: OSI, SNA, and TCP/IP* (Reading, MA: Addison-Wesley, 1991); and Timothy F. Bresnahan and Shane Greenstein, "Technological Competition and the Structure of the Computer Industry," *The Journal of Industrial Economics* 47 (1999): 30.

[44] Langlois and Robertson, "Networks and Innovation in a Modular System: Lessons from the Microcomputer and Stereo Component Industries," 297-313.

Second, the limited size of each national market prevented the national champions from generating the economies of scale and scope necessary to compete with IBM.[45] Finally, standardization efforts among European telecommunications and computing professionals in the ITU, INWG, and the European Computing Machinery Association were working at cross-purposes, without sufficient levels of cooperation. As a result, when the International Organization for Standardization (ISO) created a subcommittee in 1977 to create a new network architecture, Open Systems Interconnection (OSI), each of the various constituencies (along with representatives from national standards bodies in the United States, Japan, and Canada) joined in the effort to create an international consensus network architecture.

OSI defined a seven-layer Reference Model in which standards could fit and work together. This Reference Model did not specify individual standards—those could be proposed and negotiated by constituent groups. In other words, OSI set the ground rules for network interconnection, and left the specific terms of interconnection to standards that fit within the overarching Reference Model.[46] OSI, then, was a departure from the standards typically sanctioned by ISO: in most cases, ISO standardized existing technologies and designs; but OSI was a rare case of "anticipatory standardization," where ISO moved ahead of the existing state of technology and sought to shape future

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[45] Chandler, *Inventing the Electronic Century*, 177-189; Bresnahan and Malerba, "Competitive Capabilities in the World Computer Industry," 102.

[46] Hubert Zimmerman, "OSI Reference Model—The ISO Model of Open Architecture for Open Systems Interconnection," *IEEE Transactions on Communications* 28 (1980): 425-432; and Richard des Jardins, "Overview and Status of the ISO Reference Model of Open Systems Interconnection," *Computer Networks* 5 (1981): 77-80.

developments.[47] Like the Internet, OSI emphasized principles of layering and modularity; however, unlike the Internet, OSI sought to impose the network architecture in a top-down manner, rather than developing protocols in an organic and—to an outsider—almost haphazard way. OSI was designed by professionals, who saw the Internet as an experimental work in progress and a playground for graduate students and the American military.[48]

During the 1980s and early 1990s, the OSI effort within ISO enjoyed widespread support from national governments, particularly in Western Europe, North America, and the Far East.[49] ISO was an "industrial legislature" on an international scale—a direct descendent of the efforts of Paul Gough Agnew and Charles Le Maistre, two pioneers of consensus standardization in the early twentieth century.[50] Indeed, the organization that Agnew had championed for so long—the American Standards Association—sent

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[47] In their ongoing work on the history of ISO, JoAnne Yates and Craig Murphy emphasize that the original intent of ISO was to coordinate existing standards, and not to promulgate new standards. JoAnne Yates and Craig Murphy, "From Setting National Standards to Coordinating International Standards: The Formation of the ISO," *Business and Economic History Online* 4 (2006).

[48] The creation and partial adoption of OSI standards is a rich topic, fully deserving of future research. Four excellent (if brief) starting points already exist. See Abbate, *Inventing the Internet*, 147-169; Peter H. Salus, *Casting the Net: From ARPANET to INTERNET and beyond…* (New York: Addison-Wesley Publishing Company, 1995), 110-126; Tinekee Egyedi, "'Tension between Standardisation and Flexibility' Revisited: A Critique," in Kai Jakobs and Robin Williams, eds., *Standardisation and Innovation in Information Technology: Conference Proceedings of the 1st IEEE Conference on Standardisation and Innovation in Information Technology* (Piscataway, NJ: IEEE, 1999), 65-74; and Computer Science and Telecommunications Board, *Global Networks and Local Values: A Comparative Look at Germany and the United States* (Washington, DC: National Academies Press, 2001), 23-35.

[49] See for example Thyra Whitty, "OSI: the UK approach," *Communications* Vol. 7 No. 2 (1990), 20-24; Larry Caffrey, "EPHOS: Towards a European GOSIP," *Computer Networks and ISDN Systems* 19 (1990): 265-269. For an analysis of ISO's position within the system of European standardization bodies, see Schmidt and Werle, *Coordinating Technology*, 39-57.

[50] Joanne Yates and Craig N. Murphy, "Charles Le Maistre: Entrepreneur in International Standardization," paper presented to the Business History Conference, June 2, 2007.

representatives to participate on OSI committees.[51] ISO's organizational culture—concerned with defining and controlling the future of information and telecommunication services on behalf of its representatives from national governments—resembled democratic legislative bodies that utilized voting and partisan compromises.

Unfortunately, the ISO process was also a focal point for the ongoing conflict between representatives from the computer and telecommunications industry, and its bureaucratic safeguards often introduced substantial delays into an already complicated technological project. IBM, in the midst of an effort to embrace the turn toward interoperable open systems while maintaining its own powerful position, was one of the chief culprits that introduced delay and confusion within the development of OSI.[52] In the early 1980s, IBM saw the biggest payoffs from its strategy of creating an "open architecture" for a new, smaller and more affordable line of computers known as personal computers.[53] However, IBM reverted to its customary proprietary strategy in markets for local area networking (LAN) technology during the same period. As a consortium of firms led by Digital, Intel, and Xerox mobilized to support the Ethernet standard in the early 1980s, IBM chose to pursue its Token Ring technology in the hopes that it could

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51 Abbate, *Inventing the Internet*, 172-177. The American Standards Association was renamed twice during the 1960s, and adopted its current name, the American National Standards Institute (ANSI) in 1969.
52 Lewis M. Branscomb, "Computer Communications in the Eighties—Time to put It All Together," *Computer Networks* 5 (1981): 3-8.
53 Richard N. Langlois, "External Economies and Economic Progress: The Case of the Microcomputer Industry," *Business History Review* 66 (1992): 1-50.

deliver a technologically superior product and defeat Ethernet—a strategy that would ultimately fail.[54]

Within the system of ISO subcommittees, IBM exploited opportunities to use the committee to advance its own strategic goals. One tactic used by IBM was to alter its System Network Architecture in 1982 to be compatible with OSI. According to John Day, an American who participated in the Internet standards process as well as many OSI meetings, IBM representatives also manipulated the egos of representatives from various constituencies who were "fighting over who would get a piece of the pie." Day continued, "IBM played them like a violin. It was truly magical to watch." The experience led Day to conclude, "I think I could write a 'Discourses on Livy' for standards committees."[55] Although IBM's Machiavellian behavior inspired admiration from some (and fury from others), it ultimately detracted from ISO's effort to establish a universal network architecture for packet-switched computer networks. A different approach—one that occurred within the informal and relatively insulated environment of Internet researchers—provided more usable results.

4.4 Internet Protocols and Institutional Evolution, 1979-1992

After his education in the *realpolitik* of European standards-setting, Vint Cerf must have been relieved to concentrate on the development of Internet standards within the small community of like-minded ARPA contractors and researchers. Cerf became the

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[54] Urs von Burg, *The Triumph of Ethernet: Technological Communities and the Battle for the LAN Standard* (Stanford: Stanford University Press, 2001).

[55] John Day, *Patterns in Network Architecture: A Return to Fundamentals* (Prentice-Hall PTR, 2007), Chapter 10.

director of ARPA's Internet program from 1976 to 1982, and along with Kahn and MIT computer scientist David Clark, created a new set of institutions to coordinate the Internet community and standards-setting process. As these institutions grew and changed between the late 1970s and the early 1990s, Cerf, Kahn, Clark, and their colleagues struggled to find a balance between maintaining a fluid and informal environment while at the same time ensuring that the Internet standards-setting process could stay open to new participants and new ideas. By the early 1990s, this informal process emerged as one of the keys to the Internet's growth on a global scale.

When he began at ARPA in 1976, Cerf worked informally with a small group of researchers to test and refine the Internet protocols. By 1979, Kahn and Cerf agreed that more regular meetings of researchers in the community would be desirable. Kahn recalled,

> when we started the Internet program in the mid 1970s, originally it was just me in the office running the program. And after Vint was hired, then it was just Vint running the program with me to kibitz. And he was so good at what he did that he basically had everything in his head. What I worried about was what would happen if he got hit by a truck? Number two, what would happen if he would ever have to leave? And number three, how was anybody else in the community ever going to be part of the thinking process. So he set up, after some discussions, a kind of kitchen cabinet, if you will, of knowledgeable people that he would convene periodically. These were mostly the workers in the field, the key people who were implementing protocols… When he left, that group stayed intact.[56]

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[56] Kahn interview, Charles Babbage Institute. The term "kitchen cabinet" dates from the administration of President Andrew Jackson, who preferred to consult with an informal group of advisors—in the White House kitchen, according to legend—instead of his formal "Parlor" cabinet. See Robert V. Remini, *Andrew Jackson: The Course of American Freedom, 1822-1832* (Baltimore: The Johns Hopkins University Press, 1998), 315-330.

Cerf's "kitchen cabinet" was the Internet Configuration Control Board (ICCB), created in 1979 and chaired by David Clark, a computer scientist at MIT. The ICCB expanded control over Internet development by bringing more of the users of the network—technical experts distributed in universities, firms, and government agencies—into Cerf's inner circle in a more structured way. For Kahn, the ICCB was an important innovation because it "brought a wider segment of the research community more directly into the decision-making aspects of the Internet project which, until then, had been almost solely undertaken by ARPA."[57] Yet, despite this gradual diffusion of control, the ICCB was still immune from the commercial pressures and political rivalries that riddled standards development within ISO.

The members of the Internet community enjoyed their work, were energized by it, and took a great deal of pride in it. In a 2004 interview, David Mills, who participated in the group as an employee of two ARPA contractors—COMSAT (1977-1982) and Linkabit (1982-1986)—as well as a professor at the University of Delaware (1986-present), reflected on the informality and energy of the ICCB meetings that Clark chaired.

> Dave [Clark] is a technical guy. His style at meetings, the meetings kind of crackled, because new ideas would fly back and forth, and frequently a bunch of us wanted to talk at the same time. He'd go like this [points and stares]. And he'd say, "there's this issue," and you'd raise your hand. And he'd go, "you, go." I called it eyeball meetings. Floor control by eyeball.[58]

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[57] Robert E. Kahn, "The Role of the Government in the Evolution of the Internet," *Communications of the ACM* 37 (August, 1994): 16.
[58] David A. Mills interview, February 26, 2004, in Newark, DE, conducted by Andrew L. Russell.

As Cerf and Kahn were developing new versions of the Internet Protocol and Transmission Control Protocol, they would frequently convene the community to test different implementations of the protocols and compare which versions worked the best. Jon Postel, a computer scientist at the University of Southern California, often hosted these tests, which were commonly referred to as "Bake Offs."[59] Postel, who died in 1998, was a fair-minded and technically gifted individual, known for his long hair, grey beard, and sandals. He was the longtime editor of the Request for Comments series, and was in charge of a number of administrative functions for the Arpaent and Internet. Mills recalled him as "the Internet glue"; Cerf, who memorialized Postel in RFC 2468, referred to him as

> our resident hippie-patriarch at UCLA. He was a private person but fully capable of engaging photon torpedoes and going to battle stations in a good engineering argument. And he could be stubborn beyond all expectation. He could have outwaited the Sphinx in a staring contest, I think.[60]

Postel's Bake Offs were technically rigorous and enjoyable at the same time. Postel developed a scoring metric for successful implementations of TCP and IP that he divided into three divisions—featherweight, middleweight, and heavyweight. Implementations would have to navigate difficult network conditions, including "flakeways," which Postel defined as "a purposely flakey gateway."[61] On the basis of the

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[59] Postel reflected on the legacy of the bakeoffs in an RFC published in 1987. See Jon Postel (1987), "TCP and IP Bake Off," RFC 1025, http://www.ietf.org/rfc/rfc1025.txt. A different document series, the "Internet Engineering Notes," contain reports on bakeoffs as they occurred in the late 1970s and early 1980s. See ftp://ftp.rfc-editor.org/in-notes/ien.

[60] Mills interview, February 26, 2004; Vint Cerf (1998), "I Remember IANA," RFC 2468, http://www.ietf.org/rfc/rfc2468.txt.

[61] Postel, RFC 1025. He also awarded bonus points for "the best excuse" and "the fewest excuses."

data accumulated through the Bake Offs, Postel articulated a "Robustness Principle" that he wrote in to the standard definitions of TCP and IP: "be conservative in what you do, be liberal in what you accept from others."[62] Although the Robustness Principle was written to aid in the implementation of TCP and IP in diverse computing environments, one cannot help but conclude that this principle was also a product of the tolerant cultural milieu in which Postel, as a hippie in Southern California, spent his life.

David Mills was one of the members of the Internet community who participated in Postel's Bake Offs as well as demonstrations of packet-switched networks that he referred to as "packet poppers."

> One of my favorite packet poppers was some admiral at sea, in Monterrey Bay, wanted to talk to his counterpart at Eastcom in Stuttgart, Germany. And this involved a satellite hop, involved a packet radio hop, it traversed several networks—and he wanted to do it in real time. Just actually being able to do that was a good demonstration for the military. Another was packet radio. To get the whole idea of packet radio. And one packet popper to do that involved me sitting in the back of a Land Rover bouncing around the hills of mountain England, reading my [electronic] mail in the U. S. And dodging sheep on the back roads. That was fun.[63]

Mills' recollections demonstrate the longevity of the vision first articulated by Licklider in the early 1960s—that interesting research problems for computer scientists could also be valuable for military command and control. One of the benefits of ARPA's sponsorship was that, when necessary, it could force Arpanet users to act in specific ways, even when it was against the wishes of individual researchers. The most significant example of ARPA-mandated action occurred on January 1, 1983, when Kahn,

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62 Jon Postel, ed. (1981), "Transmission Control Protocol: DARPA Internet Program Protocol Specification," RFC 793, http://www.ietf.org/rfc/rfc793.txt.
63 Mills interview, February 26, 2004.

as Director of IPTO (Cerf had left in 1982 to pursue opportunities in the private sector), forced all sites on the Arpanet to stop using NCP as their primary means of connecting to the network. In place of NCP, all sites transitioned to TCP/IP—a transition that was traumatic for some users, who created buttons that bragged "I survived the TCP transition."[64] With the universal adoption of TCP/IP, Internet sites could more easily be connected to local area networks, and the Internet's growth intensified. In light of this growth, Kahn realized that he needed to reconsider "the process that ARPA was using to manage the evolution of the network."[65]

Barry Leiner—who replaced Vint Cerf as head of the ARPA Internet program in 1983—assisted Kahn in this "rethinking" of the Internet's management. In September 1984, Leiner disbanded the ICCB and, in its place, created the Internet Advisory Board (IAB).[66] Clark continued his close involvement as the first Chair of the IAB—a position that conferred the title of "Internet Architect."[67] Within the IAB, Leiner created a number of small groups (called Task Forces) focused on various aspects of Internet

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[64] Amy Slaton and Janet Abbate, "The Hidden Lives of Standards: Technical Prescriptions an the Transformation of Work in America," in Michael Thad Allen and Gabrielle Hecht, eds., *Technologies of Power: Essays in Honor of Thomas Parke Hughes and Agatha Chipley Hughes* (Cambridge: The MIT Press, 2001), 95-144. For a discussion of the strategy behind this transition, see Jon Postel (1981), "NCP/TCP Transition Plan," RFC 801, http://www.ietf.org/rfc/rfc801.txt. The "trauma of the birth of the Internet proper on January 1, 1983" is captured in the "TCP/IP Digests," an electronic mailing list that Arpanet engineers used to trade stories and advice. See ftp://ftp.rfc-editor.org/in-notes/museum/tcp-ip-digest/.

[65] Kahn, "Role of Government," 16.

[66] The acronym "IAB" remained consistent since 1984, but the "A"—and the meanings behind it—have changed. From 1984 to 1986 the IAB was the Internet Advisory Board; in 1986 its name changed to the Internet *Activities* Board; in 1992 it changed once again, this time to the Internet *Architecture* Board. See "A Brief History of the Internet Advisory / Activities / Architecture Board," http://www.iab.org/about/history.html.

[67] Clark was Internet Architect from 1983 to 1989; Cerf served from 1989 to 1991, and was followed by Lyman Chapin (through March 1993).

technologies, such as gateway algorithms, end-to-end protocols, privacy, and security.[68] Clark, as Chair of the IAB, selected the chairs of each Task Force, and, in consultation with the Internet community, decided whether new members should be invited. Consequently, the IAB had a much narrower constituency than the ISO committees and was thus less susceptible to strategic behavior, power politics, and other delays that were characteristic of more mature and formal standards-setting organizations.[69] Given this description, it is not difficult to see why author and computer scientist Ed Krol described the IAB as a "council of elders."[70] Although there were tensions within the community, there was also a strong *esprit de corps* and a shared recognition that the community's research efforts were dedicated toward the continued growth of the Internet, and not toward the financial ambitions of any particular individual.

This *esprit de corps*—and the non-commercial orientation of Internet engineers—became strained as the Internet grew and more and more people sought to have a voice in the Internet's design and standardization process. A major source of new interest came from researchers who had been working on the NSFNET, a packet-switched network created in 1984 by the National Science Foundation and open to university researchers. By 1986, the convergence of the Arpanet and NSFNET meant that the number of networks connected via the Internet grew dramatically, with several thousand hosts

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[68] http://www.iab.org/about/history.html.

[69] See Barry M. Leiner, Vinton G. Cerf, David D. Clark, Robert E. Kahn, Leonard Kleinrock, Daniel C. Lynch, Jon Postel, Larry Roberts, and Stephen Wolff, "A Brief History of the Internet," last revised December 10, 2003, http://www.isoc.org/internet/history/brief.shtml. See also Kahn interview, Charles Babbage Institute; and Vinton Cerf (1990), "The Internet Activities Board," RFC 1160, http://www.ietf.org/rfc/rfc1160.txt.

[70] Ed Krol (1993), "FYI on 'What is the Internet?'" RFC 1462, http://www.ietf.org/rfc/rfc1462.txt.

connected to over 400 networks via 120 gateways located within the network. Because of the importance of these gateways for ensuring that new networks could connect, the Gateway Algorithms and Data Structures Task Force experienced tremendous growth, and split into two groups: the Internet Architecture Task Force (INARC) and the Internet Engineering Task Force (IETF). INARC became a focus for forward-looking research problems; the IETF became the place to hammer out the messy details of day-to-day implementation, and to formulate technical standards that would facilitate the growth of the Internet.[71]

Because of its broad mandate and importance for the engineering of the present, the IETF became the main focus of attention for newcomers. After its first meeting in January 1986, the IETF met four times in 1986 and 1987, and three times annually in every subsequent year. Twenty-one people attended the January 1986 meeting, and 35 attended the October 1986 meeting. The number of attendees increased dramatically in 1987, from 35 at the February meeting to 101 at the July meeting. At first, only invited participants could attend the IETF meetings; by the end of 1987, anyone interested in the Internet—including representatives from commercial firms not under government contracts—were welcomed at the meetings.[72]

A "Brief History of the Internet" co-authored by a number of Internet pioneers (including Cerf, Clark, Kahn, and Leiner) describes this formation of community governance as a "steady evolution of organizational structures designed to support and

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[71] Mills interview, February 26, 2004.
[72] IETF Proceedings are available from http://ietf.org/meetings/past.meetings.html.

facilitate an ever-increasing community working collaboratively on Internet issues."[73] These structures combined two models of governance. The first model, the structure led by Cerf that coordinated the development of the Internet at ARPA, was a self-selected, experienced group—a "council of elders." Historians of the Internet unequivocally praise this group as a source of its astounding growth. Frequently described as a meritocracy, this close-knit network of people worked together since the early Arpanet days (many as graduate students at MIT or UCLA or as engineers at Bolt, Beranek and Newman, the consulting firm that had designed aspects of the Arpanet) and provided the bulk of the technical and bureaucratic leadership necessary to keep the Internet up and running.[74] "Relatively few, competent, highly motivated people were involved," recalled Larry Press, "and they had considerable autonomy."[75]

Kahn's observation about the ICCB's role as a sort of kitchen cabinet provides an insight into the second model of governance, which has received less attention from historians: the function of the ICCB, IAB, and IETF as mechanisms for engaging and directing the efforts of a distributed group of Internet researchers. The Internet user community was small enough in 1979 that the ICCB functioned simultaneously as both

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73 Leiner, et al., "Brief History." In a 1993 article, Dave Crocker concurred: "In general, the IETF is applying its own technical design philosophy to its own operation." Dave Crocker, "Making Standards the IETF Way," *StandardView* 1 (1993): 54. The 1968 musings of Melvin Conway are also strikingly relevant: "there is a very close relationship between the structure of a system and the structure of the organization which designed it." See Melvin E. Conway, "How Do Committees Invent?" *Datamation* Vol. 14, No. 4, April 1968, 30; and "Conway's Law," at http://www.catb.org/~esr/jargon/html/C/Conways-Law.html.

74 See for example Norberg and O'Neill, *Transforming Computer Technology*; and Hughes, *Rescuing Prometheus*.

75 Larry Press, "Seeding Networks: the Federal Role," *Communications of the ACM* 39 (1996): 11-18.

"council of elders" and a "grass-roots mechanism" for Internet standards.[76] By the early 1990s, the IAB maintained the character of the "council of elders," responsible for architectural and bureaucratic oversight. The IETF, as a task force for "Internet engineering," assumed responsibility for the distributed, hands-on tasks involved in the engineering and implementation of protocols and provided a forum for interested newcomers. The transfer of responsibility for technical standards from the ICCB to the IAB and then the IETF demonstrated a strong desire on the part of the "council of elders" to engage and empower the broader community that wanted to contribute to the further development of the Internet. Under this system, the architectural oversight of the Internet remained with the reconstituted IAB, while the efforts of participants in the IETF were channeled toward the technical aspects of protocol development and implementation.

The Internet community established several foundational standards for Internet applications during the ongoing institutional evolution in the 1980s. For example, in August 1982, Dave Crocker, a computer scientist at the University of Delaware, published an RFC that specified addressing conventions for electronic mail that are still in use today. In April 1984, Charles Hornig of the Symbolics Cambridge Research Center published an RFC that provided a way to sent Internet packets over Ethernet local area networks. In October 1984, Joyce Reynolds, a computer scientist at the University of Southern California's Information Sciences Institute, published an RFC that provided a simple method for remote clients to retrieve electronic mail from dedicated mailbox

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[76] The description of the ICCB as a "grass-roots mechanism" comes from Kahn, "Role of Government," 18.

servers. And in September 1985, David Mills proposed a precise method for synchronizing time across the Internet in RFC 958, "Network Time Protocol."[77]

Each of these four examples illustrate the Internet community's decentralized and iterative style of developing standards. After discussing their protocols within the community, the authors published stable drafts as RFCs. In subsequent months and years, these authors (as well as others who were interested in those specific functions and protocols) published RFCs that revised the initial protocol based on changing conditions outside the Internet community as well as their own trial-and-error experiments. For example, the standardization of Ethernet technologies within the Institute of Electrical and Electronic Engineers (IEEE) prompted a group of Internet engineers, led by Joyce Reynolds and Jon Postel, to publish in 1988 a new standard for transmitting Internet packets over Ethernet networks. The subsequent popularity of Ethernet (including the development of wireless Ethernet, known as IEEE 802.11 or "Wi-Fi") led to the creation of new standards as well as formal liaisons between the IETF and the IEEE so that the two groups could further coordinate their standardization initiatives for wireless Internet applications.[78]

Another example—the Network Time Protocol—demonstrates the increasingly international orientation of Internet research and standards. In 1988, David Mills

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[77] David H. Crocker (1982), "Standard for the Format of ARPA Internet Text Messages," RFC 822, http://www.ietf.org/rfc/rfc822.txt; Charles Hornig (1984), "A Standard for the Transmission of IP Datagrams over Ethernet Networks," RFC 894, http://www.ietf.org/rfc/rfc894.txt; Joyce K. Reynolds (1984), "Post Office Protocol," RFC 918, http://www.ietf.org/rfc/rfc918.txt; David L. Mills (1985), "Network Time Protocol," RFC 958, http://www.ietf/org/rfc/rfc958.txt.
[78] See "Letter from IEEE 802.11 to IETF/IESG," February, 2002), available from https://www.ietf.org/IESG/LIAISON/ieee802.11.txt.

published a more extensive and sophisticated version of the "architectures, algorithms and protocols" used in the Network Time Protocol "which have evolved over several years of implementation and refinement," including two years of operation in the Internet.[79] Two years later, two British academic computer scientists published an RFC that specified a version of the Network Time Protocol for use in OSI networks. In 1992, Mills published a third revision of the Network Time Protocol, and also published the "Simple Network Time Protocol" that could "be used when the ultimate performance of the full NTP implementation described in RFC-1305 is not needed or justified."[80] Mills again revised the Network Time Protocol in 1996 and 2006, and continues to run experiments to further refine and improve it.[81] In the meantime, several other researchers—including a computer scientist working for Cisco Systems' office in Bangalore, India—continued to publish extensions and adaptations of the Network Time Protocol.[82]

Despite the increasing sophistication of Internet technologies during the late 1980s and early 1990s (as well as the institutions that coordinated technological development), officials in the ITU, ANSI, and the U. S. Department of Defense did not think of the Internet as a serious competitor to OSI. Mills recalled that the very names of

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79 David L. Mills (1988), "Network Time Protocol (Version 1): Specification and Implementation," RFC 1059, http://www.ietf.org/rfc/rfc1059.txt.

80 David L. Mils (1992), "Network Time Protocol (Version 3): Specification, Implementation and Analysis," RFC 1305, http://www.ietf/org/rfc/rfc1305.txt; David L. Mills (1992), "Simple Network Time Protocol (SNTP)," RFC 1361, http://www.ietf.org/rfc/rfc1361.txt.

81 David L. Mills (1996), "Simple Network Time Protocol (SNTP) Version 4 for IPv4, IPv6 and OSI," RFC 2030, http://www.ietf.org/rfc/rfc2030.txt; David L. Mills (2006), "Simple Network Time Protocol (SNTP) Version 4 for IPv4, IPv6 and OSI," RFC 4330, http://www.ietf.org/rfc/rfc4330.txt; and Mills interview, February 26, 2004.

82 V. Kalusivalingam (2005), "Simple Network Time Protocol (SNTP) Configuration Options for DHCPv6," RFC 4075, http://www.ietf.org/rfc/rfc4075.txt.

the bodies to coordinate Internet standards—the "Internet Configuration Control Board" and the "Internet Activities Board"—were intentionally crafted as bland and non-threatening names, much like the Request for Comments series.[83] Although the ITU and ANSI did not see the Internet as a significant long-term competitor to OSI, the Defense Department—having spent millions of dollars developing the Arpanet and Internet—looked more closely at the relative merits of the two network architectures. In 1983, the Defense Department asked the National Research Council to compare the transport protocols of both network architectures and advise the Defense Department officials in charge of procurement. The National Research Council's final report in 1985 compared TCP and its functional counterpart in OSI, a protocol called TP-4. The report presented three options: keep the two as co-standards; adopt TP-4 as soon as it was shown to be ready for military networks; or keep TCP and defer indefinitely a decision on TP-4.[84] The Defense Department supported Option 2 and planned to "move ultimately toward exclusive use of TP-4."[85]

The National Bureau of Standards also supported OSI protocols, first through a series of workshops cosponsored by the IEEE, and eventually by creating a version of OSI, known as Government Open Systems Interconnection Profile (GOSIP), for use in the American federal government. By August 1990, federal agencies were required to

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83 Mills interview, February 26, 2004. Mills was the Chair of short-lived Internet Architecture Task Force (INARC).

84 Board on Telecommunications and Computer Applications Commission on Engineering and Technical Systems, National Research Council, *Transport Protocols for Department of Defense Data Networks: Report to the Department of Defense and the National Bureau of Standards Committee on Computer-Computer Communication Protocols* (Washington, D.C.: National Academy Press, 1985).

85 Jon Postel (1985), "A DoD Statement on the NRC Report," RFC 945, http://www.ietf.org/rfc/rfc945.txt. See also Michael Witt, "Moving from DoD to OSI Protocols: A First Step," *Computer Communication Review* 16 (April/May, 1986): 2-7.

procure GOSIP-compliant products.[86] Through this procurement requirement, the government intended to stimulate the market for OSI products and fall in line with the global consensus growing around OSI. However, since products designed around TCP/IP were more familiar and readily available—and OSI products were not—this requirement did not achieve the intended result.[87]

4.4.1 "OSI Bigots" and "IP Bigots": The Culture of Standards Wars

Tensions between researchers in the OSI and Internet communities became apparent in the early 1980s. For example, in their 1983 paper describing the similarities between the ARPA and ISO protocol architectures, Danny Cohen and Jon Postel painted the ISO model as an abstraction, far too rigid in its reliance on seven interrelated layers, and inappropriate to be used "as a model for all seasons."[88] In this unusually colorful paper, Cohen and Postel—both of whom were instrumental in the early history of TCP/IP—mockingly speculated that "mystical" traditions such as Early Zoroastrianism, New Testament celestial beings, and the Christian seven deadly sins might have "shaped the choice of Seven."[89] Another Internet advocate, in his 1991 "technical travelogue" of networking in 21 countries across the world, suggested that trying to implement OSI over

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[86] "U.S. Government Open Systems Interconnection Profile," U.S. Federal Information Processing Standards Publication 146, Version 1, August 1988, cited in Vinton Cerf and Kevin Mills (1990), "Explaining the Role of GOSIP," RFC 1169 http://www.ietf.org/rfc/rfc1169.txt. See also Phillipe Janson, Refik Molva, and Stefano Zatti, "Architectural Directions for Opening IBM Networks: The Case of OSI," *IBM Systems Journal* 31 (1992): 313-335. ("Many government agencies around the world, including the U.S. Department of Defense, require OSI on all systems they purchase").
[87] Mills interview, February 26, 2004.
[88] Daniel Cohen and Jonathan Postel, "The ISO Reference Model and Other Protocol Architectures," in R. E. A. Mason, ed., *Information Processing 83: Proceedings of the IFIP 9th World Computer Congress, Paris, France, September 19-23, 1983* (New York: North-Holland, 1983), 34.
[89] Cohen and Postel, "The ISO Reference Model," 30.

slow, low-quality lines was "akin to looking for a hippopotamus capable of doing the limbo."[90]

The resentment of Cohen, Postel, and their Internet colleagues stemmed from their frustration with the technical aspects of OSI as well as with the organizational culture of ISO. Where TCP/IP was developed through continual experimentation in a fluid organizational setting, Internet engineers viewed OSI committees as overly bureaucratic and out of touch with existing networks and computers. OSI's political and formal process did not endear the TCP/IP Internet community—who were accustomed to a decentralized division of labor throughout the standards process—to the ISO Reference Model. In a scathing 1985 critique of OSI and its advocates, one veteran of the Arpanet and Internet community, Mike Padlipsky, characterized the ARPA Internet Reference Model as "Descriptive" and ISO Reference Model as "Prescriptive." "Another way of putting it," Padlipsky wrote, "is that whereas the Descriptive approach is suitable for technology, the Prescriptive approach is suitable for theology."[91] David Mills, who was also active in ARPA's networking experiments during this time, agreed: "Internet standards tended to be those written for implementers. International standards were written as documents to be *obeyed*."[92]

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[90] Carl Malamud, *Exploring the Internet: A Technical Travelogue* (Englewood Cliffs, N.J.: PTR Prentice Hall, 1992), 191.
[91] M. A. Padlipsky, *The Elements of Networking Style, And Other Animadversions on the Art of Intercomputer Networking* (Lincoln, NE: iUniverse, 2000, first edition Prentice-Hall, 1985), 11. In his characteristically witty prose, Padlipsky recommended that the ISO Reference Model, or ISORM, be pronounced "Eyesore-mmm."
[92] Mills interview, February 26, 2004,.

A spirited rivalry between respective advocates of OSI and TCP/IP networks emerged as they fought for jurisdiction over standards for computer internetworks. Richard des Jardins—an early contributor to the ISO Reference Model and President of the GOSIP Institute—captured the intensity this rivalry when, in a 1992 article, he compared the "OSI Bigots" and the "IP Bigots" to people who objected to "the convergence of cultures and races in the world at large."[93] Despite their heated rhetoric, many researchers were active in finding ways to make the Internet and OSI work together. The first such proposal appeared in an RFC published in April 1986 that described (in self-consciously defensive language) a method to implement some features of OSI over TCP.[94] Beginning in 1987, the IETF established several Working Groups to integrate Internet and OSI technologies for electronic mail, directory services, and fundamental network protocols. However, this work was far from universally admired among IETF participants, especially those who had become frustrated with the ISO process, OSI technologies, or personal relationships with OSI proponents.[95]

4.4.2 "We reject: kings, presidents and voting"

Apart from the external OSI threat, the Internet community faced a succession of internal problems throughout the Internet's rapid growth during the 1980s and early

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[93] Richard des Jardins, "OSI is (Still) a Good Idea," *ConneXions* Vol. 6, No. 6 (1992), 33. Des Jardins added, "let's continue to get the people of good will from both communities to work together to find the best solutions, whether they are two-letter words or three-letter words, and let's just line up the bigots against a wall and shoot them."

[94] D. E. Cass and M. T. Rose (1986), "ISO Transport Services on Top of TCP," RFC 983, http://www.ietf.org/rfc/rfc983.txt.

[95] Cerf and Mills, RFC 1169. See also Erik Huizer, "The IETF integrates OSI related work," *ConneXions* 7, No. 6 (1993), 26-28.

1990s. As Internet advocates battled against OSI, they also continued to struggle with the organizational problems of their own standardization process. Some critics felt that the IAB "failed at times to provide a solid agenda and timetables of engineering problems" for the IETF to address.[96] The informal character of the IAB's oversight of the IETF also created problems, and there were occasions when IETF engineers perceived that IAB decisions favored the commercial interests of vendors over the technical consensus of the Internet community.[97]

The tensions between the IAB and IETF came to a head in 1992, when the IAB considered incorporating one of the OSI protocols into the Internet architecture. The IAB took this step in order to avoid a major technical obstacle to Internet growth. The problem stemmed from the amount of network addresses that could be handled by the Internet Protocol (IP version 4, or IPv4).[98] IPv4, designed in the late 1970s, did not take into account the explosion of computers and networks that would join the Internet. By the early 1990s, it appeared that the address space in IPv4 would soon be exhausted—an event that would prevent new machines from joining the network, thus throttling the Internet.[99] To avoid this problem, the IAB considered adopting the ConnectionLess Network Protocol (CLNP), which was the OSI functional counterpart to IPv4.[100]

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96 Malamud, *Exploring the Internet*, 196.

97 Malamud described one such conflict at the 1991 IETF meeting: "the issue was not technical, it was procedural. How to run an informal standards process like the IETF, yet preserve due process safeguards, has been a continuing problem as the body grew in size from the original 13 participants." Malamud, *Exploring the Internet*, 151.

98 For a close analysis of the limits of IPv4 and the politics of creating a new Internet Protocol, see Laura E. DeNardis, "IPv6: Politics of the Next Generation Internet" (Ph.D. dissertation, Virginia Polytechnic Institute and State University, 2006).

99 Published in December 1991, RFC 1287 noted "increasing strains on the fundamental architecture, mostly stemming from continued Internet growth." David Clark, Lyman Chapin,

Although they were aware of strong opposition to OSI within the Internet community, the members of the IAB felt that CLNP could help the Internet overcome the address space problem. From this perspective, the technical rationale for incorporating CLNP into the architecture of the Internet supported the broader interests of the community and the mandate of the IAB—keeping the network open for anyone who wanted to connect.[101] As a result, at its June 1992 meeting in Kobe, Japan, the IAB developed a draft proposal—a starting point for discussion within the Internet community—to use CLNP as the basis for a larger address space. To the IAB, this seemed a responsible path to take, given the limits of the IPv4 address space and the widespread desire for the Internet to accommodate as many users as possible. As IAB member Christian Huitema later recalled:

> The IAB discussed [the draft proposal to incorporate CLNP] extensively. In less than two weeks, it went through eight successive revisions. We thought that our wording was very careful, and we were prepared to discuss it and try to convince the Internet community. Then, everything accelerated. Some journalists got the news, an announcement was hastily written, and many members of the community felt betrayed. They perceived that we were selling the Internet to the ISO and that

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Vinton Cerf, Robert Braden, and Russ Hobby (1991), "Towards the Future Internet Architecture," RFC 1287, http://www.ietf.org/rfc/rfc1287.txt. Lyman Chapin, IAB Chairman in 1992, said in May 1992 that the shortage of Internet addresses was "definitely the most significant engineering problem on the Internet now." Ellen Messmer, "Internet Architect Gives Long-Term View," *Network World* 9 (May 18, 1992), 37.

100 For one proposal to incorporate CLNP, see Ross Callon (1992), "TCP and UDP with Bigger Addresses (TUBA), A Simple Proposal for Internet Addressing and Routing," RFC 1347, http://www.ietf.org/rfc/rfc1347.txt.

101 In addition to this technical rationale, Clark suggested that ISO and the American National Standards Institute (ANSI) were pressuring the IAB to implement CLNP as the Internet host protocol. David D. Clark, personal communication, October 27, 2001.

headquarters was simply giving the field to an enemy that they had fought for many years and eventually vanquished. The IAB had no right to make such a decision alone.[102]

The fact that this proposal provoked such outrage from hundreds of engineers and computer scientists reflects the passion and commitment of engineers in the pitched battle of a standards war. The Internet engineer Carl Cargill preferred a religious metaphor to Huitema's military metaphor: "For the general membership of the IETF," he commented, "this was rank heresy."[103] Both metaphors were apt: where Huitema's military metaphor captured the strategic and organizational tensions between the competing standards bodies, Cargill's religious metaphor captured the emotional commitment that Internet engineers had invested in their underdog network architecture.

Many IETF participants, while aware of the limitations of IPv4, assumed that the Internet and OSI would coexist for the foreseeable future. Because they were convinced of the superiority of the Internet, they certainly would not allow an outside body—even the "council of elders" in the IAB—to make such dramatic and offensive changes to the Internet architecture with the presumption that the IETF would go along.[104] Lyman Chapin, who served as the IAB Chair from July 1991 to March 1993, was fully aware of the IETF's leading role in the Internet standards process: indeed, in March 1992 he published RFC 1310, "The Internet Standards Process," in which he stated that the IETF

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[102] Christian Huitema, *IPv6: The New Internet Protocol* (Upper Saddle River, NJ: Prentice-Hall PTR, 1998), 2. Minutes of the IAB discussion are available from http://www.iab.org/documents/iabmins/IABmins.1992-06-18.html.

[103] Cargill, *Open Systems Standardization*, 257; Scott Bradner, "The Internet Engineering Task Force," *OnTheInternet*, 7 (2001): 24; Cerf, "IETF and ISOC."

[104] These two objections—technical and procedural—were the primary topics of discussion on the two mailing lists—the IETF discussion list and the "big-internet" list—dedicated to these issues. The list archives are available from ftp://ftp.ietf.org/ietf-mail-archive/ietf/ and ftp://munnari.oz.au/big-internet/list-archive/.

had "primary responsibility for the development and review of potential Internet standards from all sources." However, Chapin was also a firm believer in "an Internet that supports multiple protocol suites," and supported efforts to utilize OSI standards within the Internet architecture.[105] Chapin assumed that the entire Internet community shared his support of OSI. In a May 1992 interview, he remarked that "The most comprehensive solution [to the shortage of Internet addresses] is to replace the Internet Protocol in the Internet with the Open Systems Interconnection Connectionless Network Protocol. That idea is already almost universally accepted."[106] Subsequent events would show that he badly misjudged the mood of the Internet engineering community.

At the July 1992 IETF meeting in Cambridge, Massachusetts, irate IETF participants—over 700 people attended the meeting—protested about what they perceived as a unilateral decision by the IAB. Although many IETF participants had technical reservations about CLNP, their resistance was also motivated by the fear that the IAB was violating established procedures and turning the Internet into the thing they most despised. Faced with such resistance, the IAB backed down from its CLNP proposal. Vint Cerf, a member of the IAB (and formerly IAB Chair from July 1989 to July 1991), used the occasion of his plenary address to try to win back the support of the IETF. As he addressed the IETF, he slowly removed the layers of his signature three-piece suit, performing a striptease that revealed a t-shirt: "IP on Everything." The t-shirt,

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105 Internet Activities Board, Lyman Chapin, Chair (1992), "The Internet Standards Process," RFC 1310, http://www.ietf.org/rfc/rfc1310.txt.

106 Chapin remarked in May 1992, Clearly Chapin was mistaken in his assessment of community support for CLNP. Messmer, "Internet Architect," 46.

according to Cerf, was to reiterate a goal of the IAB: to run IP on every underlying transmission medium.[107]

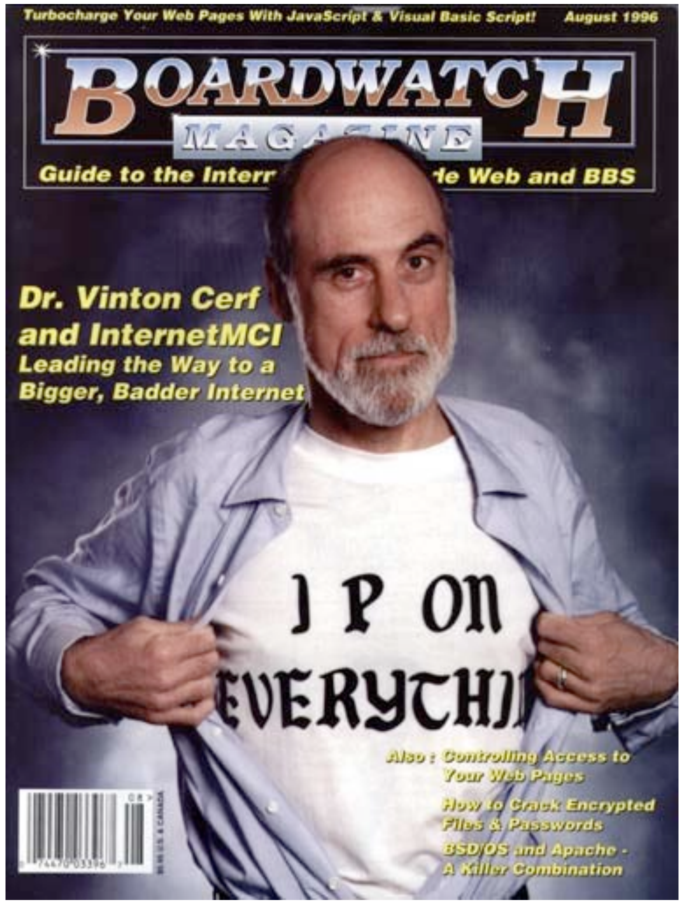

Figure 4.4: Vint Cerf posing in his "IP on Everything" t-shirt, circa 1996.
Source: http://ietf20.isoc.org/videos/ip_on_everything.jpg.

Another *emeritus* Internet Architect and founding father, David Clark, viewed his plenary presentation as an opportunity to "rally the troops" and reaffirm the shared values of the Internet community.[108] Clark framed his talk, titled "A Cloudy Crystal Ball: Visions of the Future (Alternate Title: Apocalypse Now)," in terms of architectural choices in front of the IETF. After spending several minutes urging the audience to focus

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107 Vinton G. Cerf, personal communication, January 27, 2002.
108 Bradner, "The Internet Engineering Task Force," *OnTheInternet*, 24.

on how network security challenged the basic assumptions of the protocol architecture, Clark considered how the IETF should "manage the process of change and growth." He amused the audience by taking a shot at ISO, calling it the "standards elephant of yesterday." But he also warned the audience that the IETF would itself become a standards elephant if it failed to strike a balance between an open and closed process, between a fast and slow process, and if it ignored the signals coming from the market.[109] Near the end of his talk, Clark summarized his view of the IETF approach: "We reject: kings, presidents and voting. We believe in: rough consensus and running code."[110]

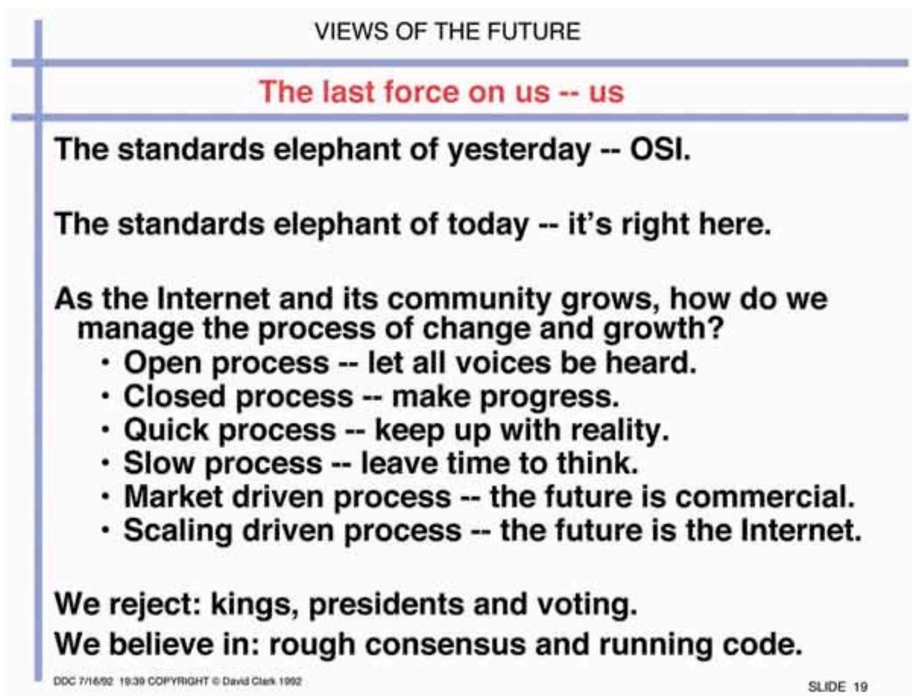

Figure 4.5: Slide from David D. Clark, "A Cloudy Crystal Ball," 1992.
Source: David D. Clark.

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109 David D. Clark, "A Cloudy Crystal Ball: Visions of the Future (Alternate Title: Apocalypse Now)," presentation at the July 1992 meeting of the Internet Engineering Task Force. Available from http://ietf20.isoc.org/videos/future_ietf_92.pdf. On the occasion of the IETF's twentieth anniversary in 2006, Clark delivered an encore of this presentation. The video of his talk is available from http://ietf20.isoc.org/videos.
110 Clark, "A Cloudy Crystal Ball."

The IETF community responded with overwhelming approval. "Rough consensus and running code" was so popular that one IETF participant created the ultimate form of computer geek approval: T-shirts with the phrase emblazoned across the front. "Rough consensus and running code" generated and sustained this level of enthusiasm because of the way it framed the successful aspects of the IETF process as a critique of the ISO process. The *rough consensus* component of this motto referred to the decision-making process within IETF working groups. Since its inception, the IETF did not have a formal voting structure. In the tradition of Cerf's "kitchen cabinet" meetings in the late 1970s, IETF leaders encouraged newcomers to contribute their expertise, and approved proposals that enjoyed broad support within the group. IETF veterans placed an acceptable level of agreement at around 80 to 90%: a level high enough to demonstrate strong support, but flexible enough to work in the absence of unanimity. In short, *rough consensus* was an apt description of an informal process where a proposal must answer to criticisms, but need not be held up if supported by a vast majority of the group.[111] To IETF participants, this process was vastly superior to the bureaucratic and political approach of ISO.

As a complement to rough consensus, *running code* meant "multiple actual and interoperable implementations of a proposed standard must exist and be demonstrated

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111 Scott Bradner, "The Internet Engineering Task Force," in Chris DiBona, Sam Ockman, and Mark Stone, eds., *Open Sources: Voices from the Open Source Revolution* (Cambridge, MA: O'Reilly, 1999), 47-53. See also Dave Crocker, "Making Standards the IETF Way," 48-54.

before the proposal can be advanced along the standards track."[112] Since most standards began with a proposal from an individual or small group—and not from the IAB or IETF leadership—the party behind the proposal needed to provide multiple working versions of the proposal. This burden of proof upon the proposed standard facilitated the adoption of new standards across the diverse computing platforms on the Internet. *Running code* also evoked a major difference between the IETF and ISO approaches: where the IETF protocols represented "the result of intense implementation discussion and testing," ISO committees developed a theoretical model that was difficult to alter or implement fully.[113] Lyman Chapin, who participated in both OSI and Internet standards committees before becoming IAB Chair in 1991, summarized the difference between the two approaches in 1990: "it didn't take long to recognize the basic irony of OSI standards development: there we were, solemnly anointing international standards for networking, and every time we needed to send electronic mail or exchange files, we were using the TCP/IP-based Internet!"[114] Or, as Internet pioneer Einar Stefferud was fond of saying, "OSI is a beautiful dream, and TCP/IP is living it."[115]

Beyond serving as a concise description of the IETF's organizational and technical approach, "rough consensus and running code" also served as a means of self-identification and a positive summary of the IETF's model for standards development.

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112 Bradner, "The Internet Engineering Task Force," *OnTheInternet*, 26. Bradner's summary is telling: "In brief, the IETF operates in a bottom-up task creation mode and believes in 'fly before you buy.'" Bradner, "The Internet Engineering Task Force," *Open Sources*, 51.
113 Padlipsky, *Elements of Networking Style*, 104.
114 Lyman Chapin, quoted in Gary Malkin (1990), "Who's Who in the Internet: Biographies of IAB, IESG, and IRSG Members," RFC 1336, http://www.ietf.org/rfc/rfc1336.txt.
115 Einar Stefferud, quoted in Marshall T. Rose, "Comments on '*Opinion*: OSI Is (Still) a Good Idea,'" *ConneXions* 6, No. 8 (1992): 20-21.

The internal divisions exacerbated by the controversy over CLNP prompted a good deal of reflection among those who were committed to defending the traditions of the IETF. While most of his presentation was devoted to the pressing technical and organizational problems within the Internet standards community, Clark's memorable phrase was an attempt to unite the fractured community by pointing out the shortcomings of ISO, while simultaneously challenging the IETF to maintain its unique identity. Given the dramatic events they had just witnessed, one can imagine IETF engineers leaving the July 1992 meeting with a certain sense of optimism about the future of the Internet.

Although the IAB had abandoned its CLNP proposal by the end of the July 1992 meeting, the underlying technical problems remained. Over the next two years, the IAB (which was renamed the Internet *Architecture* Board in 1992) and the IETF debated various proposed designs for the next generation of the Internet Protocol.[116] By January 1995, the community arrived at a consensus over the broad outlines of the new protocol, known as Internet Protocol version 6 (IPv6), that would be developed within the IETF over the next several years.[117] In the meantime, another protocol developed within the IETF, the Dynamic Host Control Protocol, helped to ensure that the Internet did not run out of address space. The technical crisis was averted; but the procedural drama of the 1992 meetings precipitated what Scott Bradner, a longtime IETF participant, later

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116 Tim Dixon (1993), "Comparison of Proposals for Next Version of IP," RFC 1454, http://www.ietf.org/rfc/rfc1454.txt; Scott Bradner and Allison Mankin (1993), IP: Next Generation (IPng) Working Paper Solicitation," RFC 1550, http://www.ietf.org/rfc/rfc1550.txt.
117 See Scott Bradner and Allison Mankin (1995), "The Recommendation for the IP Next Generation Protocol," RFC 1752, http://www.ietf.org/rfc/rfc1752.txt; Huitema, *IPv6: The New Internet Protocol*; and DeNardis, "IPv6: Politics of the Next Generation Internet." The webpages at http://playground.sun.com/pub/ipng/html/ contain source materials, meeting minutes, and links to organizations that promote the adoption of IPv6.

referred to as a "constitutional crisis."[118] For engineers in the IETF, the Kobe proposal called the IAB's legitimacy and authority into question. Consequently, the Internet community began an effort to better define the informal process that had served the Internet so well for so long.

Between 1992 and 1996, members of the Internet community revised and clarified the Internet standards process so that future constitutional crises would be avoided. These reforms also sought to strengthen and maintain the integrity of the Internet standards process in the face of increasing commercial interest.[119] In 1993, the IETF published an RFC titled "The Tao of the IETF" that introduced newcomers to the customs and norms of the IETF. Such changes also were motivated by the need to make the Internet standards process more international and legitimate in the eyes of non-American engineers and government officials who were looking to the Internet as an element of their strategies to build national information infrastructures. The days of informal discussions among bearded and sandaled graduate students were in the past; instead, a greater proportion of IETF attendees in the late 1990s worked for private companies and wore suits and ties—a vivid reminder that the world of Internet standards had changed.[120]

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118 Bradner, "The Internet Engineering Task Force," *OnTheInternet*, 24.

119 Scott Bradner (1996), "The Internet Standards Process—Revision 3," RFC 2026, http://www.ietf.org/rfc/rfc2026.txt; Richard Hovey and Scott Bradner (1996), "The Organizations Involved in the IETF Standards Process," RFC 2028, http://www.ietf.org/rfc/rfc2028.txt.

120 Gary Malkin (1993), "The Tao of the IETF—A Guide for New Attendees of the Internet Engineering Task Force," RFC 1391, http://www.ietf.org/rfc/rfc1391.txt. The "Tao" was subsequently revised in 1993, 1994, 2001, and 2006. The most recent version is Paul Hoffman and Susan Harris (2006), "The Tao of the IETF—A Novice's Guide to the Internet Engineering Task Force," RFC 4677, http://www.ietf.org/rfc/rfc4677.txt.

Even as the Internet community struggled to accommodate rapid commercialization, Internet standards continued to be adopted widely. In 1991, the National Science Foundation, which had operated the backbone of the Internet since 1986, lifted its restriction on commercial activity over the Internet—thus paving the way for the Internet to serve as a new commercial infrastructure.[121] Another turning point for the popularity of the Internet also occurred in 1991 when Tim Berners-Lee released the World Wide Web, an application that used the Internet to create links between hypertext documents. In 1994, the National Bureau of Standards (renamed National Institute of Standards and Technology in 1988) abandoned its GOSIP program in favor of the TCP/IP Internet. The market for network protocols had tipped in favor of TCP/IP, the Internet-OSI religious war was over, and grand future planned for OSI had vanished. The Internet had emerged as the victor.[122]

4.5 Conclusions

The computer network architectures developed between the 1960s and the 1990s were not simply technological innovations. They were also organizational and political critiques, embodiments of specific beliefs about who should control the processes of

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[121] Abbate, *Inventing the Internet*, 181-220; Tim Berners-Lee, *Weaving the Web: The Original Design and Ultimate Destiny of the World Wide Web by its Inventor* (San Francisco: HarperSanFrancisco, 1999), 16.

[122] See John S. Quarterman, "The Demise of GOSIP," *Matrix News* 4, No. 10 (1994): 6; David C. Wood, "Federal Networking Standards: Policy Issues," *StandardView* 2 (1994): 218-223; Libicki, *Information Technology Standards*, 108-119; and Ray Hunt, "The Future of TCP/IP and OSI/GOSIP – Migration or Coexistence?," *Networks '93: Integrating networks with business objectives, Birmingham, June 1993* (London: Blenheim Online, 1993), 423-437. On the failure of X.400, the electronic mail standard within OSI, see Kai Jakobs, "Even Much-Needed Standards Can Fail—The Case of E-Mail," *The Journal of the Communications Network* 5 (2006).

innovation and standardization. In the late 1960s and early 1970s, the Arpanet was created as a response to the market's failure to provide networking solutions that permitted connections between proprietary mainframes. Between the late 1970s and the early 1990s, Open Systems Interconnection was ISO's response to the fractured political economy of European telecommunications and computing. At the same time, the Internet Engineering Task Force proudly defined its informal, technically-oriented work style in opposition to ISO and the "official" standards bodies—"We reject: kings, presidents and voting. We believe in: rough consensus and running code."

By the mid-1990s, the success of the Internet represented a fundamental shift in the political economy of communications networks. No longer were executives in monopoly telephone companies in charge of providing voice communications; by the end of the twentieth century, thousands upon thousands of consumers subscribed to digital phone service—known as Voice over Internet Protocol (VoIP)—that had no use whatsoever for the legacy analog and circuit-switched telephone network. Many VoIP products, offered by startup companies such as Vonage and Skype as well as cable television providers such as Time Warner and Comcast, utilized standards developed within the IETF in the late 1990s.[123] The new network architects were no longer AT&T executives who were pursuing complete control over a proprietary network. Instead, they

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[123] For a ethnographic case study of the IETF that examines the organizational culture of the committees that designed this underlying standard, the Session Initiation Protocol, see Natalie Nelson Marsh, "Reconsidering the Conceptual Relationship Between Organizations and Technology: A Study of the Internet Engineering Task Force as a Virtual Organization" (Ph.D. dissertation, University of Colorado at Boulder, 2006).

were leaders of the IAB and IETF, struggling mightily to provide coherence and direction within the modular industry structure of the Third Industrial Revolution.

The failure of OSI stemmed from its inability to overcome the political and strategic differences among its diverse and powerful constituencies. Perhaps, over time, OSI would have become the comprehensive network architecture envisioned by its leaders. In the meantime, users found that they could buy and customize products designed to work around TCP/IP standards—thus feeding a boom in the global computer networking industries.[124] The key to the Internet's success was its dynamic and fluid institutional foundation and work culture. By circumventing the industrial legislatures responsible for the "official" standards process, and by developing their network architecture in a homogenous environment insulated from commercial and political pressures, Internet engineers were able to develop a network that "only just works."[125] To sustain their technological innovations, the Internet community developed a structure and process that generated sufficient levels of consensus and legitimacy to continue their experiments in internetworking. While it is now common to see participants in the Internet standards community refer to the "rough consensus and running code" ideal for their technical work, Clark's rejection of alternative forms of decision-making—kings, presidents and voting—reminds us of the close links between network standards, international politics, and visions of a new future free from hierarchical control.[126] As

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124 See William Aspray and Paul Ceruzzi, eds., *The Commercial Internet and its Impact on American Business* (Cambridge: The MIT Press, forthcoming [2007]).
125 Mark Handley, "Why the Internet Only Just Works," *BT Technology Journal* 24 (2006): 119-129.
126 On "rough consensus and running code" as IETF credo, see Erik Huizer (1996), "IETF-ISOC Relationship," RFC 2031, http://www.ietf.org/rfc/rfc2031.txt; Scott Bradner, "The Internet

Lawrence Lessig summarized in his influential 1999 book *Code and Other Laws of Cyberspace*, "rough consensus and running code" was "a manifesto that will define our generation."[127]

However, the Internet's informal process led many observers—especially those outside the United States—to be suspicious of the Internet standards process. Before the late 1980s, this process did not allow all interested participants to have a voice in the process and fell well short of the procedural safeguards, treasured by groups such as ANSI and ISO, that ensured an open and fair standardization process. With the advent of commercial interest in the Internet in the 1990s—and given the continued ambitions of commercial firms to disrupt the end-to-end architecture of the Internet for their proprietary gain—the Internet community has only been partially successful in assuring outsiders that its processes are fair and robust.[128]

In the meantime, engineers and regulators in the American and European telecommunications industries experimented with different approaches to building networks for digital cellular telephony. As the next chapter describes, even though these

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Engineering Task Force," *Open Sources*, 50; and Harald Alvestrand (2004), "A Mission Statement for the IETF," RFC 3935, http://www.ietf.org/rfc/rfc3935.txt. Newer standards bodies, such as the World Wide Web Consortium and the Global Grid Forum, have adopted "rough consensus and running code" as a basis for their own activities. See for example Berners-Lee, *Weaving the Web*, 98; and "Global Grid Forum Overview: Structure and Process," http://www.gridforum.org/L_About/Struc_Proc.htm.

[127] Lawrence Lessig, *Code and Other Laws of Cyberspace* (New York: Basic Books, 1999), 4.

[128] On pressures on the IETF and the end-to-end model, see Philip J. Weiser, "The Internet, Innovation, and Intellectual Property Policy," *Columbia Law Review* 103 (2003): 573-576; and Mark A. Lemley and Lawrence Lessig, "The End of End-to-End: Preserving the Architecture of the Internet in the Broadband Era," *UCLA Law Review* 48 (2001): 925-972. For a lengthy and enthusiastic appraisal of the IETF as "an international phenomenon that conforms well to the requirements of [Jürgen] Habermas's discourse ethics," see A. Michael Froomkin, "Habermas@Discourse.Net: Toward a Critical Theory of Cyberspace," *Harvard Law Review* 16 (2003): 749-873.

experiments occurred during a similar time period as the development of the Internet and OSI (between the 1970s and the early 1990s), historical constraints and political events shaped the cellular industry in different ways—and generated different results.

Chapter 5: The Cellular Telephone as Political Instrument: Standardization in the United States and Europe, 1982-2000[1]

5.1 Introduction

Cellular telephone networks provide another example of a central argument of this dissertation: new communication networks embodied technological and ideological critiques of existing networks. American firms—led by AT&T and Motorola—dominated the first generation of cellular networks. The cellular concept was first defined in 1947 by the Bell Labs engineer Douglas H. Ring, but commercial service only began in 1980, when AT&T and Motorola ran successful tests of the first commercial systems. In 1982, the Federal Communications Commission (FCC) bowed to intense pressure from the nascent American cellular industry and adopted the standard developed by AT&T and Motorola as the single American standard for analog cellular networks. Buoyed by the stability that this regulatory decision created, American firms stepped up their production of analog cellular equipment, and found ready customers in the United States and in more than 100 nations around the world. The booming market for American analog cellular equipment provided a vivid demonstration of the "bandwagon effects" and economies of scale that can follow from government-mandated standards.[2]

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[1] My title is an adaptation of a title used by W. Bernard Carlson for an article in which he suggested that "political ideology should not be explored merely in the realm of ideas." W. Bernard Carlson, "The Telephone as Political Instrument: Gardiner Hubbard and the Political Construction of the Telephone, 1875-1880," in Michael Thad Allen and Gabrielle Hecht, eds., *Technologies of Power: Essays in Honor of Thomas Parke Hughes and Agatha Chipley Hughes* (Cambridge, MA: The MIT Press, 2001), 25-55.

[2] For a description of the cellular concept and Ring's unpublished paper, W. R. Young, "Advanced Mobile Phone Service: Introduction, Background, and Objectives," *Bell System Technical Journal* 58 (1979): 1-14. Yes, his name really was Ring. The development of first generation (analog) networks is described in Jeffrey L. Funk, *Global Competition Between and*

In Europe, the development of analog cellular networks during the late 1970s and early 1980s reflected the prevailing European approach in which national governments protected their domestic telecommunications firms by developing analog systems through their own state sponsored monopolies.[3] With the exception of some important collaborations between several Nordic countries, many of the largest European nations including France, Germany, Great Britain, and Italy applied a defensive mindset to the development of analog mobile technology. While these "national champion" strategies protected domestic industries from foreign competition, they also had the unintended consequence of creating a patchwork of incompatible systems across Europe.[4] As a result, customers who "roamed" from one country to another could not use their phones. Additionally, the limited size of equipment markets made it difficult for manufacturers to generate economies of scale in production of network equipment and handsets, which kept prices high and sales low.[5]

Within Standards (London: Palgrave, 2002), 9-18, 38-68; Garry A. Garrard, *Cellular Communications: Worldwide Market Development* (Boston: Artech House, 1998), 30-47; and Dan Steinbock, *Wireless Horizon: Strategy and Competition in the Worldwide Mobile Marketplace* (New York: AMACOM, 2002), 85-112.

[3] In some nations, telecommunications services fell under the direct supervision of state agencies, such as the Bundespost in Germany or the French Ministry of Post, Telegraph, and Telephone. In other nations, a regulated monopoly dominated the operation of telecommunications networks (such as Televerket in Sweden). In most nations, network equipment suppliers benefited from protective regulation and close ties to the national service provider. See Eli Noam, *Telecommunications in Europe* (New York: Oxford University Press, 1992).

[4] Funk, *Global Competition Between and Within Standards*, 47-48, 57-63. The various systems included NMT in Scandinavia, C-Netz in Germany, and TACS in Great Britain, RTMS in Italy, and RC2000 in France.

[5] For a discussion of the importance of scale economies in these markets, see Michelle Egan, *Constructing a European Market: Standards, Regulation, and Governance* (New York: Oxford University Press, 2001), 44-55.

As engineers developed the second generation of cellular networks during the mid-1980s and 1990s, this basic state of affairs—a unified American approach and a fragmented European approach—was turned upside down. The second generation of networks were built around digital transmission technologies instead of analog, and hence required new transmission standards. In both the United States and Europe, prevailing ideological currents pushed the respective cellular industries in opposite directions. Throughout the 1980s, regulators in the FCC rejected both government control and monopoly control of the American telecommunications industry.[6] Instead, they decided in 1988 that their social, economic, and political goals could best be met by allowing firms in the cellular industry to set standards through market mechanisms, without government mandates. This decision split the American industry between two competing standards specified within industry standards committees, and left room for alternative standards to emerge in market niches.[7]

By the time the FCC arrived at its decision, telecommunications regulators in Europe had backed away from their defensive strategies and linked the creation of the second (digital) generation of cellular networks with a broader social and economic vision of a unified Europe. In 1982, the Europeans decided to create a single pan-European standard. The technological features of the standard—known as the Global

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[6] Peter Temin with Louis Galambos, *The Fall of the Bell System: A Study in Prices and Politics* (New York: Cambridge University Press, 1987).
[7] The two standards, TDMA (Time Division Multiple Access) and Code Division Multiple Access (CDMA), are discussed below. A third standard, iDEN, was developed by Motorola and used exclusively in the Nextel "push to talk" networks.

System for Mobile Communication, or GSM—were in place by the end of 1987, and every European nation committed to create commercial digital cellular networks by 1991.

In Europe, decisive political action generated tremendous first mover advantages for the companies—mostly but not exclusively European—that participated in the GSM process. The European standard soon became the dominant global standard, and the European success in system-building generated immediate benefits for European businesses and consumers: European firms such as Nokia and Ericsson became global leaders, and European consumers enjoyed the liberating effects of the new technology that were unavailable to Americans.[8]

Date	GSM (Europe)	CDMA (US)	TDMA (US)	GSM/CDMA ratio
12/1995	13,034,000	9,000	2,055,000	1448:1
12/1996	32,878,500	987,000	2,700,000	33:1
12/1997	71,359,000	5,980,000	6,900,000	11:1
12/1998	138,107,240	22,771,750	17,729,410	6:1
11/1999	200,000,000	45,000,000	n/a	4.4:1
6/2000	331,500,000	67,000,000	n/a	5:1
12/2000	455,100,000	82,200,000	65,200,000	5.5:1
12/2001	627,700,000	113,000,000	93,300,000	5.5:1
12/2002	787,500,000	143,000,000	109,200,000	5.5:1

Table 5.1: Worldwide digital cellular subscribers by standard, 1995-2002. Third-generation standards are not considered. GSM is the European standard; CDMA and TDMA are the two leading American standards. Sources: Cellular Online; GSM Association; CDMA Development Group.[9]

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8 For positive assessments of the European approach, see for example Wayne Sandholtz, "Institutions and Collective Action: The New Telecommunications in Western Europe," *World Politics* 45 (1993): 242; and Jacques Pelkmans, "The GSM Standard: Explaining a Success Story," *Journal of European Public Policy* 8 (2001): 432-453. The term "bureaucratic miracle" comes from Jon Agar, *Constant Touch: A Global History of the Mobile Phone* (Cambridge: Icon Books Ltd, 2003), 55.

9 http://www.cellular.co.za/stats/statistics_global_by_standard.htm; http://www.gsmworld.com/news/statistics/index.shtml; http://www.cdg.org/index.asp.

As the European cellular industry boomed in the 1990s, many analysts celebrated the "bureaucratic miracle" that created the foundations for market success and for Europe's emerging "mobile society."[10] A 2003 article in *Telecommunications Policy* summarized the conventional wisdom: "Many have argued that the EC adoption of a uniform 2G/GSM standard is one of the great successes of European telecommunications policy, and the North American regulators' decision to let the market determine standards is a great failure."[11] Some analysts, however, departed from this conventional wisdom and praised the American decision to resist mandates and allow firms to experiment with new technologies. The emergence of CDMA, a standard that provided a more efficient means to use the scarce amounts of spectrum available for cellular networks, provided compelling evidence for this dissenting view. For the firms that designed their equipment around CDMA technologies, smoother transition paths to subsequent generations of broadband cellular networks (third generation, or 3G)—all of which are based on versions of CDMA technologies—provided further evidence of the merits of the American *laissez-faire* approach.[12] In sum, mandated *de jure* standards gave European firms strong first-mover advantages, but *de facto* and consensus standardization in the

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[10] For an entrée to the literature on the social implications of cellular telephony, see Manuel Castells, Mireia Fernandez-Ardevol, Jack LinchuanQiu, and Araba Sey, *Mobile Communication and Society: A Global Perspective* (Cambridge, MA: The MIT Press, 2006); and Richard Ling, *The Mobile Connection: The Cell Phone's Impact on Society* (San Francisco: Morgan Kaufmann, 2004).
[11] Neil Gandal, David Salant, and Leonard Waverman, "Standards in Wireless Telephone Networks," *Telecommunications Policy* 27 (2003): 325-332. See also John Leslie King and Joel West, "Ma Bell's Orphan: US Cellular Telephony, 1947-1996," *Telecommunications Policy* 26 (2002): 189-203 ("The question is not *whether* [American firms] missed the boat, but rather *how* they missed it given their advantage at the time").
[12] See for example Philip J. Weiser, "Which Broadband Nation?," *Foreign Affairs* (Sept/Oct 2005); and Johannes M. Bauer, Yu-Chieh Lin, Carleen F. Maitland, and Ankur Tarnacha, "Transition Paths to Next-Generation Wireless Services," TPRC 2004, the 32nd Research Conference on Communication, Information, and Internet Policy, Alexandria, VA (October, 2004).

United States created greater incentives for innovation and allowed American firms to catch up with and surpass European technology—even though the European standard retained its dominant share of global markets.

Given the unfolding state of digital cellular markets, it is impossible to determine how this standards war will play out over the long term. Where most analysts contrast the relative technological and ideological merits of the American and European styles of system-building, this chapter situates these systems within a broader and longer historical context. When we look at the decisions and tradeoffs that regulators and engineers made, we can see how these divergent paths of innovation embodied critiques of the existing order, drawn from the lessons these professionals had learned from previous generations of communication networks, and applied as they hoped to lead the way toward a more prosperous future. Moreover, by stepping outside of a strictly comparative framework and adopting a longer and broader historical view, we can see how both the European and American decisions indicate that the institutional basis of standardization in the telecommunications industry had abandoned its roots in national monopolies, and turned to consensus committees to set new standards, define new network architectures, and coordinate the constituent components. In short, the history of digital cellular in the United States and Europe illustrates two different strategies for managing the transition to the modular technologies and industry structures of the Third Industrial Revolution. The differences between these two strategies lie in different styles of reaching and implementing "consensus" standards—one enforced by government, one subject to market forces.

5.2 European Integration: Ideology, Politics, and Technology

As European regulators contemplated a new generation of digital cellular networks in the early 1980s, they reflected on the drawbacks of the existing patchwork of incompatible analog cellular networks across Europe. First, the incompatible networks added friction to the political and economic integration of Europe, a movement that had been gaining momentum under the Commission of European Communities and Council of Ministers. Second, the "lack of spontaneous cooperation" between firms in the European telecom industry seemed certain to spell doom in competitive global markets against the industrial giants of America and Japan. The Commission declared that a "more systematic, more effective approach" would be necessary to spark the European industry.[13] European telecommunications professionals confronted these challenges at two interrelated levels: within the political bureaucracy of the Commission of European Communities and within the technological bureaucracy of standard-setting committees.

The modern basis of European integration began after World War II, when several European leaders committed to a course of political and economic cooperation that they hoped would prevent the recurrence of the bloody wars that had scarred Europe for centuries.[14] In 1967, a European Merger Treaty created three bodies to work in tandem: a Commission of European Communities ("Commission"), Council of Ministers

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[13] Commission of the European Communities, *Telecommunications (Communication from the Commission to the Council)*, COM (83) 329 final (Brussels: CEC, 9 June 1983), 1-2, 5, 7.
[14] Six European countries (Belgium, Italy, France, Luxembourg, the Netherlands, and West Germany) took formal steps toward this integration by establishing three groups—the European Coal and Steel Community (1951), the European Atomic Energy Community, and European Economic Community (both formed by the 1957 Treaties of Rome).

("Council") and European Parliament.[15] The Commission struggled to establish consensus over European tariffs and industrial policy during a "decade of stagnation" between 1973 and 1983, but by the early 1980s they began a new round of initiatives to establish a single European market.[16]

One such initiative was in the area of mobile telecommunications, which the Commission saw as an important sector for growth both as infrastructure for other European industries and as a significant market in itself—"no less essential than coal and steel were at the beginning of the fifties," according to one document.[17] Engineers from Commission member states coordinated the technical development of the new cellular network in a strikingly productive series of negotiations that occurred between 1984 and 1987.[18] The landmark publication of this era of technical diplomacy was the Commission's June 1987 Green Paper entitled "Towards a Dynamic European

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[15] In general, the Commission was responsible for proposing and implementing legislation and policies; the Council was the highest decision-making body, whose decisions were binding for member nations. For a seminal analysis of the political economy of European integration, see Charles S. Maier, "The Politics of Productivity: Foundations of American International Economic Policy after World War II," in Charles S. Maier, ed., *The Cold War in Europe* (New York: Markus Wiener Publishing, Inc., 1991), 169-201.

[16] See Keith Middlemas, *Orchestrating Europe: The Informal Politics of European Union 1973-1995* (London: Fontana Press, 1995), 73-155; and Egan, *Constructing a European Market*, 61-81.

[17] Commission of the European Communities, *Telecommunications (Communication from the Commission to the Council)*, COM (83) 329 final (Brussels: CEC, 9 June 1983), 10. See also Commission of the European Communities, *Communication from the Commission to the Council on Telecommunications – Lines of Action*, COM (83) 573 (Brussels: CEC, 1983), 6-7.

[18] See for example Council of Ministers, *Council Recommendation of 12 November 1984 concerning the implementation of harmonization in the field of telecommunications*, 84/549/EEC (Brussels: EEC, 12 November 1984). See also Council of Ministers, *Council Directive of 24 July 1986 on the initial stage of the mutual recognition of type approval for telecommunications terminal equipment*, 86/361/EEC (Brussels: EEC, 24 July 1986); and Council of Ministers, *Council Decision of 22 December 1986 on standardization in the field of information technology and telecommunications*, 87/95/EEC (Brussels: EEC, 22 December 1986).

Community."[19] The Green Paper reinforced the importance of telecommunications as the "'nervous system' of modern society," and highlighted the consensus conclusion that traditional forms of organization that enforced "national frontiers" would prevent new technologies from reaching their full potential.[20] Although some areas of disagreement persisted, the specific provisions for the creation of a pan-European digital mobile network—including the need for "a substantial re-inforcement of resources applied to standardisation"—enjoyed broad support. [21]

This emerging political and technological consensus required new institutions to create technical standards that would be acceptable to all parties. Between 1980 and 1982, the Conference of European Posts and Telecommunications Administrations (CEPT), a powerful group of national regulators from 26 European countries, conducted a thorough analysis of the European cellular industry. In their December 1982 report, they declared that a band of spectrum between 862 and 960 MHz would be set aside for a pan-European mobile system, and created a committee of technical experts called the Groupe Spéciale Mobile, or GSM, to plan and design of the new system.[22] Much like the negotiated and iterative process that the Commission had followed at the diplomatic level, the engineer-statesmen of the GSM met regularly between 1982 and 1989. These

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[19] Commission of the European Communities, *Towards a dynamic European economy: Green Paper on the development of the common market for telecommunications services and equipment,* COM (87) 290 (Brussels: CEC, 30 June 1987).
[20] CEC, *Green Paper*, 1.
[21] Commission of the European Communities, *Towards a competitive community-wide telecommunications market in 1992: Implementing the Green Paper on the development of the common market for telecommunications services and equipment*, COM (88) 48 final (Brussels: CEC, 9 February 1988).
[22] See Garrard, *Cellular Communications*, 63; and "GSM Plenary Report," GSM Temporary Document 32-83, (P-83-032), December 1982.

technical negotiations, chaired skillfully by the Swedish telecommunications engineer Thomas Haug, operated according to similar procedural values that sought to establish a widely shared consensus through focused and diplomatic discussion. Haug recalled that the consensus process "may not be the speediest way to reach a decision, but on the other hand, a consensus makes it almost certain that everyone is going to stick to the decision."[23]

One benefit of Haug's leadership was that he was an experienced leader in situations that called for international negotiations. The major source of his experience was a series of collaborations between Nordic countries in the 1970s and early 1980s to create a single Nordic analog system (known as NMT).[24] This Nordic system was born out of a 1969 Swedish proposal to collaborate with Denmark, Finland, and Norway to create a mobile telecommunications network.[25] The Nordic system emerged as a potent competitor to American analog systems, and the commercial success of the Nordic system demonstrated the economic and technical viability of an international alliance of telecommunications firms and regulators.[26]

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[23] Haug recalled that the consensus process "may not be the speediest way to reach a decision, but on the other hand, a consensus makes it almost certain that everyone is going to stick to the decision." Thomas Haug, "The GSM Standardisation Work 1982-1987," in Friedhelm Hillebrand, ed., *GSM and UMTS: The Creation of Global Mobile Communication* (New York: John Wiley & Sons, 2002), 16.

[24] Thomas Haug, "A Commentary on Standardization Practices: Lessons from the NMT and GSM Mobile Phone Standards Histories," *Telecommunications Policy* 26 (2002): 104. See also Ari T. Manninen, "Elaboration of NMT and GSM Standards: From Idea to Market" (Ph.D. Diss., University of Jyväskylä, 2002).

[25] See Haug, "A Commentary on Standardization," 101-107; and Janne Lehenkari and Reijo Miettinent, "Standardisation in the Construction of a Large Technological System—the Case of the Nordic Mobile Telephone System," *Telecommunications Policy* 26 (2002): 109-127.

[26] Funk, *Global Competition Between and Within Standards*, 53-56.

In early 1982, the Nordic alliance expanded to include the Netherlands. Together, they proposed to create a common European standard that would suit the political goals of European integration.[27] Soon thereafter, a separate and competing European alliance emerged with France and Germany at its core. This Franco-German alliance was itself a remarkable departure from the bitter technological disputes between the two nations in the post-war era, most visible in a series of disputes during the 1960s over the standardization of color television. Between 1983 and 1985, the French and German ministries cooperated to create an interim analog system as well as a joint research and development program for digital cellular technologies.[28] The Franco-German alliance expanded to include Italy in 1985 and British network operators in 1986. As with the Nordic collaborations, the Franco-German cooperative relationship was an experiment to build an international standards alliance in order to benefit their respective national manufacturers.[29]

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[27] The Netherlands, Denmark, Finland, Norway, and Sweden submitted joint statements to CEPT asserting that concerted action for 900 MHz band was needed before each country developed its own system. See "GSM Study Plan," GSM Temporary Document 2/82 (P-82-002), June 1982; and "Public Mobile Communications Systems in the 900 MHz band," GSM Temporary Document 4/82 (P-82-004), June 1982. See also Thomas Haug, "The Market Fragmentation in Europe and CEPT Initiatives in 1982," in Hillebrand, ed., *GSM and UMTS*, 12-14.

[28] See Philippe Dupuis, "The Franco-German, tripartite and quadripartite co-operation from 1984 to 1987," in Hillebrand, ed., *GSM and UMTS*, 26-29. Dupuis served as assistant for mobile communications to the French Director General of Telecommunications from 1981 to 1988, and was deeply involved in French participation in GSM activities. See also Rhonda Crane, *The Politics of International Standards: France and the Color TV War* (Norwood, NJ: Ablex Publishing Corporation, 1979).

[29] Europeans alliances to support this "national champion" strategy existed in a number of high-tech industries, including computers and airplanes. See David C. Mowery and Richard R. Nelson, eds., *Sources of Industrial Leadership: Studies of Seven Industries* (New York: Cambridge University Press, 1999).

Beginning in 1986, the engineers in the GSM committee evaluated eight competing proposals to determine a single European standard for digital cellular networks. The GSM committee sought to base its decision on the technical performance of the competing networks. To generate data for comparison, engineers in the GSM committee undertook a series of field tests in 1986 and 1987—somewhat reminiscent of Jon Postel's "bake-offs" (discussed in the previous chapter) in the early 1980s to determine the best implementations of Internet protocols.[30]

Leading up to a tense meeting in Madeira, Portugal in February 1987, the eight proposals had been narrowed down to two: one developed by Franco-German alliance, and the other created by the Nordic alliance. At the Madeira meeting, the Nordic proposal gained the support of all of the fifteen GSM representatives except two, the French and the German. The French and German opposition was not technical; instead, it stemmed from political pressure from their respective national governments, who had subsidized their joint proposal and, for economic and cultural reasons, strongly preferred to see a standard developed by their own engineers adopted as the European standard. However, the French and German representatives in GSM eventually convinced their domestic leaders that the Nordic system would be economically and technically superior.

Outflanked by the Nordic alliance and unwilling to endure further delays to fight what appeared to be a hopeless battle, the telecommunication ministers in the French and German governments dropped their objections in May 1987 and supported the Nordic

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[30] Dupuis, "Franco-German cooperation," in Hillebrand, ed., *GSM and UMTS*, 23-36.

proposal.[31] Ericsson, a prominent firm in the Nordic alliance, sweetened the deal for France and Germany by cooperating with Alcatel and Siemens, two of the champion firms of the latter two countries.[32] Shortly thereafter, the consensus negotiated in the GSM committee received a political blessing from the European Council, which required that member states to defer to the GSM committee for "planning all system aspects of a second-generation cellular mobile radio infrastructure."[33] In other words, the technical consensus forged within the GSM committee was backed by the legal authority of the European Council, thus elevating their consensus standard to *de jure* status.

Two subsequent institutional innovations paved the way for the GSM standard to move quickly to market. First, representatives from 14 national telecom monopolies and private network operators from 13 European countries signed a Memorandum of Understanding in September 1987 that committed the signatories to work toward the commercial introduction of GSM networks by July 1, 1991.[34] The Memorandum of

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31 See "Declaration of the ministers on the introduction of a pan European public digital cellular radiocommunication service," GSM Temporary Document 68/87 (P-87-068), 19 May 1987. For a glimpse into the politics involved, see Haug, "The GSM Standardisation Work," in Hillebrand, ed., *GSM and UMTS*, 21-22; Dupuis, "Franco-German cooperation," in Hillebrand, ed., *GSM and UMTS*, 31-35.

32 Rudi Bekkers and Isabelle Liotard, "European Standards for Mobile Communications: The Tense Relationship between Standards and Intellectual Property Rights," *European Intellectual Property Review* 3 (1999): 110-126.

33 Council of Ministers, *Council Directive of 25 June 1987 on the frequency bands to be reserved for the coordinated introduction of public pan-European cellular digital land-based mobile communications in the Community*, 87/372/EEC; Council of Ministers, *Council Recommendation of 25 June 1987 on the coordinated introduction of public pan-European cellular digital land-based mobile communications in the Community*, 87/371/EEC.

34 GSM, "Memorandum of Understanding on the implementation of a pan European 900 MHz digital cellular mobile telecommunications service by 1991," 7 September 1987. In his comments on the importance of British initiation of the MoU, Stephen Temple (a GSM participant from the UK) suggested that Prime Minister Margaret Thatcher's policy of promoting competition in telecommunication injected "into the European strategic thinking in standards making a strong

Understanding was significant because it ensured market acceptance and thus reduced the risks of investments in research, development, and manufacturing. If the Green Paper confirmed the political viability of a pan-European digital mobile network, the Memorandum of Understanding confirmed the commercial viability of the system to be created by the GSM committee.

The second institutional innovation brought private manufacturers and network operators into the standardization process. In 1989, the standards development work of the GSM committee moved to the newly created European Telecommunications Standards Institute (ETSI).[35] At the same time, the GSM standard itself was renamed Global System for Mobile Communication, and retained the "GSM" acronym. The main difference between ETSI and the pre-existing international telecommunications standards bodies was that ETSI's rules allowed participation from private firms. By taking this step, European regulators acknowledged that the *ancien* regime where national monopolies dominated telecommunications had passed: in the new order, private firms—even non-European firms with significant operations in Europe—had equal standing in the standardization process. The private firms responded eagerly to this new opportunity

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dose of market realism." Stephen Temple, "The GSM Memorandum of Understanding – the Engine that Pushed GSM to the Market," in Hillebrand, ed., *GSM and UMTS*, 37-40.

35 Created in March 1988 to coordinate European telecom standards in an era of deregulation, ETSI was a child of multilateral jurisdictional conflicts between the Community (which was pushing for liberalization of equipment markets), CEPT (which was interested in maintaining national sovereignty), and CEN and CENELEC (the electronics industry and standards bodies who felt telecommunications standards were on their turf). Stanley M. Besen, "The European Telecommunications Standards Institute: A Preliminary Analysis," *Telecommunications Policy* 14 (1990): 521-530. See also Egan, *Constructing a European Market*, 146-151.

to shape standards, and membership in ETSI grew rapidly, with over 135 members by 1990.[36]

Once the European nations reached a political consensus and established new institutions to create the needed standards for the new digital network, one of the most important issues within the standards committee was how they would treat patented technologies. Which patented technologies were essential for the GSM standard? On what terms would these patents be licensed? The two questions were linked. As the committee developed the technical specifications, they discovered conflicting norms between many of the European firms and one American firm in particular, Motorola. Motorola, which was able to participate within the European process because of its manufacturing facilities in Europe, embodied a more aggressive, brute force style of patent negotiation that was customary among American firms in the computing and electronics industries. European firms such as Philips, Ericsson, Nokia, Alcatel, and Siemens favored more modest terms in which patents would be licensed on either "reasonable and non-discriminatory" terms or at no cost (otherwise known as "royalty-free" terms). These leading companies eventually resolved the conflict through an exchange of patent licenses. The resulting cross-licensing regime meant that the firms with the strongest patent portfolios (Motorola, Nokia, Ericsson, Siemens, and Alcatel) were best positioned to manufacture equipment for GSM networks at the lowest cost—an

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[36] For a nuanced analysis of this shift away from the "*ancien* regime," see William J. Drake, "The Transformation of International Telecommunications Standardization: European and Global Dimensions," in Charles Steinfield, Johannes M. Bauer and Laurence Caby, eds., *Telecommunications in Transition: Policies, Services, and Technologies in the European Community* (Thousand Oaks, CA: Sage Publications, 1994), 71-96.

advantage that translated into market success for these firms. The "passive behavior" of Philips, as well as Japanese companies such as NEC and Mitsubishi—which declined to participate in cross-licensing agreements—meant that they were initially frozen out of manufacturing for GSM handsets and equipment.[37]

Taken together, this series of institutional innovations—the multilateral Memorandum of Understanding that committed signatories to developing GSM networks, and the development of patent exchanges among private firms within the GSM committee—provided the technological and commercial foundations for market adoption of GSM standards. The resulting rapid adoption of GSM networks within European and global markets indicates that the European professionals successfully managed the transfer of power from the old order of national monopolies to the new order where power resided with private firms and international organizations. At both the political and technical levels, European telecommunications professionals engaged in a power-laden diplomatic process, infused with complicated technical issues, in which their home nations ceded power and authority to international organizations in order to reap the benefits of cooperation. The benefits were substantial: by the early 1990s the leading European firms were growing far more quickly than their American and Japanese rivals. GSM grew from 250,000 users in 1992 to over 450 million users in 2000 – almost 70% of all digital mobile customers worldwide. By the turn of the twenty-first century, GSM

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[37] Bekkers and Liotard, "European Standards for Mobile Communications: The Tense Relationship between Standards and Intellectual Property Rights," 110-126; and Rudi Bekkers, Bart Verspagen, and Jan Smits, "Intellectual Property Rights and Standardization: the Case of GSM," *Telecommunications Policy* 26 (2002): 171-188.

networks were present in 147 countries on all continents.[38] When viewed in light of earlier failures of European high-tech initiatives, such as the failure of the OSI computer network architecture, the success of GSM was indeed a "bureaucratic miracle"—a technological manifestation of the new ideology of European cooperation.

5.3 American Deregulation: Spectrum Scarcity and Mandated Competition

In the European setting, ideology pulled together the most important institutions in the telecommunications industry; in the United States, ideology pulled these institutions apart. Digital cellular technologies came of age at the same moment when American regulators finally decided to dismantle the Bell System and began experiments to, somewhat paradoxically, mandate more competition in the telecommunications industry—"contrived competition" in the assessment of historian Richard Vietor.[39] The Federal Communications Commission (FCC), the agency that directed these experiments, has been the subject of criticism that included allegations of incompetence and utter subservience to the lobbyists of the industries under their jurisdiction. However, a more sympathetic look at the FCC provides a picture of civil servants under siege, whose embrace of market-oriented reforms was as much a product of the intrinsic logic of these reforms as it was an attempt to save their own necks.

Throughout its history, the central function of the FCC was to manage a scarce resource: the radio spectrum. All of the complex technical and bureaucratic issues that

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[38] Friedhelm Hillebrand, "GSM's Achievements," in Hillebrand, ed., *GSM and UMTS*, 1-10.
[39] Richard H. K. Vietor, *Contrived Competition: Regulation and Deregulation in America* (Cambridge, MA: Harvard University Press, 1994).

permeate the history of the FCC stem from the simple fact that the radio spectrum could not accommodate all of the signals that people want to transmit over it.[40] The FCC managed this scarcity through a complex licensing scheme: it allocated specific portions of the spectrum for specific uses, and then assigned licenses for private parties to use the spectrum.[41] For example, the FCC assigned licenses to television broadcasters to use the spectrum in the 512-608 MHz band only for broadcast television. They were not allowed to use that spectrum for other uses, such as mobile telephony, radio broadcasts, or satellite transmission.

During the twentieth century, the FCC utilized two strategies to alleviate the technical and political problems associated with the allocation of spectrum. One strategy was to re-allocate or re-assign spectrum for new or different uses based upon technical proposals from private firms. Although these comparative hearings—commonly known as "beauty contests"—were ostensibly based on technical criteria, in practice they subjected the FCC to tremendous amounts of pressure from private firms, lobbyists, and elected officials (often acting on behalf of private interests). The process of setting standards clearly illustrates these problems. One familiar example is the FCC's decision to set color TV standards in 1950 that benefited CBS, only to reverse that decision and

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[40] On the early history of the FCC and the "scarcity" rationale for its existence, see Robert W. McChesney, *Telecommunications, Mass Media, & Democracy: The Battle for the Control of U. S. Broadcasting, 1928-1935* (New York: Oxford University Press, 1993).

[41] For a recent overview of the complexities of spectrum management, see Government Accountability Office, "Telecommunications: Preliminary Information on the Federal Communications Commission's Spectrum Allocation and Assignment Process," GAO-06-212R, November 10, 2005.

mandate a different standard—to the memorable delight of RCA President David Sarnoff—in 1953.[42]

Given the difficult bureaucratic problems associated with the FCC's tight control over spectrum allocations and uses, one can understand the enthusiasm for a second strategy to alleviate spectrum scarcity: technological solutions that used spectrum more efficiently. This quest for a technological fix has been one of the consistent themes in the history of the FCC, and has always been a prominent concern in the FCC's regulation of land mobile communication. The FCC frequently turned to competition to create incentives for developing more spectrum-efficient technologies. In 1949, the FCC established two separate sets of land mobile frequencies in every geographical region, one for firms with existing wireline operations (such as AT&T) and one for a group of hundreds of smaller firms classified as Radio Common Carriers. As the mobile industry grew over the next thirty years, its representatives tried to persuade the FCC to re-allocate UHF spectrum from television broadcasters. Time and again, the broadcasters resisted such incursions, leaving the FCC with the unenviable task of mediating the demands of both industries.[43]

The cellular concept was a central breakthrough in this quest for spectrum-efficient technologies. As opposed to the traditional "one-to-many" style of radio communication where signals were broadcast over tens or hundreds of miles, the cellular

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[42] Hugh R. Slotten, *Radio and Television Regulation: Broadcast Technology in the United States, 1920-1960* (Baltimore: The Johns Hopkins University Press, 2000), 189-231.
[43] This complex story is told by Dale N. Hatfield, "FCC Regulation of Land Mobile Radio—A Case History," in Leonard Lewin, ed., *Telecommunications: An Interdisciplinary Text* (Dedham, MA: Artech House, 1984), 105-132.

concept called for a system of towers arranged in a cell-like grid that would transmit signals for only a few miles. This lily pad network architecture, in which radio signals persisted only over small distances, provided a more efficient way to use the scarce amounts of available radio spectrum by allowing the same frequencies to be reused many times in a given geographic area.[44]

Technical complexity and regulatory hurdles delayed the testing of a cellular system until 1962, when Richard Frenkiel and Joel Engel (also in Bell Labs) presided over a team of almost 200 engineers who put the cellular concept into practice. Because Western Electric was barred from entering markets for mobile equipment by the 1956 antitrust decree, Motorola—a company that had established itself as a leader in mobile equipment since before World War II—quickly emerged as the premier American manufacturer. The industry seemed poised to grow quickly, but continued political squabbles delayed the further development of cellular networks until the late 1960s.[45] It took until 1980 for AT&T and Motorola to conduct the first successful tests of cellular systems. These tests generated tremendous demand for mobile service, which in turn overwhelmed the both the capabilities of cellular systems and the capacity of the available spectrum. In 1982, the FCC bowed to pressure from Motorola and AT&T to endorse the analog standard jointly developed by the two companies as the single

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[44] This description is necessarily brief and simplified. Young, "Advanced Mobile Phone Service: Introduction, Background, and Objectives," 1-14.

[45] The main political problem was that the slice of spectrum most desired by AT&T and Motorola was allocated to UHF television, and the powerful broadcasting industry managed to delay any attempts to convince the FCC to change that status quo. Hatfield, "FCC Regulations of Land Mobile Radio," 112-130.

American standard. This mandate, however, was only a temporary fix, and did nothing to alleviate the underlying problem of spectrum scarcity.[46]

5.3.1 Ideology and FCC Domain Contraction

As the FCC struggled to guide the technological development of the cellular industry, broader changes in the realm of political economy led the FCC to reconsider its policy of mandating standards for wireless services. In 1984, a landmark antitrust settlement split up the Bell System and completed the process of shattering the structure of the American telecommunications industry. The FCC became the chief regulatory authority for the new industry structure that took the place of the Bell System, one that sought to replace a single bureaucracy with a competitive marketplace. This introduction of regulated competition in American telecommunications illustrated broader ideological shifts in American regulation that had begun in the late 1970s. As a reaction to rising inflation, stagnant productivity, and pressure from global competition, regulatory reformers altered the structure of a number of major industries, including airlines, banking, and natural gas. This deregulatory turn embodied a rising distrust of government and an emerging bipartisan conviction that the regulatory system was interfering with, instead of aiding, innovation and consumer welfare.[47]

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[46] Louis Galambos and Eric John Abrahamson, *Anytime, Anywhere: Entrepreneurship and the Creation of a Wireless World* (New York: Cambridge University Press, 2002), 32; see also Garrard, *Cellular Communications*, 31; Funk, *Global Competition Between and Within Standards*, 39-58; and Stanley M. Besen and Leland L. Johnson, *Compatibility Standards, Competition, and Innovation in the Broadcasting Industry* (Santa Monica, CA: RAND Corporation, 1986), 125-129.

[47] In Richard Vietor's summary, "new technology in the hands of aggressive entrepreneurs forced changes" in the regulatory system that had protected AT&T from competitive entry in services

Under the leadership of Charles Ferris (appointed by President Carter in 1977) and Mark Fowler (appointed by President Reagan in 1981), the FCC embraced marketplace solutions to regulatory problems.[48] One example of the FCC's new approach was evident in proceedings between 1980 and 1982 in which the FCC weighed competing standards for AM stereo. After years of technical evaluations and industry lobbying, in 1980 the FCC chose a system by Magnavox over four alternatives as the AM stereo standard. Predictably, the sponsors of the losing systems objected strenuously, thus legally obligating the FCC to reconsider its choice. On the basis of its extensive technical tests and data analysis between September 1980 and March 1982, the FCC staff declared that it could not identify any clearly superior technical system.[49] Industry responses to the FCC's call for comments were split between those who urged the FCC to let standardization occur through a commercial adoption and those who argued that the FCC could promote market stability and growth by mandating a single standard. According to political scientist Sanford Berg, this ideological split also existed within branches of the Reagan administration, with the FCC's Office of Plans and Policy in favor of the marketplace approach, and the White House Office of Science and Technology in favor of mandatory standards. Faced with the prospect of further appeals

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and equipment. Vietor, *Contrived Competition*, 19. In contrast, Peter Temin argued that ideological changes were more decisive than changes in technology. Temin, *Fall of the Bell System,* 7-9, 336-348.

[48] See Mark S. Fowler and Daniel L. Brenner, "A Marketplace Approach to Broadcast Regulation," *Texas Law Review* 60 (1982): 207-256.

[49] Several commentators argue that the FCC's reduction of technical and engineering staff during this period—whether caused by a budget crunch or because of an ideological preference for economists—may have influenced the FCC's ability to make technical judgments. See e.g. Christopher H. Sterling, "The FCC and Changing Technological Standards," *Journal of Communication* 32 (1982): 140.

and reported legal threats from losing competitors, the FCC declined to mandate a standard, defending a market-oriented approach as more likely to facilitate subsequent innovation and prevent monopoly control of the industry. According to Christopher Sterling, who worked at the FCC at the time, this decision represented "a benchmark in the Commission's approach to regulation of changing technology."[50]

This market-oriented logic was evident in other FCC proceedings, most notably in the FCC *Computer Inquiries* that structured markets for telecommunications equipment and articulated the FCC policy of resisting regulation of rapidly growing markets for computer networking (so-called "advanced services")—a decision that contributed to the stunning growth of the Internet.[51]

As it evaluated its role in the regulation of communication standards across a number of technologies, the FCC faced a consistent set of difficult problems, including rapid technological change, intense lobbying from self-interested private groups, and an ideological climate that increasingly favored leaving industrial coordination and development to private firms. This combination of practical strains and shifting political winds suggests that Chairmen Ferris and Fowler's embrace of market-oriented reform

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50 Sanford V. Berg, "Public Policy and Corporate Strategies in the AM Stereo Market," in H. Landis Gabel, ed., *Product Standardization and Competitive Strategy* (New York: North-Holland, 1987), 155; and Sterling, "FCC and Changing Standards," 137. See also Besen and Johnson, *Compatibility Standards*, 38-50. In 1990, two commentators concluded that the experiment had failed to generate the desired results, and that "the adoption and diffusion of AM stereo has been retarded by the FCC's decision in 1982 to not establish a technical standard." Bruce C. Klopfenstein and David Sedman, "Technical Standards and the Marketplace: The Case of AM Stereo," *Journal of Broadcasting & Electronic Media* 34 (Spring 1990): 188.

51 See Robert Cannon, "The Legacy of the Federal Communication Commission's Computer Inquiries," *Federal Communications Law Journal* 55 (2003): 167-206; and Jason Oxman, "The FCC and the Unregulation of the Internet," (Federal Communications Commission Office of Plans and Policy, Working Paper No. 31, 1999) (arguing that the FCC's regulatory forbearance was a major contributing factor in the development of the Internet).

was an attempt to remove some of the pressure on the FCC by limiting the agency's authority through deregulation.[52] The FCC came under siege from a variety of constituencies in the early 1980s, including the broadcasting industry, the cable television industry, competing factions within the telephone industry, Congress, the federal courts, the Presidency, and public interest groups. As Florence Heffron noted, the "FCC's deregulation efforts provide an excellent example of the general circumstances under which voluntary deregulation and reduction of power emerge as a rational organizational strategy for survival in a hostile environment."[53] It was in this dynamic institutional environment—the experimental stages of regulated competition—that American telecommunications professionals pounced on opportunities to make "money from thin air" in the rapidly growing cellular industry. At the time, however, it was unclear how well this swarm of new entrants would do in place of the old, stable, cozy relationships between AT&T, Motorola, and the FCC.

In late 1983, the Bell System was on the verge of divestiture and many Americans were concerned that their world-class telecommunications system would fall into a state of disrepair. As the FCC contemplated how to ensure the technical coordination of the national network, it decided to turn to a new industry group called the Exchange Carriers Standards Association (ECSA). The ECSA's legitimacy was in part a function of its size: firms in the ECSA served 95% of American customers. In response to an FCC

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[52] Florence Heffron, "The Federal Communications Commission and Broadcast Deregulation," in John J. Havick, ed., *Communications Policy and the Political Process* (Westport, CT: Greenwood Press, 1983), 61-67; Gail Crotts Arnall and Lawrence M. Mead, "The FCC as an Institution," in Lewin, ed., *Telecommunications: An Interdisciplinary Text*, 37-104.
[53] Heffron, "The Federal Communications Commission," 40.

proceeding on standards in the post-monopoly world, the ECSA volunteered to sponsor a committee that would follow the guidelines of the American National Standards Institute that sought to ensure openness, due process, and balance of interests. With the approval of the FCC and the industry, the ECSA created committee T1 in February 1984. The new T1 committee was able to fill the coordinating role previously assumed by the Bell System, and thus provided a template for future standardization policy decisions.[54]

5.3.2 The FCC and the Creation of Cellular Competition

The FCC's determination to create competition in hundreds of local markets throughout the United States led to a slow and inefficient license assignment process, one that did not begin until 1982 and dragged on until 1989.[55] The causes of this delay stemmed from the inability of FCC staff to create a process for assigning spectrum that was both fair and efficient. At first, the FCC invited technical proposals (the traditional "beauty contest" approach), but applicants overwhelmed the FCC by adding charts, maps, and market forecasts—in short, anything and everything they thought would help them win.[56] Unable to review the proposals—let alone judge their technical merits—the FCC

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[54] Ian M. Lifchus, "Standards Committee T1—Telecommunications," *IEEE Communications Magazine* 23 (1985): 34-37; and Arthur K. Reilly, "Defining the U.S. Telecommunications Network of the Future," in Brian Kahin and Janet Abbate, eds., *Standards Policy for Information Infrastructure* (Cambridge: The MIT Press, 1995), 579-593.

[55] See James B. Murray, Jr., *Wireless Nation: The Frenzied Launch of the Cellular Revolution in America* (Cambridge, MA: Perseus Publishing, 2002); and O. Casey Corr, *Like Money from Thin Air: The Story of Craig McCaw, the Visionary who Invented the Cell Phone Industry, and His Next Billion-Dollar Idea* (New York: Crown Business, 2000).

[56] Much of this application fodder seems to have been pure speculation. As one participant in the process later wrote, "The dirty little secret was that everyone was guessing about almost everything—and frequently guessing very badly." Murray, *Wireless Nation*, 46; and Galambos and Abrahamson, *Anytime, Anywhere*, 164.

abandoned the beauty contests in favor of a system of lotteries on April 11, 1984. Once again, spectrum speculators found ways to "game" the lotteries and further frustrate efforts to conduct a fair and efficient assignment process. These various gaming tactics—including some that were legally and ethically dubious—detracted from the serious, capital-intensive work required to build cellular systems. Some went so far as to create "application mills" that reduced applications for wireless spectrum to little more than binder-sized lottery tickets.[57]

Consequently, many winners of the spectrum lotteries were interested only in reselling spectrum, and completely uninterested and incapable of building cellular systems that could compete—as the FCC intended—against the cellular subsidiaries of the Baby Bells. A wave of consolidation ensued over the next few years as entrepreneurs such as Craig McCaw bought up licenses in a freewheeling market.[58] Because the cellular market became a laboratory for mandating competition in the immediate aftermath of AT&T's divestiture, the American process of spectrum assignments was far less efficient than the European strategy of international harmonization. This difference accounts more than any other factor for the lag in the development of the American cellular industry.

Given this state of affairs—the fragmented state of the cellular industry and the scarce amount of spectrum allocated for cellular service—the American digital cellular

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57 Murray, *Wireless Nation*, 127-161.

58 On the enigmatic McCaw's leading role, see Corr, *Money From Thin Air*. Murray provides an insiders view of the "wheeling and dealing" for cellular licenses. Murray's account is full of tales of ad hoc alliances, frontier-esque speculation, and an impressive amount of whiskey and cigars. See Murray, *Wireless Nation*, including chapters entitled "The Boys' Club," "Le Grand Deal," "The Big Monopoly Game," "Last Call at the Casino," and "After the Gold Rush."

industry was in desperate need of clear rules to stabilize commercial development. The FCC, which had thus far hesitated to provide guidance or leadership, finally initiated proceedings in October 1987 to create new rules and clarify the existing rules that governed the cellular industry. The main thrust of the FCC's proposal was to move away from specific rules mandating what spectrum licensees could or could not do with their spectrum. In this form, "deregulation" would, in the view of the Commissioners, "promote the public interest by encouraging the development of more spectrum-efficient cellular technologies and by permitting more efficient and intensive use of the frequencies that have been allocated for cellular service."[59] Cellular operators could achieve this goal by experimenting with "alternative technologies" to the previously mandated analog standards. The FCC found additional justification for its proposal from what it referred to as "very positive" recent experiences with market-oriented rule changes. Further, given the dynamic state of cellular technologies, the FCC deemed intervention in cellular standards to be "premature," and instead suggested that market competition would be the best way to achieve its primary goal: the development of new technologies that would use the existing spectrum more efficiently.[60]

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[59] *Notice of Proposed Rule Making*, Gen. Docket 87-390, 2 FCC Rcd 6244 (1987), 1 [hereinafter *Notice of Proposed Rule Making*, Docket 87-390]. The allocated frequencies were in the 824-849/869-894 MHz frequency bands.

[60] *Notice of Proposed Rule Making*, Docket 87-390, 2. See also *Report and Order*, Gen. Dockets 84-1231, 84-1233 and 84-1234, 61 RR 2d 165 (1986), which allocated 10 MHz of spectrum for cellular service expansion, and noted that future needs demanded the development of spectrum-efficient cellular technologies. For an enunciation of "general policy guidelines [the FCC] would follow in considering the deregulation of technical standards," see *Report and Order*, Gen. Docket 83-114, 99 FCC 2d 903, 910-911 (1984).

Most responses to the FCC's proposal supported the greater technical flexibility for wireless firms.[61] One of the central issues that emerged from these comments was controversy over familiar questions: should the FCC leave firms in the cellular industry to choose their own network standards and technologies? Or should it extend its earlier practice of mandating cellular standards?

In their comments to the FCC, AT&T's lawyers made a particularly strong case for market standards: the choice of technology should be left to the service provider. Other major network operators, including McCaw, Ameritech, and SBC supported AT&T on this point.[62] The main concern expressed in these comments was that immediate market opportunities would be delayed if service providers had to wait until either the FCC or an industry body created standards. Mandated standards—either from the FCC or from an industry committee—would invite further delay, and could also, in AT&T's view, "deter innovation and stifle competition."[63] AT&T preferred an alternative: service providers could use whatever technologies they desired, the FCC would refrain from mandates, and when the standards committee completed its work, network operators and equipment manufacturers could take those standards into account. Implicit—yet unstated—in AT&T's comments was the recognition that their preferred

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[61] The exception to this support came from firms in the paging industry, which pleaded en masse for the FCC to protect it from competition. Many reply comments—including McCaw's—blasted the paging industry's appeals; see section II.B. entitled "The Comments Opposing Flexible Cellular Policies Generally Reflect the Parochial Interests Of Their Authors," in "Reply Comments of McCaw Cellular Communications, Inc." Gen. Docket 87-390 (March 18, 1988), 7-14.
[62] "Reply Comments of American Telephone and Telegraphy Company," Gen. Docket 87-390 (March 18, 1988), 5.
[63] "Reply Comments of AT&T," i. In its *Report and Order*, the FCC noted that Nortel and International Mobile Machines, two manufacturing firms, supported this approach. See *Report and Order*, Gen. Docket 87-390, 25 FCC Rcd. 3d 7033 (1988), 7-8.

"market-oriented" approach would give large and well-financed companies (such as AT&T) the opportunity to buy up additional spectrum and consolidate their position in the industry. Of course, they could also participate actively within the industry committees that would eventually generate a voluntary consensus standard.

Several firms, including General Electric, Bell Atlantic, PacTel Cellular, and Ericsson, submitted comments that took the opposite perspective and urged the FCC to mandate a cellular standard. Of these comments, Ericsson's were the most compelling. By this point in 1988, Ericsson's engineers had participated in the development of equipment for several different cellular standards. In their comments to the FCC, Ericsson's lawyers pointed out that its "breadth of experience"—including the successful Nordic analog system and the ongoing GSM digital system—made it "uniquely qualified" to comment on the present proceeding.[64] The high costs of incompatible standards, Ericsson's lawyers argued, would harm the infant industry by limiting roaming capabilities and requiring higher expenditures for research and development. Only uniform standards would ensure compatibility and therefore stimulate the earliest possible development of the American digital cellular industry. Such development, from Ericsson's point of view, could not emerge solely from the "operation of the marketplace." Ultimately, Ericsson recommended that the industry develop its own standards through existing technical bodies, and that the FCC codify those standards into *de jure* standards. To achieve this goal, Ericsson encouraged the FCC to take part as an

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[64] These standards included the Nordic analog standard (NMT), the American analog standard (AMPS), the British analog standard (TACS), and GSM. "Comments of Ericsson North America Inc.," Gen. Docket 87-390 (January 15, 1988), 2-3.

"active participant" in "the context of a standards setting organization which includes cellular service providers, the various equipment manufacturers, and relevant trade groups."[65]

Despite the split in the industry between companies that opposed mandated standards and those that supported mandates, firms on both sides of the divide agreed on that two industry groups should play key roles in the development of industry standards. The first group was the Electronic Industries Association (EIA), a technical body that the American National Standards Institute recognized as an accredited standards-setting body.[66] Through its Cellular and Common Radio section, EIA oversaw the specification of the analog cellular standard that the FCC had adopted as a *de jure* standard in 1982. In early 1988, the EIA created a new subcommittee to work on a new digital cellular standard. By virtue of the broad participation of cellular operators and manufacturers, the EIA argued that its committees were "in an excellent position to yield the optimal technical solution" and thus "contribute substantially" to the FCC's political and technological objectives.[67]

The second industry group, the Cellular Telecommunications Industry Association (CTIA), was a trade association and an industry advocate for policy, economic, legal, and technical issues that faced the cellular industry. Its membership

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65 "Comments of Ericsson," ii-iii, 10-11, 14, 15.
66 See Sophie J. Chumas, ed., *Directory of United States Standardization Activities* (Washington, DC: U. S. Department of Commerce National Bureau of Standards, 1975), 76. On the Radio Manufacturers Association and the politics of setting standards, see Slotten, *Radio and Television Regulation*, 81-92.
67 "Reply Comments of the Cellular and Common Carrier Radio Section of the Electronic Industries Association," Gen. Docket 87-390 (March 18, 1988), 2-3.

included approximately 90 percent of all American cellular network operators (49 firms) as well as many other manufacturing and support firms in the industry.[68] As a complement to the technical role of the standards-setting committees in the EIA, the CTIA was created in 1984 as a forum for the fragmented industry to coordinate and promote their products. In its comments to the FCC, the CTIA endorsed the standardization work of the EIA committee, and announced its own committee to continue to evaluate new cellular technologies. The combined message from the EIA and CTIA was clear: the industry had its own mechanisms and incentives to accommodate future change on a coordinated, industry-wide basis, and there was no need for the FCC to intervene.[69] In the realm of standards, industry "self-governance" had worked well in the past; there was no reason for the FCC to intrude into this domain.

The FCC, having found sufficient support for its preferred course of action, ruled in December 1988 to permit "greater freedom" to cellular carriers. It explicitly refused to set mandates or to intervene in the standards process, based on the belief that "industry is in a far better position to evaluate the technical advantages and disadvantages of the various cellular technologies and develop approaches to compatibility." Further, the FCC's ruling promised that it planned "to monitor the progress of the industry Committee."[70] Significantly, it also flatly denied a request to open a new proceeding on digital standards, leaving little doubt that the future of the American digital cellular industry was in the hands of the industry itself.

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[68] Garrard, *Cellular Communications*, 42; and "Comments of the Cellular Telecommunications Industry Association," Gen. Docket 87-390 (January 15, 1988), 1-2.
[69] CTIA, "Comments," 10-11.
[70] *Report and Order*, Gen. Docket 87-390, 8.

By the time the FCC issued its ruling in December 1988, the industry was off to a running start: members of the cellular industry association had been debating the technological and strategic merits of various digital cellular technologies since January. In the meantime, the EIA had passed all of its existing telecommunications projects to a new group called Telecommunications Industry Association (TIA).[71] The TIA, like the EIA before it, was an accredited standards development organization, which meant that it adhered to the basic tenets of the consensus process—even representation of producers and consumers, due process, rights of appeal, and open membership—that had first been articulated in Paul Gough Agnew's era in the 1920s. Beginning in January 1989, the TIA began work on the technical specifications of the technology chosen by the CTIA, and published a first draft of the resulting standard by mid-1990.[72] Cellular networks based on the new standard, which was commonly known as Time Division Multiple Access (or TDMA), were in operation by 1992, only one year after the first GSM networks were established in Europe.[73]

Even though the American standard arrived only a year later than the European standard, the immediate market success of the respective standards had already been determined by the cooperation (in Europe) and confusion (in the United States) that had taken place over the preceding ten years. The regulatory certainty and widespread *a priori* commitments to building systems based on the European GSM standard translated

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[71] The Telecommunications Industry Association (TIA) was formed after a merger of United States Telecommunications Suppliers Association and the Information and Telecommunications Technologies Group of EIA. See http://www.tiaonline.org/about/overview.cfm.
[72] The standard was officially named IS-54, but is more commonly known by the underlying technology, Time Division Multiple Access, or TDMA.
[73] Garrard, *Cellular Communications*, 313-326.

into an overwhelming share of the global market. At the end of 1995, over 13 million people worldwide subscribed to GSM networks, where just over 2 million subscribed to TDMA networks. This trend of GSM dominance would continue as millions of consumers moved from their analog service to digital service, and millions—and eventually billions—more became new subscribers.

5.3.3 The Wisdom of Restraint and the Emergence of CDMA

As it considered its role in the creation of digital cellular networks, regulators at the FCC were not particularly concerned with the type of diplomatic questions that motivated the GSM process in Europe. Nor did they pay much attention to the position of American firms in the global market for cellular standards. Instead, they were preoccupied with the question that had vexed the agency throughout its entire history: how to make more efficient use of scarce spectrum?

One solution arrived more quickly than most observers anticipated. In 1989, a San Diego start-up firm, Qualcomm, began to promote a new cellular transmission technology, Code Division Multiple Access (CDMA), to the cellular industry. CDMA was based on spread-spectrum technology that, like so many other American innovations after World War II, had its origins in military research and was developed during the Cold War by defense contractors. Some of these contractors created Qualcomm in 1985, hired a team of physicists and engineers who were veterans of the Cold War military-industrial-academic complex, and developed commercial applications of spread-spectrum technology. By gathering a team that had decades of experience with mobile communications systems, most notably for the military and the trucking industry, Qualcomm instantly possessed substantial organizational and technological capabilities in research and development, as well as an impressive portfolio of patents for spread-spectrum technologies. It was, in short, ideally positioned to play a major role in the cellular industry.[74]

In 1989 and 1990, the cellular industry was in the final stages of specifying a consensus standard that was designed around TDMA technology. Undeterred, Qualcomm executives began a campaign to gather allies in the cellular industry and convince the industry standards bodies to develop a second standard based on CDMA. On paper, CDMA's advantages were overwhelming: for manufacturers and network operators, it promised at least ten times greater capacity than current analog networks, with better security and fewer required towers. For consumers, CDMA networks offered better voice quality, cleaner connections, and longer lives for handset batteries.[75]

Technical merit, by itself, is rarely sufficient to drive the adoption of a new, disruptive technology. In practice, Qualcomm succeeded with CDMA through a sustained marketing campaign to promote CDMA's technical features and to build alliances with network operators and equipment manufacturers. Qualcomm founder and chief executive Irwin Jacobs publicized CDMA at industry conferences and described its

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[74] For a celebratory history of Qualcomm, see Dave Mock, *The Qualcomm Equation: How a Fledgling Telecom Company Forged a New Path to Big Profits and Market* (New York: AMACOM, 2005).
[75] Mock, *The Qualcomm Equation*, 73-75.

features in a journal article in 1990.[76] Technical demonstrations backed up the hype: a CDMA trial in San Diego in late 1989 and another in Manhattan in February 1990 generated substantial financial commitments from leading cellular firms (including AT&T, NYNEX Mobile, Ameritech Mobile Communications, Motorola, and PacTel Cellular) to support the creation of commercial CDMA systems within two years.[77] In June 1992, the CTIA agreed to standardize Qualcomm's technology; by 1994, this work was complete and the United States had two industry consensus cellular standards.[78]

The chaotic condition of the American cellular industry in the late 1980s soon gave way to consolidation and rapid growth. By the late 1990s, the American market had grown substantially—from 7.5 domestic subscribers in December 1991 to over 100 million by July, 2000.[79] CDMA growth was modest in the United States, but extensive in Asian countries such as South Korea and China that had not committed to using the European GSM standard. South Korea was a particularly interesting case of the global dimensions of this standards war: in July 1993, the Korean government adopted CDMA as a national standard, and Korean firms such as Samsung, LG, and Hyundai became the

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[76] Klein S. Gilhousen, Irwin M. Jacobs, Roberto Padovani, and Lindsay A. Weaver, Jr., "Increased Capacity Using CDMA for Mobile Satellite Communication," *IEEE Journal on Selected Areas in Communications* 8 (1990): 503-514.

[77] Galambos and Abrahamson, *Anytime, Anywhere*, 176-181; Mock, *The Qualcomm Equation*, 75-81; Garrard, *Cellular Communications*, 317-319.

[78] Mock, *The Qualcomm Equation*, 102-104; Garrard, *Cellular Communications*, 317-326; and Joel West, "Qualcomm's Standards Strategy," *Proceedings of the 2nd IEEE Conference on Standardization and Innovation in Information Technology* (Boulder, CO: International Center for Standards Research, 2001), 62-76.

[79] Garrard, *Cellular Communications*, 43; and Cellular Telecommunications and Internet Association, "Industry Celebrates 100 Million Wireless Customers," July 26, 2000. http://files.ctia.org/pdf/Wireless_Quick_Facts_October_05.pdf

first CDMA licensees, which gave them a head start in handset manufacturing.[80] It may still be too soon to assess the long-term consequences of the American "marketplace" approach, but the strong medium-term performance of Qualcomm indicates that the FCC was right to anticipate plenty of room in domestic and global markets for more than one cellular network standard.[81]

The rapid expansion of the global cellular market, driven by sinking costs of cellular telephones and service as well as insatiable consumer demand, meant that the global market for cellular standards did not "tip" toward any one standard. Further, international adoption of the more efficient CDMA technology indicated that American firms possessed the capabilities to catch up with the European first-mover advantage, particularly as global cellular networks began to migrate to a third generation of digital broadband networks—a process that is still unfolding. The fact that all third-generation cellular standards, even in Europe, are based on CDMA technology indicates that the fundamental American tradeoff, one that sacrificed short-term stability for long-term innovation, successfully sowed the seeds for the widespread deployment of more efficient cellular technologies.[82]

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[80] Garrard, *Cellular Communications*, 327-8, 390.
[81] Don Clark, "Qualcomm Profit Jumps on Demand for 3G Cellphones," *The Wall Street Journal* (Eastern edition), November 3, 2005, B.4.
[82] Bauer, et al, "Transition Paths to Next-Generation Wireless Services"; Philip J. Weiser, "The Internet, Innovation, and Intellectual Property Policy," *Columbia Law Review* 103 (2003), 586.

Date	GSM (Europe)	CDMA (US)	TDMA (US)	GSM/CDMA ratio
12/1995	13,034,000	9,000	2,055,000	1448:1
12/1996	32,878,500	987,000	2,700,000	33:1
12/1997	71,359,000	5,980,000	6,900,000	11:1
12/1998	138,107,240	22,771,750	17,729,410	6:1
11/1999	200,000,000	45,000,000	n/a	4.4:1
6/2000	331,500,000	67,000,000	n/a	5:1
12/2000	455,100,000	82,200,000	65,200,000	5.5:1
12/2001	627,700,000	113,000,000	93,300,000	5.5:1
12/2002	787,500,000	143,000,000	109,200,000	5.5:1

Table 5.2: Worldwide digital cellular subscribers by standard, 1995-2002. Third-generation standards are not considered. GSM is the European standard; CDMA and TDMA are the two leading American standards. Sources: Cellular Online; GSM Association; CDMA Development Group.[83]

The global competition between GSM, CDMA, and other standards—as well as the competition between firms who seek to earn royalties by embedding their patented technology within standards—has also created a new generation of legal problems. Examples of these new problems may be found in the recent escalation of litigation over aspects of the GSM and CDMA standards between several industry leaders, including Nokia and Qualcomm. Qualcomm's aggressive tactics within standards committees have invited allegations of criminally anticompetitive behavior.[84] These lawsuits underline the strategic and legal importance of patents in the standard-setting process—a topic I explore in depth in the next chapter. The lawsuits also illustrate the continued importance of regulation in an era of "deregulation": even if regulators do not directly

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[83] http://www.cellular.co.za/stats/statistics_global_by_standard.htm; http://www.gsmworld.com/news/statistics/index.shtml; http://www.cdg.org/index.asp.

[84] Antitrust and patent litigation are two common ways to attack competitors through regulation. See for example Don Clark, "Qualcomm Adds to Patent Row; Suit Filed Against Nokia Is Latest in Legal Tanglings Over Cellphone Technology," *The Wall Street Journal* (Eastern edition), November 8, 2005, B.4; and Don Clark, "Suit by Broadcom Says Qualcomm Seeks a Monopoly," *The Wall Street Journal* (Eastern edition), July 6, 2005, B.3.

mandate standards or control the standards process, other branches of government are required to respond to private disputes over patents, contracts, and allegations of anticompetitive behavior.

5.4 Conclusions

The history of digital cellular standards in Europe and the United States shows how different ideological and political convictions shaped the same basic technology in different ways, and ultimately led to the creation of three different standards. There can be no dispute that the GSM process was a major bureaucratic, technological, and economic triumph for Europe. The overarching ideological motivation behind GSM was European integration; this ideology, translated into concrete political and economic goals, called for a single pan-European standard that could generate economies of scale for manufacturers and roaming capabilities for consumers. European telecommunications professionals did not want to repeat past mistakes. An active and decisive government role in this centrally planned standards process not only created first mover advantages for European firms (such as Nokia and Ericsson) competing in global equipment markets; it also provided a symbol for the economic strength of the new, unified Europe.[85]

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[85] GSM is probably the most successful instance of a recent trend in which European policymakers fostered inter-firm alliances to coordinate economic and technological aspects of European integration. For broader discussions, see Giovanni Dosi and Luigi Marengo, "The co-evolution of technological knowledge and corporate organizations"; Patrick Llerena and Mireille Matt, "Inter-organizational collaboration: the theories and their policy implications"; and Antoine Bureth, Sandrine Wolff, and Antonello Zanfei, "Cooperative learning and the evolution of inter-firm agreements in the European electronics industry," all in Alfonso Gambardella and Franco Malerba, eds., *The Organization of Economic Innovation in Europe* (New York: Cambridge University Press, 1999).

Different ideological convictions drove the American approach to digital cellular standards. American regulators sought to create a new, competitive industry structure to replace institutional forms of coordination from the past—including monopoly control and government control—that had fallen out of favor. The FCC translated these ideological convictions into political goals that could be achieved in the technical realm of spectrum policy, where regulators aimed to promote experiments with new technologies that could utilize scarce spectrum in a more efficient manner. Ideology and politics meant that American firms fell far behind their European counterparts in global markets for cellular standards, but the FCC's *laissez faire* regime soon generated the very sort of technology they had envisioned, an indication of the continued vitality of American technological capabilities in an era of global competition.

Scholars who analyzed the European approach to GSM misunderstood the ideological, political, and technological nuances of the American cellular industry. As they celebrated the GSM "success story," they dismissed the American cellular industry as "non-cooperative" or as lacking in the necessary institutions to guide the standards-setting process.[86] Their error was to base their judgment of the American policy on the unique ideological and political conditions that prevailed in Europe, and to assume that

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[86] Gandal, Salant, and Waverman, "Standards in Wireless Telephone Networks."; Pelkmans, "The GSM Success Story," 447-449. King and West—perhaps because their article omitted any discussion of the FCC, the EIA/TIA, or the CTIA—concluded that the United States lacked "sufficient agency power at the institutional level to channel the disparate interests of a pluralistic group of self-interested competitors." John Leslie King and Joel West, "Ma Bell's Orphan: US Cellular Telephony, 1947-1996," *Telecommunications Policy* 26 (2002): 200.

governance can only occur through the exercise of government authority.[87] In other words, the "great failure" assessment was fundamentally ahistorical insofar as it failed to consider the constraints and choices of American regulators and industry professionals in their own unique context. When we situate the American decision within its proper historical context, and take the standardization process itself as the vantage point from which to view this history, we might reasonably conclude that the FCC's choice to allow the industry committees to set standards was, in fact, a wise—albeit initially costly—decision.

Despite the ideological and political differences in the standardization process that unfolded in Europe and the United States—and the technical differences in the standards they created—there were two striking similarities in the standard-setting institutions they depended upon. First, the order that had prevailed for most of the twentieth century, where national monopolies determined standards, no longer held. The tasks of defining new network architectures and new standards fell to committees of technical experts who reached decisions by consensus. Of course, powerful actors emerged within these committees, and consensus decisions were implemented and enforced in different ways in Europe and the United States. Moreover, the structure and constituency of specific committees changed in response to changing regulatory and technological conditions. For these committees to be successful—which they ultimately were, each according to their own objectives—they needed to remain flexible and adaptable to these changing conditions.

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[87] Walter Mattli and Tim Büthe, "Setting International Standards: Technological Rationality or Primacy of Power?", *World Politics* 56 (2003): 1-42.

Second, the standards committees in Europe and the United States succeeded because the major firms in the global industry participated in the standardization process. Their participation included the contribution of technological innovations—often covered by patents and facilitated by cross-licensing agreements—as well as *a priori* commitments to implement the standards produced by the committees. Regulators played an indirect yet vital role in this process by endorsing the participation (and in the United States, leadership) of private firms, and by defining clearer rules under which standards committees could lawfully operate.[88] They did so with an awareness, more acute in Europe than in the United States, that the standardization process had significant implications for their respective positions in a competitive global industry.

These two trends in the standardization process—the move from national monopolies to flexible consensus committees, and the participation of leading firms from a variety of nations—illustrate the new order that sustained the development of networks in the Third Industrial Revolution. The cellular industry's dependence on voluntary consensus standards is one example of a new liberalized and pluralistic regime that scholars have observed in standardization for electronics, telecommunications, and information technology.[89] In addition to the institutions mentioned above, the other major players in standardization for these technologies—including the Institute of

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[88] D. Linda Garcia, Bethany L. Leickly, and Scott Willey, "Public and Private Interests in Standards Setting: Conflict or Convergence," in Sherrie Bolin, ed., *The Standards Edge: Future Generation* (Ann Arbor: Sheridan Books, 2005), 117-139; and Roger B. Marks and Robert E. Hebner, "Government/Industry Interactions in the Global Standards System," in Sherrie Bolin, ed., *The Standards Edge: Dynamic Tension* (Ann Arbor: Sheridan Books, 2004), 103-114.

[89] Drake, "The Transformation of International Telecommunications Standardization"; and Paul A. David and Mark Shurmer, "Formal Standards-Setting for Global Telecommunications and Information Services," *Telecommunications Policy* 20 (1996): 789-815.

Electrical and Electronics Engineers, the Internet Engineering Task Force, and a variety of industry consortia such as the World Wide Web Consortium—also relied upon consensus-based procedures that differ little from the procedures developed in the American Engineering Standards Committee during the 1920s.[90]

As the new order in international telecommunications standardization emerged in the 1980s, no single firm possessed the technical or organizational capabilities to create an entire cellular system from the ground up. Instead, firms managed this complexity through "pure-play" strategies that focused on narrow market segments, such as manufacturing microchips, handsets, or network equipment, or operating cellular systems.[91] Each of these components worked within the larger system by conforming to predetermined interface standards, such as GSM or CDMA. In the absence of monopoly control, the institutional grounding for this style of "alliance capitalism" occured in standards setting committees—a clear demonstration of a new era of modularity in the technological and organizational structures of the global telecommunications industry.[92]

Standards committees, in turn, struggled to assume the coordinating role that had once been the domain of national monopolies. The overarching trend of institutional experimentation to coordinate modular technologies and organizations intensified during

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[90] Charles Vincent and L. Jean Camp, "Looking to the Internet for Models of Governance," *Ethics and Information Technology* 6 (2004): 161-173.

[91] Galambos, "Recasting the Organizational Synthesis," 14-19; and Galambos and Abrahamson, *Anytime, Anywhere*, 251-261.

[92] Two seminal analyses of these types of modular industry structures are Richard N. Langlois, "Modularity in Technology and Organization," *Journal of Economic Behavior & Organization* 49 (2002): 19-37; and Stefano Brusoni and Andrea Prencipe, "Unpacking the Black Box of Modularity: Technologies, Products and Organizations," *Industrial and Corporate Change* 10 (2001): 179-205. The term "alliance capitalism" comes from Galambos and Abrahamson, who called the wireless industry a "key example of the new era of alliance capitalism." Galambos and Abrahamson, *Anytime, Anywhere*, 255.

subsequent efforts in the 1990s and early 2000s to create standards for third-generation cellular networks, or "mobile broadband" networks that represented the convergence of the Internet and the telephone. The creation of standards for third-generation networks proceeded in new, tightly focused forums—none of them supported by government mandates—including the World Wide Web Consortium, the Open Mobile Alliance, the Open Mobile Terminal Platform, the 3rd Generation Partnership Project (a GSM offspring), and the 3rd Generation Partnership Project 2 (a CDMA offspring). Each of these committees continued to experiment with different features of the consensus process, including the scope of participation, the tension between moving quickly (on the one hand) and obtaining a widespread consensus (on the other), and terms under which key patents could be licensed. As they defined and honed their institutional structures and procedures, they also competed against one another to exercise jurisdiction over the next generation of standards. The next chapter examines one of these bodies—the World Wide Web Consortium—and the tradeoffs that its designers made as they sought to maintain their standing in the dynamic political economy of consensus standardization.

Chapter 6: Democracy, Legitimacy, and Patents: Setting Standards for the World Wide Web, 1990-2003

6.1 Introduction

> You're about to throw away the geek community's respect for the W3C. And we're the people who write software… Don't do this. It's suicidally stupid. We will bypass you. We will surpass you. Will [sic] will make fun of you. And eventually, we will completely ignore you.
>
> - Rob Landley[1]

The World Wide Web, like the Internet and cellular telephones, was one of the seminal network innovations that sustained the Third Industrial Revolution. The development of Web standards illustrates a broader phenomenon that occurred during the 1990s in which a new organizational form, industry consortia, emerged as a common site of consensus standardization. The history of Web standards and standard-setting institutions sheds light on the promise and perils inherent in this new organizational form.

Tim Berners-Lee wrote the first Web browser and server software in the late 1980s and early 1990s. Throughout the 1990s, he took repeated steps to ensure that the underlying code remained freely available to anyone and not subject to proprietary claims or licensing restrictions. This strategy made Berners-Lee a champion to open source programmers, a group of individuals who believed that software code is knowledge that should be shared freely and publicly. It was also the strategy that made the Web an exciting new tool for social and commercial applications, and a symbol of a new era of global communication.

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[1] Rob Landley, "Proprietary standards," September 30, 2001, http://lists.w3.org/Archives/Public/www-patentpolicy-comment/2001Sep/0305.

In the autumn of 2001, however, the World Wide Web Consortium (W3C)—the standards-setting organization created by Berners-Lee to preserve the openness and universality of the Web—nearly turned its back on this open and free character of Web standards. A proposal for a new patent policy, first released on August 16, recommended that the W3C incorporate royalty-generating patents into Web standards. Chaos ensued. The W3C was besieged by thousands of angry protests, almost universally in support of open source software and against patents in W3C standards. Faced with the potentially fatal consequences of an open source mutiny, the W3C made changes in its procedure that took dissenting views into account. Based in large part on this procedural change, the W3C quickly reversed course and, in May 2003, formally adopted a royalty-free patent policy.

The purpose of this chapter is to examine this flashpoint, and to situate it within a longer and broader historical context. Over the past ten to twenty years, a growing number of economists, lawyers, and management scholars have generated a large body of quantitative, legal, and prescriptive analyses of patents in the standardization process.[2] However, amidst these efforts to isolate the precise economic and strategic effects of patent licensing and disclosure, this literature risks losing sight of how patents and patent policies are linked to fundamental questions of power in a technological society. The

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[2] Benjamin Chiao, Josh Lerner, and Jean Tirole, "The Rules of Standard Setting Organizations: An Empirical Analysis," CEPR Discussion Papers 6141 (February, 2007); Mark A. Lemley, "Intellectual Property Rights and Standard-Setting Organizations," *California Law Review* 90 (2002): 1889-1980; Timothy S. Simcoe, "Open Standards and Intellectual Property Rights," in Henry Chesbrough, Wim Vanhaverbeke, and Joel West, eds., *Open Innovation: Researching a New Paradigm* (New York: Oxford University Press, 2006), and Andrew S. Updegrove, "The Essential Guide to Standard Setting Organizations and Standards," available from http://www.consortiuminfo.org/essentialguide.

epigraph, a quote from open source programmer Rob Landley, captures the horrified and defiant reaction that the W3C's proposal elicited from the open source community. Such visceral and emotional reactions are familiar components of the consensus-building process, but they are often forgotten or written out of the story when told from an economic or technical point of view.

The W3C's patent policy is particularly compelling because it revealed a clash of values that defined the terms on which standards could be created and implemented. On one side were programmers and engineers who believed that the values of open source should be the bedrock of the W3C. On the other side were representatives of corporations that paid $50,000 every year to participate in the W3C, and believed that the patent system rightly rewarded inventors for their investments in research and development. The W3C, as it stood at the intersection of these two opposing worldviews, needed to resolve this fundamental conflict in order to maintain its standing as a legitimate forum for creating standards for the Web.

The W3C's problems, in this light, were not exclusively technical, economic, or legal, but also political. How could the W3C convince its constituents that it was a legitimate forum for creating the rules—the technical standards—to which they should adhere? This question can shed light on a broader problem that Sheila Jasanoff identified, namely, "the possibility of democratic rule in societies where technically trained elites perform so much of the everyday work of governance."[3]

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[3] Sheila Jasanoff, "Technology as a Site and Object of Politics," in Robert E. Goodin and Charles Tilly, eds., *The Oxford Handbook of Contextual Political Analysis* (New York: Oxford University Press, 2006), 745-763.

Technically trained elites work within private and public institutions that seek to establish the legitimacy of their decisions. The process by which an institution gains legitimacy in scientific and technical settings can be complex, even within the context of representative governing bodies whose rules are backed by the force of law.[4] However, the voluntary character of Web and Internet standards create an additional dimension of complexity. By definition, voluntary consensus standards bodies lack any inherent authority to enforce the use of their standards. Instead, authority is conferred through legitimacy, which arises through a social process constructed over time, in the face of competing jurisdictional efforts.[5]

This social construction of authority and legitimacy has two interrelated dimensions, one cultural, one economic. Due to his position as the Web's inventor and champion, Berners-Lee's status was what one observer in 1998 called "a moral authority that is the closest thing the Internet has to law."[6] When he created the W3C in 1994, Berners-Lee consciously began a social experiment, one that would attempt to institutionalize his moral authority and place the founding values of the Web in the care of the broader community of Web developers. During the patent policy dispute in 2001, the charged rhetoric of the open source community suggested that this social experiment

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[4] See for example Sheila Jasanoff, "Science, Politics, and the Renegotiation of Expertise at EPA," *Osiris* 7, 2nd Series (1992): 194-217; and Jody Freeman and Laura I. Langbein, "Regulatory Negotiation and the Legitimacy Benefit," *NYU Environmental Law Journal* 9 (2000): 60-138.
[5] See for example Raymund Werle and Eric J. Iversen, "Promoting Legitimacy in Technical Standardization," *Science, Technology & Innovation Studies* 2 (2006): 19-39; A. Michael Froomkin, "Habermas@Discourse.Net: Toward a Critical Theory of Cyberspace," *Harvard Law Review* 116 (2003): 751-873; and Andrew Feenberg, *Transforming Technology: A Critical Theory Revisited* (New York: Oxford University Press, 2002).
[6] Simson L. Garfinkel, "The Web's Unelected Government," *Technology Review* 101 (November/December, 1998), 42.

was placing the open and free Web—as well as the legitimacy of the W3C—in great peril.

Landley's threat to "bypass, surpass, and ignore" the W3C reminds us of the economic issues that co-exist with the cultural. The ultimate success or failure of a voluntary consensus standard is determined by market demand and acceptance. Within this market for standards, open source advocates—and, indeed, any participant in the process—can choose from three options: loyalty, voice, or exit.[7] Viewed from this perspective, the W3C's patent policy marked a strategic turning point where the group could either maintain or squander its leading position in the market for Web standards.

When faced with an open source revolt over its proposed policy to incorporate patents into its standards, the W3C demonstrated its legitimacy by reforming and democratizing its rule making process, which in turn confirmed its authority to set standards for the free and open Web. For scholars and practitioners alike, this episode is significant because it advanced a sharp critique of closed and proprietary standards, and demonstrated the practical and ideological merits of open standards and an open process. As such, it reinforces a major theme developed in this dissertation—that standardization is simultaneously technological, economic, cultural, and political.

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[7] Albert O. Hirschman, *Exit, Voice, and Loyalty: Responses to Decline in Firms, Organizations, and States* (Cambridge: Harvard University Press, 1970).

6.2 The Political Economy of Consortia

Beginning in 1980, American firms in a variety of high-technology industries began to participate in research consortia. Research consortia, blessed by the financial and legal support of the federal government, existed to distribute the costs of research and development in order to create technological and economic advantages as they competed in global markets against Japanese and European firms. One of the most prominent of these consortia was SEMATECH, a federally-funded effort created in 1987 to catch up with Japanese dominance in global markets for semiconductor memory chips. As it developed in the late 1980s and early 1990s, SEMATECH took on functions that had traditionally been filled by trade associations, including the distribution of information and "best practices," the establishment of technical standards, and the coordination of basic and applied research and development.[8]

By the late 1980s and early 1990s, competing firms in the telecommunications and information technology industries also began to form consortia to coordinate their products and accelerate market development. Unlike SEMATECH, many of these consortia focused exclusively on the establishment of technical standards and marketing strategies for technologies such as the UNIX operating system and automated teller machines in the banking industry, and did not attempt to dictate the research and

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[8] Congress of the United States, *The Benefits and Risks of Federal Funding for Sematech* (Washington, DC: Congressional Budget Office, 1997); Peter Grindley, David C. Mowery, and Brian Silverman, "SEMATECH and Collaborative Research: Lessons in the Design of High-Technology Consortia," *Journal of Policy Analysis and Management* 13 (1994): 723-758.

development agendas of their member firms.[9] Another difference between these consortia and SEMATECH was the absence of direct financial support from the federal government. Instead, federal support for information technology consortia occurred through indirect policy measures, such as the National Cooperative Research Act of 1984 and the National Cooperative Research and Production Act of 1993, that sanctioned cooperative standard-setting so long as participants did not fix prices or engage in other illegal forms of collusive behavior.[10]

During the 1980s and 1990s, firms in the information technology industry responded to this favorable regulatory climate by creating and joining hundreds of consortia.[11] These consortia were both critiques of and complements to existing standard-setting organizations, such as the American National Standards Institute (ANSI) and the International Organization for Standardization (ISO), that followed extensive rules to ensure that all interested parties could have a voice in the standardization process. The new consortia adopted many features of the consensus process utilized within ANSI and ISO, such as a reliance on negotiations within a subcommittee structure. However, the consortia rejected the rules—first developed in Paul Gough Agnew's era in the 1920s,

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[9] Steven C. Salop, "Deregulating Self-Regulated ATM Networks," *Economics of Innovation and New Technology* 1 (1988): 85-96; Garth Saloner, "The Economics of Computer Interface Standardization: the Case of UNIX," *Economics of Innovation and New Technology* 1 (1989): 135-156.

[10] Michelle K. Lee and Mavis K. Lee, "High Technology Consortia: A Panacea for America's Competitiveness Problems?" *Berkeley Technology Law Journal* 6 (1992): 335-372; Andrew Updegrove, "A Work in Progress: Government Support for Standard Setting in the United States, 1980-2004," *Consortium Standards Bulletin* 4 (2005).

[11] Some examples include the X/Open Consortium (created in 1984) to set standards for the Unix operating system; CableLabs (created in 1988); the Video Electronic Standards Association (created in 1989); and the Asynchronous Transfer Mode Forum (created in 1991). For hundreds of additional examples, see Andrew Updegrove, "The Consortiuminfo.org Standard Setting Organization and Standards List," http://www.consortiuminfo.org/links/.

and existing in a modern form in ANSI and ISO—that required an equal balance of consumers and producers within each committee. Instead of emphasizing inclusiveness and fairness in a strictly technical process, consortia were more attentive to speed and marketing considerations. In most cases, consortia did not override or compete with consensus standards, but instead focused on narrow market niches and built upon existing standards.[12]

One example of this process was visible in the creation of wireless Internet standards. In 1990, the Institute of Electrical and Electronics Engineers (IEEE) created a committee to develop standards for wireless Ethernet local area networks. The committee completed the first of these standards—known as IEEE 802.11—in 1997. In 1999, several firms that had contributed to the development of the 802.11 standards created the Wireless Ethernet Compatibility Alliance. This consortium, which eventually grew to include hundreds of firms, devised a set of tests to verify that vendor products conformed to the standard, and created a logo and trademark—"Wi-Fi"—that could be used by products that complied with the tests. Wi-Fi soon became wildly successful, available in coffee shops, restaurants, and airports, as well as a standard feature in desktop and laptop computers and home routers. In sum, Wi-Fi was a textbook example

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12 Richard Hawkins, "The Rise of Consortia in the Information and Communication Technology Industries: Emerging Implications for Policy," *Telecommunications Policy* 23 (1999): 159-173; Martin Weiss and Carl F. Cargill, "Consortia in the Standards Development Process," *Journal of the American Society for Information Science* 43 (1992): 559-565; and Carl F. Cargill, "Consortia Standards: Towards a Re-Definition of a Voluntary Consensus Standards Organization," Subcommittee on Environment, Technology, and Standards, Committee on Science, United States House of Representatives, June 28, 2001.

of a successful marketing strategy built around a consensus standard and advanced through the promotional efforts of an industry consortium.

However, significant practical problems emerged as consortia proliferated and became a common feature of the information technology industries in the 1990s. First, firms had to devote significant resources to consortia membership and participation. Membership fees ranged anywhere from $5,000 to $60,000, and travel, research, and legal costs presented an additional expense. Since large firms such as Sun, Microsoft, and IBM participated in several consortia, the overall expense for a single firm could quickly reach several millions of dollars—figures that standards engineers struggled to justify to executives who wondered how the investment would pay off. Second, because of the *ad hoc* process in which consortia were created, there existed tremendous potential for consortia to work at cross-purposes, or even produce conflicting or competing specifications. This created a situation reminiscent of the uncoordinated development of standards for screw threads in the early 1900s (discussed in Chapter Two), where no central body coordinated several overlapping committee initiatives.

A third problem with consortia was that their *ad hoc* and uncoordinated character spawned rules and policies that varied widely from one consortium to another. Some consortia adopted strict policies governing the use of intellectual property and patents within their committees; others failed to define clear rules. This variety forced engineers to consult intellectual property lawyers to clarify their contribution to standards projects—thus adding further costs to the process. Finally, because consortia standards did not (by design) adhere to the procedures that ANSI established for balance, openness, and due process, many observers were skeptical of consortia standards, and viewed them simply as attempts by large firms to control the market that were unaccountable to regulators or to the general public. In some cases, this perceived illegitimacy was not a problem if consortia standards could take the market by brute force. In other cases—particularly in the realm of government procurement—consortia standards did not conform with the government definition of a "standard," and hence could not be eligible to be included in lucrative government procurement contracts.[13]

In sum, although consortia presented a quicker alternative than existing institutions for firms that wanted to create standards, they also had the potential to introduce a new set of legal and practical problems into the standardization process. The creation of standards for the World Wide Web illustrates the various advantages and drawbacks of consortia standards in a specific historical setting.

6.3 The World Wide Web Consortium

Berners-Lee invented the Web when he worked as a software engineer at CERN, a European physics research laboratory located in Geneva. Berners-Lee, having observed how scientists communicated and shared ideas in a non-hierarchical, networked fashion, decided that CERN needed a system for cataloging information that could mimic these physical interactions. He first developed a proposal for a hypertext-based system that he called the WorldWideWeb in 1989, and by the end of 1990 he had set up the first Web

[13] Hawkins, "The Rise of Consortia"; Cargill, "Consortia Standards." Federal rules that govern the inclusion of standards in federal procurement practices are defined in "Federal Participation in the Development and Use of Voluntary Consensus Standards and in Conformity Assessment Activities," Office of Management and Budget (OMB) Circular A-119, Revised February 10, 1998.

server and created a program for browsing and editing hypertext pages. The technical foundations of his Web server and browser software included a language for rendering hypertext pages—the HyperText Markup Language, or HTML—and a protocol for sending hypertext documents over a network—the HyperText Transfer Protocol, or HTTP.[14]

The Web's initial growth was a direct consequence of Berners-Lee's open source strategy, which was guided by a mix of ideological and practical concerns. Berners-Lee's ideal for a collaborative approach to Web development was shaped by his background in science (he earned a physics undergraduate degree from Oxford in 1976) as well as Richard Stallman's crusade for free software. In a note circulated in a CERN computing newsletter, Berners-Lee wrote, "A source of much debate over recent years has been whether to write software in-house or buy it from commercial suppliers." He continued, "Now, a third alternative is becoming significant in what some see as a revolution in software supply. Richard Stallman's almost religious campaign for usable free software led to the creation of the Free Software Foundation and GNU General Public License." In addition to the idealism contained in Stallman's "third alternative," Berners-Lee was particularly attracted by the scientific and academic characteristics of

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[14] This section draws primarily on three sources: Sources for this section: Tim Berners-Lee, *Weaving the Web: The Original Design and Ultimate Destiny of the World Wide Web by its Inventor* (San Francisco: HarperSanFrancisco, 1999); James Gillies and Robert Cailliau, *How the Web Was Born* (New York: Oxford University Press, 2000); and Dan Connolly, "A Little History of the World Wide Web," http://www.w3.org/History.html.

this approach toward software. "Just as we publish our physics for free," he wrote, "should we not in certain cases 'publish' our software?"[15]

The academic ideal for open Web standards also suited a bureaucratic imperative: it bypassed the costly and time-consuming licensing process. Accordingly, Berners-Lee posted a description of his browser and server software—as well as a link to their source code—on several mailing lists and online discussion groups in August 1991.

By early 1993, Berners-Lee's decision to release the browser's source code and ask others to collaborate and experiment with it—to "harness the geeks," as one account put it—had ignited a tremendous amount of interest in the Web. The number of Web servers and browsers grew by leaps and bounds. Berners-Lee later attributed this explosive growth to "a grassroots syndrome…. A very significant factor was that the software was all (what we now call) open source. It spread fast and could be improved fast—and it could be installed within government and large industry without having to go through a procurement process."[16]

This reference to the "procurement process" again reminds us of the bureaucratic choices that shaped the Web's early development as an open information platform. In addition to the intellectual merits of allowing free access to the Web's source code, there were also significant practical benefits to this approach. In early 1993, the fate of another online information system—the gopher system developed at the University of Minnesota—further confirmed Berners-Lee's skepticism of proprietary strategies for

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[15] Berners-Lee, quoted in Gillies and Cailliau, *How the Web Was Born*, 209.
[16] Gillies and Cailliau, *How the Web Was Born*, 215; Berners-Lee, quoted in Paul Festa, "Charting the Web's Next Transformation," *CNet News.com*, December 12, 2001, http://news.com.com/2102-1082-276939.html.

developing software. Gopher enjoyed a growing user base in the early 1990s. However, in February 1993, Minnesota announced a plan to charge users (apart from non-profit and academic users) an annual fee to use gopher. The plan backfired. According to Berners-Lee,

> This was an act of treason in the academic community and the Internet community. Even if the university never charged anyone a dime, the fact that the school had announced it was reserving the right to charge people for the use of the gopher protocols meant it had crossed the line. To use the technology was too risky. Industry dropped gopher like a hot potato.[17]

Berners-Lee immediately was pressed by members of the Internet community who wondered if CERN would follow in Minnesota's footsteps and require a license to use the Web. Berners-Lee was convinced that any licensing requirements would suffocate the Web—gopher provided the proof—and renewed his effort to have CERN place the Web technology in the public domain. In April 1993, CERN administrators agreed to a public domain release that Berners-Lee has frequently celebrated as a key moment that ensured the continued growth of the Web.[18]

During this same period in the early 1990s, several Web browsers—alterations of Berners-Lee's original design—were under development, including Midas, Erwise, Viola, and NCSA Mosaic. Berners-Lee recognized that, absent some sort of institutional effort to coordinate these divergent projects, the Web might balkanize into a variety of incompatible standards. As the Web's inventor, he was in a unique position to lead such an institutional initiative. However, CERN administrators were clearly not interested in

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[17] Berners-Lee, *Weaving the Web*, 73. See also Philip K. Frana, "Before the Web There Was Gopher," *IEEE Annals of the History of Computing* 26 (2004): 20-41.
[18] The CERN declaration is available from http://tenyears-www.web.cern.ch/tenyears-www/Welcome.html.

providing the resources to support the growth of the Web. One traditional option in such situations is to create a private company that can internalize transaction costs and provide greater managerial coordination.[19] Berners-Lee and his collaborator Robert Cailliau briefly contemplated this option, but quickly rejected it as too much of a financial risk and unlikely to prevent the balkanization of Web protocols.

Instead, Berners-Lee decided that an alternative institutional form—some sort of standardization body—would provide the best means for promoting the universality of the Web. One obvious venue was the Internet Engineering Task Force (IETF), a large and respected body that had developed the core Internet protocols. However, Berners-Lee was discouraged by his initial efforts (in 1992 and 1993) to set standards through the IETF process because it forced him to compromise important aspects of his vision for the Web. Moreover, although he was anxious to move quickly, progress in the IETF was slow, due in part to "endless philosophical rat holes down which technical conversations would disappear."[20]

In early 1994, a meeting with Michael Dertouzos, the Director of MIT's Laboratory for Computer Science, convinced Berners-Lee that he should start his own standards consortium. Dertouzos based his suggestion on a prior success: he had overseen the creation of the X-Consortium to coordinate the development of X-Window graphical system that, like the Web, was an academic project that grew and attracted

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[19] Ronald H. Coase, "The Nature of the Firm," *Economica*, New Series, 4 (1937): 386-405; Alfred D. Chandler, Jr., *The Visible Hand: The Managerial Revolution in American Business* (Cambridge: Belknap Press, 1977).

[20] Berners-Lee, *Weaving the Web*, 61-63; Tim Berners-Lee (1994), "Universal Resource Identifiers in WWW," RFC 1630, http://www.ietf.org/rfc/rfc1630.txt; Roy Rada, "Consensus Versus Speed," *Communications of the ACM* 38 (1995): 21-23.

interest from a broad and diverse community. After meeting with Dertouzos in February 1994, Berners-Lee agreed to move to MIT to be the Director of the World Wide Web Consortium (W3C).

For Berners-Lee, the W3C was the best option in his menu of institutional choices. Such a consortium would allow him to focus on the Web's proliferation from a "neutral viewpoint," as opposed to the competitive life of corporate employment. It would also allow Berners-Lee to keep a close eye on the Web's development, without forcing him to be a centralized point of authority or control. Instead, he thought that the Web should be "out of control," and thought that the W3C could function as a coordination mechanism, a middle ground between unilateral control and extreme decentralization. As he summarized in 1999,

> Starting a consortium, therefore, represented the best way for me to see the full span of the Web community as it spread into more and more areas. My decision not to turn the Web into my own commercial venture was not any great act of altruism or disdain for money, of which I would later be accused.[21]

Indeed, the W3C provided a way for Berners-Lee to leverage his status as the Web's inventor and stay at the heart of the action—hardly an altruistic or selfless gesture.

Berners-Lee envisioned that the W3C itself would be a type of social experiment. Although he preferred to start his own consortium, he borrowed heavily from the IETF's structure and process. The Internet's success as an information platform was due to the fact that its standards were open and freely available for anyone to implement or improve. In 1992, Dave Clark (another computer scientist at MIT's LCS), famously

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[21] Berners-Lee, *Weaving the Web*, 85, 89, 99.

summarized the Internet's philosophy of standardization: "We reject: kings, presidents and voting. We believe in: rough consensus and running code." This model of open participation, with its rapid and informal specification process, appealed to Berners-Lee. He did not, however, share the IETF's wholesale rejection of "kings"; he simply thought that kings should preside over a technological style of parliamentary democracy. As he remarked in 1998, "A lot of people, including me, believe in the 'no kings' maxim at heart…. The wise king creates a parliament and civil service as soon as he can, and gets out of the loop."[22] Finally, Berners-Lee decided that the W3C should mimic the informal terminology that the IETF used to refer to its products:

> We wrestled over terms—whether the consortium should actually set a "standard" or stop just short of that by issuing a formal "recommendation." We chose the latter to indicate that getting "rough consensus and running code"—the Internet maxim for agreeing on a workable program and getting it out there to be tried—was the level at which we would work.[23]

Once the W3C was established, the major problems for Berners-Lee's vision came from the explosion of commercial interest in the Web—manifest most visibly in the "browser wars" between Netscape Navigator and Microsoft Internet Explorer. In 1999, Dertouzos wrote that Berners-Lee's "consistent aim was to ensure that the Web would move forward, flourish, and remain whole, despite the yanks and pulls of all the companies that seemed bent on controlling it."[24] Beyond the browser wars, the most

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[22] Berners-Lee, quoted in Garfinkel, "The Web's Unelected Government," 47. See also Andrew L. Russell, "'Rough Consensus and Running Code' and the Internet-OSI Standards War," *IEEE Annals of the History of Computing* 28 (July-September, 2006), 48-61.
[23] Berners-Lee, *Weaving the Web*, 98.
[24] Michael Dertouzos, forward to Berners-Lee, *Weaving the Web*, x.

significant threat to the unified development of the Web—patents—emerged in the late 1990s. "Software patents are new," Berners-Lee lamented in 1999.

> The Internet ethos in the seventies and eighties was one of sharing for the common good, and it would have been unthinkable for a player to ask for fees just for implementing a standard protocol such as HTTP. Now things are changing.[25]

Berners-Lee understood that open standards fueled the growth of the Web. He saw no reason to alter this founding value of the Web, and warned that he would continue to advocate keeping the Web open to the widest possible group of users: "If someone tries to monopolize the Web—by, for example, pushing a proprietary variation of network protocols—they're in for a fight."[26]

6.4 Patent Policy Working Group: October 1999 – May 2003

> Corporate IT strategists should think very carefully about committing to the use of features which will bind them into the control of any one company. The web has exploded because it is open. It has developed so rapidly because the creative forces of thousands of companies are building on the same platform. Binding oneself to one company means one is limiting one's future to the innovations that one company can provide.
>
> -Tim Berners-Lee, 1996[27]

For the first ten years of the Web's existence, tradition and Berners-Lee's personal feelings had prevented the use of proprietary code in Web standards. By 1999, however, the pressures of the dot-com economy—most visible in the heavily corporate

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[25] Berners-Lee, *Weaving the Web*, 197.
[26] Berners-Lee, *Weaving the Web*, 108.
[27] Tim Berners-Lee, "W3C and standards, 1996," http://www.w3.org/People/Berners-Lee/FAQ.html#standards.

Membership of the W3C as well as patent holders outside the W3C Membership—challenged this tradition.[28]

The first sign of trouble came in August 1997, when Sun Microsystems announced that they were awarded a patent that covered methods for making anchors, or hyperlinks within an individual webpage. A similar issue cropped up in February 1999, when Microsoft was awarded a patent that could have been applied to cover the W3C's Cascading Style Sheet standard, a method that made it simple for designers to use consistent formatting within and across a number of webpages. In both cases, the W3C and the patent holders moved quickly to ensure that the patents could be licensed on royalty-free terms.

However, this *ad hoc* means of resolving patent issues failed in 1999, when another W3C Member, a company called Intermind, claimed that they held a patent over methods used in a W3C's project, the Platform for Privacy Preferences (P3P). P3P was an attempt to solve a social problem through technological means. The social problem was that different websites had widely divergent policies for the use of personal information, such as names, passwords, credit card numbers, and demographic information. By the late 1990s, many websites were beginning to articulate the ways that they would use and share personal information, but it was a tremendous inconvenience for users who were concerned about the potential misuse of their personal information to read and review the privacy policies of each and every website they visited. P3P provided a standard way for users to express their privacy preferences, and could thus

[28] Anne Eisenberg, "What's Next: Legal Squabbles in Path of Internet," *The New York Times* (December 9, 1999), G14.

partially automate the time-consuming process of evaluating the diverse privacy policies on the Web.[29]

The W3C began work on P3P in late 1997, and made substantial progress, including a public working draft, by May 1998. Work on the standard was difficult, both from a technical point of view as well as from a social point of view: even if the W3C created a privacy standard, there was no guarantee that the standard would be implemented in browsers and voluntarily followed by large companies that collected and traded personal information. Nevertheless, work continued through 1998 and 1999, until the group hit a potentially deadly hurdle in 1999.

The problem was a patent: Intermind received a patent on January 19 that covered the automated transfer of data between clients and servers—which was arguably what the W3C was attempting to develop with P3P. At first, it was unclear if the patent itself overlapped with the privacy standard under development in the W3C. Moreover, Intermind did not provide any public statement of the terms under which it would license the use of its patent. Daniel Weitzner, a W3C staff member in charge of the P3P effort, recalled that as work on P3P progressed during 1999, "it became clear that the demand that implementers pay royalties was chilling the development of the technical specification, and rendering deployment of P3P-compliant technologies unlikely."[30] As

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[29] Massimo Marchiori, ed., "The Platform for Privacy Preferences 1.0 (P3P 1.0) Specification, W3C Recommendation 16 April 2002," http://www.w3.org/TR/P3P/. See also Patrick Feng, "Designing a "Global" Privacy Standard: Politics and Expertise in Technical Standards-Setting," (Ph.D. diss., Rensselaer Polytechnic Institute, 2002).
[30] Daniel J. Weitzner, Testimony Before the United States Department of Justice and United States Federal Trade Commission Join Hearings on Competition and Intellectual Property Law and Policy in the Knowledge-Based Economy, April 18, 2002.

Intermind refused to make a public declaration, the W3C commissioned a legal analysis to determine whether the P3P standard would in fact infringe on the Intermind patent. The legal assessment, completed in October 1999, declared that the P3P did not violate the patent. However, the experience proved to be costly, time-consuming, and unnerving, and W3C staff began to explore ways to ensure that patent claims, both from W3C Members and from individuals outside the W3C, would not derail and delay future standards work.[31]

In August 1999, the W3C chartered the Patent Policy Working Group (PPWG) to study the role of patents and create a clear policy to govern the use of patents in W3C Recommendations. Berners-Lee chose Daniel Weitzner, the leader of the W3C's Technology and Society Domain, to Chair the PPWG. Before joining the W3C in September, 1998, Weitzner had worked as a policy analyst at the Electronic Frontier Foundation, and was a co-founder and deputy director of the Center for Democracy and Technology, a public interest advocacy group in Washington, DC. In an interview published soon after he joined the W3C, Weitzner noted that the "W3C has done a progressively better job of engaging outside constituencies and experts," but added that there was still more work to be done. At the W3C, he planned to "do everything I

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[31] Joseph M. Reagle and Daniel J. Weitzner, eds., "Analysis of P3P and US Patent 5,862,325" (October 27, 1999), http://www.w3.org/TR/P3P-analysis. In other standards work, such as functions of the Extensible Markup Language (XML), the W3C tracked potential patent holdups on an *ad hoc* basis. See Joseph Reagle and Donald Eastlake 3rd, "XML Signature Patent Disclosures," http://www.w3.org/Signature/Disclosures.html. As of July 2007, the W3C suspended work on P3P "as there was insufficient support from current Browser implementers for the implementation of P3P 1.1." See "Status: P3P Work Suspended," http://www.w3.org/P3P/.

possibly can to engage people who are interested in these technology-and-society issues."[32]

Although Weitzner had hoped to devote his time to helping the W3C develop ways to ensure greater online privacy, the patent claims surrounding the W3C's P3P work meant that the W3C's patent policy—with its significant implications for "technology and society"—became one of his primary tasks. At first, the W3C appointed only six people to the PPWG: Weitzner (the Chair), representatives from W3C Member companies Microsoft, Hewlett-Packard, Philips, and Apple, and a patent attorney retained by the W3C who worked on the P3P patent dispute. The group took a long time—almost two years—before publishing a Working Draft that proposed a new W3C patent policy on August 16, 2001.[33]

The Working Draft, edited by Weitzner, proposed three specific changes to W3C patent policy. The first change would establish clear ground rules by requiring W3C Working Groups to articulate in their charters whether the Recommendation would be licensed under reasonable and non-discriminatory (RAND) or royalty-free (RF) terms. The second change sought to flush out existing patents by requiring all W3C Members to disclose relevant patent claims within their contributions to the W3C's work. The third change attempted to guard against patent extortion by requiring all W3C Members to commit to RAND licensing terms. By this point, it was widely recognized that the W3C and its Members simply could not afford to leave these issues undefined. In this sense,

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32 Weitzner, quoted in Garfinkel, "The Web's Unelected Government," 43.
33 The Working Draft listed as authors the PPWG members listed above, as well as members from IBM, Reuters, Sun, The Open Group, two additional Microsoft representatives, two representatives from Nortel Networks, and three additional members of the W3C staff.

any policy would be better than no policy. However, by endorsing royalty-generating patents in W3C Recommendations, the W3C proposed a stunning departure from the Web's tradition and Berners-Lee's founding ideals.[34]

Perhaps in anticipation of the resistance to come, the Working Draft also acknowledged that the patent policy was "of significant interest to the community-at-large," and thus requested the community to direct their comments to www-patentpolicy-comment, a public mailing list maintained by the W3C. In keeping with a recent change to the W3C's procedural rules, the PPWG pledged to compile a list of public comments at the end of the Last Call period on September 30, and respond to all substantive issues.[35]

Despite these careful preparations for public comments, the "public" seemed to have been mostly unaware of the issue and the forum until late September. The list archives record only one comment in the two weeks following the August 16 draft. However, on September 29 and 30—the final days before the end of the Last Call period—747 more comments were submitted.[36]

Taken together, the comments outlined a scathing reaction against of the RAND policy as well as the process by which the W3C consulted with the broader Web

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[34] Daniel J. Weitzner, ed., "W3C Patent Policy Framework: W3C Working Draft 16 August 2001," http://www.w3.org/TR/2001/WD-patent-policy-20010816.
[35] Weitzner, ed., "W3C Patent Policy Framework: W3C Working Draft 16 August 2001." The W3C's commitment to responding to substantive objections stemmed from a change in the W3C Process in February 2001. Before the change, no formal mechanism existed for a non-member minority or dissenting party to plead his case. Previously, reporting and archiving of minority views was entirely at the discretion of the Working Group Chair. See "4.1.2 Group Consensus and Votes," http://www.w3.org/Consortium/Process-20010208/groups.html#WGVotes.
[36] See http://lists.w3.org/Archives/Public/www-patentpolicy-comment/.

community. A vast majority of the comments displayed emotions ranging from measured displeasure to outright disgust. Many feared that the W3C was losing touch with the open source development community, or, even worse, surrendering its founding traditions of free and open code to a future controlled by corporate capital. Microsoft—a company that had allegedly vowed to "embrace, extend, and extinguish" open standards—was a chief target of scorn. Microsoft and IBM employees posted notes to www-patentpolicy-comment that supported patents in general and the RAND policy in particular, which only added fuel to the fire.[37] However, representatives from other W3C Member companies, such as Sun Microsystems, came out in support of a royalty-free policy. For these companies, the economic case for a royalty-free policy was more convincing than any anti-patent ideology. Indeed, Sun and other W3C Members held extensive patent portfolios; they simply argued that a royalty-free Web would provide a platform for better growth and revenue opportunities down the road and at the edges of the Web.

Many comments also projected a bitter defiance toward the W3C. For example, one person declared,

> Basing your standards on patented methods will fragment the web and destroy your organization. If you succeed in forcing such debased standards on the web, your corporate masters will no longer need you. If you fail, you will be irrelevant. Either way W3C loses.[38]

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[37] See the W3C's extensive analysis of the comments, "Public Issues for Patent Policy Framework of 20010816," http://www.w3.org/2001/11/PPF-Public-Issues.html.

[38] William Hill, "patents in your standards," September 30, 2001, http://lists.w3.org/Archives/Public/www-patentpolicy-comment/2001Sep/0457.

With the seemingly imminent demise of the W3C as the steward of open Web standards, several open source programmers welcomed the challenge of creating open source alternatives. The ongoing success of open source projects such as the Apache server software and Linux operating system had given the open source community confidence in its technical and organizational capabilities. Apache's dominant position in the market for Web server software—over 60% market share, almost three times more than Microsoft's competing product—further emboldened the community, and provided compelling evidence that its radically decentralized and modular style of open source development was economically and technologically viable.[39]

Other critics, writing to www-patentpolicy-comment and in the trade press, charged that the W3C tried to sneak its new patent policy past an unsuspecting public. Although the W3C had established a mailing list along with its August 16 announcement, none of the leading industry news websites—such as Slashdot, LinuxToday, The Register, or CNet—had covered or reacted to the announcement. The fact that so many comments were submitted in the final days of September—within hours of the Last Call deadline—added an additional sense of drama, urgency, and even conspiracy to their collective alarmist tone.[40]

In response to these concerns about the transparency and integrity of the W3C's public outreach, the PPWG extended the comment period through October 11. In the

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[39] See for example Russ Mitchell, "Open War," *Wired* 9 (October, 2001): 135-139.
[40] Karsten M. Self, "Re: Janet Daley's comments to LinuxToday," September 30, 2001, http://lists.w3.org/Archives/Public/www-patentpolicy-comment/2001Oct/0025; Margaret Kane and Mike Ricciuti, "W3C patent plan draws protests," *CNet News.com*, October 1, 2001, http://news.com.com/2102-1023-273752.html.

meantime, Weitzner sounded worried. In an interview published on October 2, he echoed a concern that was prominent in the comments to www-patentpolicy-comment: a RAND policy in the W3C would push the open source community to abandon the W3C and create its own open source alternatives to the patent-encumbered W3C Recommendations.[41]

In an attempt to avoid this disastrous split, Weitzner introduced greater transparency in the PPWG's deliberative process—including major changes aimed at winning back the trust of the open source community and maintaining the W3C's legitimacy. At the end of the extended Last Call on October 12, Weitzner invited Eben Moglen and Bruce Perens, two prominent open source advocates who had publicly bashed the W3C for its RAND proposal, to join the closed internal deliberations of the PPWG. The PPWG also created a public homepage to make policy documents—such as summaries of working group meetings—widely accessible. For his part, Weitzner agreed to participate in online and face-to-face public forums, and restated the PPWG's commitment to responding to the substantive issues raised from the more than 2,000 emails sent to www-patentpolicy-comment.[42]

Throughout all the commotion, Berners-Lee had been conspicuously quiet. He broke his silence on October 24, with a post to www-patentpolicy-comment titled "Why I have not spoken personally about the patent policy issue." His main point was to endorse the consensus-building process. He noted that his views on patents in general were well-

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[41] Andrew Orlowski, "Web standards schism 'terrible' – W3C patent policy boss," *The Register*, October 2, 2001, http://www.theregister.co.uk/content/6/21991.html.
[42] Daniel J. Weitzner, "Next steps in W3C Patent Policy process," October 12, 2001, http://lists.w3.org/Archives/Public/www-patentpolicy-comment/2001Oct/1559.html.

known, and even provided a link to an excerpt from his autobiography where he referred to patents as a "great stumbling block for Web development." He also addressed critics who hoped he would take a decisive stand on patents by explaining that his "silence arises from the fact that I value the consensus-building process at W3C. I am not (contrary to what some of the pundits might suggest! ;-) a dictator by role or nature and so prefer to wait and let the community resolve an issue."[43]

Given the evolving nature of Berners-Lee's role as "facilitator" (not "dictator"), it is difficult to know how much influence he exerted in the subsequent internal W3C discussions: although the mailing list for comments on the W3C patent policy is open to the public, internal W3C deliberations are not. What we do know is that, after three days of meetings from October 15 to October 17, the PPWG announced that they could not reach a unanimous decision. They decided to seek guidance from the W3C Advisory Committee—a group that theoretically consists of a representative from each of the W3C's Members (at this time it had over 300 Members) and meets twice a year. No public records exist from the Advisory Committee meeting in mid-November, but one can imagine that the patent policy debate dominated the meeting.

After the meeting concluded, Weitzner posted an "action item" sent by the Advisory Committee to the PPWG that introduced a new direction for the debate. The Advisory Committee, after acknowledging the broad continuum of views on the respective merits of RAND and royalty-free licenses, instructed the PPWG to "develop as a first priority… an RF patent policy." Although Weitzner's note emphasized "this does

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[43] Tim Berners-Lee, "Why I have not spoken personally about the patent policy issue," October 24, 2001, http://lists.w3.org/Archives/Public/www-patentpolicy-comment/2001Oct/1642.html.

NOT mean that the W3C has made a final decision in favor of a RF-only policy," the reality of the situation was that the Advisory Committee shifted the terms of debate from RAND-friendly to RF-friendly ground.[44]

After several more teleconferences and meetings, the PPWG issued a revised proposal on February 26, 2002 outlining a royalty-free patent policy. Weitzner summarized this policy as a legally binding commitment for anyone participating in W3C Recommendations to make any relevant patents available on a royalty-free basis. The new policy was a remarkable change: in less than six months, the W3C had assessed consensus—among its staff, members, and the concerned public—and reversed course. The consensus of the community, as judged within the closed deliberations of the W3C, determined that a royalty-free process would best facilitate widespread development of Web applications, and simultaneously would minimize the significant transaction costs associated with licensing negotiations and intellectual property lawyers. Although the practical concerns were paramount for W3C staff, defenders of the ideals of open source claimed victory and concluded that the W3C had averted building "a tollbooth on the Internet."[45]

The final version of the W3C Patent Policy, released on May 20, 2003, assured that "Recommendations produced under this policy can be implemented on a Royalty-

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[44] Daniel J. Weitzner, "FW: Action Item from Advisory Committee Discussion on Patent Policy," November 21, 2001, http://lists.w3.org/Archives/Public/www-patentpolicy-comment/2001Nov/0147.

[45] Daniel J. Weitzner, ed., "Patent Policy Working Group: Royalty-Free Patent Policy," February 26, 2002, http://www.w3.org/TR/2002/WD-patent-policy-20020226/; Bruce Perens, "Perspective: The patent threat to the Web," *CNet News.com*, October 7, 2002, http://news.com.com/2010-1071-961018.html.

Free (RF) basis." The W3C stopped short of an exclusive Royalty-Free policy by including an exception clause that would allow for patented technologies to be included in Recommendations if no royalty-free alternative existed. Berners-Lee, in his commentary that endorsed the Patent Policy, was careful to point out that royalty-encumbered technologies could still, in theory, be included in W3C Recommendations. However, this would occur only in exceptional circumstances, after "considerable deliberation" with the "substantial consensus of both those participating in developing the technology and the W3C Membership." Hardly a victory for RAND advocates, Berners-Lee noted that the "exception process is only designed to be used in the rarest cases," and should be seen as a tool for the W3C to maintain flexibility in its technical solutions if a lack of royalty-free solutions would halt the development of W3C technologies.[46]

The revised policy was touted as a success for both constituencies of the W3C: where the open source community could claim victory over corporate control, the Member companies of the W3C took comfort that the new patent policy rendered the W3C and its Members less vulnerable to costly litigation and "submarine" patents. Any policy was better than no policy, but the best policy was one that maintained the loyalties of the various constituencies in the W3C.

Given the W3C's dramatic and very public about-face, one can only wonder how much Berners-Lee influenced the Advisory Committee's deliberations, despite his stated preference to let the community resolve the issue. Weitzner dutifully rejected this notion:

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[46] Daniel J. Weitzner, ed., "W3C Patent Policy," May 20, 2003, http://www.w3.org/Consortium/Patent-Policy-20030520.html; Tim Berners-Lee, "Director's Decision, W3C Patent Policy," May 20, 2003, http://www.w3.org/2003/05/12-director-patent-decision-public.html.

"If Tim [Berners-Lee] were going to impose his own view as the policy, he would have done that two and a half years ago and saved us all the trouble." Weitzner—who, we should recall, was hand-picked by Berners-Lee to lead the Patent Policy Working Group—continued, "He's watched this group work, looked at our product, and I think he'll respect the process we're going through."[47] In the end, the W3C patent policy decision turned out to be consistent with its founder's idealistic views of patents and software. It surely was no accident that Berners-Lee's personal views aligned with the convictions of the open source Web developing community: after all, Berners-Lee was the original open source Web developer.

6.5 Conclusions

It is, of course, too soon to evaluate the long term significance of the W3C's royalty-free patent policy. In the meantime, anecdotal evidence from the short and medium term provides grounds for cautious optimism. To its credit, the W3C anticipated the growing appetite for royalty-free licenses in Web standards, and has maintained its leadership in this arena. It has also demonstrated the importance of a vigilant stance on issues that could disrupt its authority as an institution, and has slowly and incompletely opened some of its decision making processes.[48]

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[47] Paul Festa, "At the center of the patent storm," *CNet News.com*, September 24, 2002, http://news.com.com/2102-1082-959180.html.

[48] Paul Festa, "Patent holders on the ropes," *CNet News.com*, December 2, 2002, http://news.com.com/2100-1023-975587.html; and Michael Calore, "Big Guns Jump on Open-Source Bandwagon for New Web Apps," *Wired*, May 11, 2007, http://www.wired.com/software/webservices/news/2007/05/open_source.

However, the market for standards continues to be a crowded and contested organizational field. Patent holders continue to litigate aggressively, and viable alternatives to W3C Recommendations exist for important standards for the XML language and for a suite of functions known as Web services. Industry leaders such as Microsoft and IBM remained as dues-paying W3C Members, but, at the same time, continued to seek alternative venues—competitors to the W3C—that might give them greater control over the terms and pace of standardization.[49] These alternatives include groups such as the Organization for the Advancement of Structured Information Standards (OASIS), the Institute for Electrical and Electronic Engineers, and the Joint Technical Committee of the International Organization for Standardization and International Electrotechnical Commission (known as ISO/IEC JTC 1).[50] In areas of overlap, the W3C has established liaison relationships with over three dozen such organizations, but beneath the cordial veneer of these relationships lies a reality of intense jurisdictional competition in a dynamic commercial environment.[51]

The high commercial stakes of these jurisdictional battles complicates the extent to which critics can hope to secure democratic control over new technologies. In a recent article, Sheila Jasanoff summarized some of the most important issues at stake: "Are

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49 D. Linda Garcia, "Standards for Standard Setting: Contesting the Organizational Field," in Sherrie Bolin, ed., *The Standards Edge: Dynamic Tension* (Ann Arbor, MI: Sheridan Press, 2004), 15-30; Steve Lohr, "Setback for Microsoft Ripples Through the World Wide Web," *The New York Times* (September 17, 2003); Neal Levitt, "Are Web Services Finally Ready to Deliver?," *IEEE Computer* 37 (November, 2004): 14-18.

50 See Andrew Updegrove's website, http://www.consortiuminfo.org/links/, for a list of hundreds upon hundreds of current standards-setting organizations.

51 Ian Jacobs, "W3C Liaisons With Other Organizations," http://www.w3.org/2001/11/StdLiaison.

experts accountable, to whom, on what authority, and what provision is there for the injection of non-expert values on matters that fall in the gray zones between conjecture and certainty?"[52] In the context of the W3C—as with other consortia that are privately organized and, by design, beyond the scope of government control, the answers may not be satisfying for those who seek guarantees of democratic legitimacy.

One response to this dilemma has come from engineers and lawyers employed by non-profit advocacy groups such as the Center for Democracy and Technology. In 2002, three members of this advocacy group's staff reported on their experiments in the Internet Engineering Task Force and the W3C to identify potential public policy implications of technical proposals and to ensure that these implications were adequately considered. Leaving aside the problematic questions of how "public policy implications" should be defined (the report focused on privacy and anonymity), their report emphasized the difficulties that prevented the widespread replication of their experiment, including "systemic lacks of knowledge, time, money, and experience." In short, the resources of public interest advocates were no match for those of multinational companies, and completely insufficient to exert any sort of systemic influence on the complex and decentralized standardization process.[53]

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52 Jasanoff, "Technology as a Site and Object of Politics," 759.
53 Alan Davidson, Jon Morris, and Robert Courtney, "Strangers in a Strange Land: Public Interest Advocacy and Internet Standards," paper presented to the Telecommunications Policy Research Conference, September 27, 2002, Washington, D.C. For another useful perspective on this question, see Eric J. Iversen, Thierry Vedel, and Raymund Werle, "Standardization and the Democratic Design of Information and Communication Technology," *Knowledge, Technology and Policy* 17 (2004): 104-126.

Given the relative failure of the Center for Democracy and Technology's experiment to infiltrate the standard-setting process, the most realistic avenue for addressing "matters that fall in the grey zones between conjecture and certainty" may be unsatisfactory for critics committed to the ideals of participatory democracy: we must trust the powerful leaders of the standard-setting process. In the W3C, these leaders include the reluctant monarch Berners-Lee (who, after his 2003 promotion to Knight Commander of the Order of the British Empire, is properly addressed as Sir Berners-Lee) as well as his civil servants, including Daniel Weitzner (who, recall, was a co-founder of the Center for Democracy and Technology before joining the W3C as Technology and Society Domain Leader). However, since the industrial legislatures that compete with the W3C are less receptive to the egalitarian and anti-patent ideals of open source advocates, the potential for this model to fulfill visions of democratic control is, at best, limited.

Conclusions

Networks are critiques. The four major communication networks described in chapters three through six—AT&T's national telephone network, the Internet, digital cellular networks, and the World Wide Web—arose in reaction to the limitations that their designers perceived in existing networks. These critiques were visible in the technological features of each of these four networks, for example in AT&T's centralized national control over telephony, in the Internet's distributed end-to-end architecture, in the spectrum-efficient CDMA standard for digital cellular networks, and in the non-proprietary standards produced by the World Wide Web Consortium.

Beyond these technological critiques, the architects of these four major networks also advanced organizational critiques of their predecessors that were visible in the institutions that created and maintained standards. For example, the engineers in the Internet Engineering Task Force practiced a modular style of innovation that was an explicit rejection of both the centralized model of systems innovation favored by AT&T and IBM and the bureaucratic processes used by the International Organization for Standardization. Organizational critiques also were evident in institutions that created standards for digital cellular networks—unified under the power of the state in Europe, and left to private coordination in the United States.

Networks are technological and organizational critiques of what came before, but they are not wholesale rejections or clean slates. Each of the communication networks discussed in this dissertation illustrates a general historical pattern: new infrastructures build upon and extend existing infrastructures, even as they revise and critique the existing order. The Arpanet and Internet grew by transmitting data over lines leased from AT&T; users were attracted to cellular networks in part because these networks put them in contact with the existing base of land line subscribers; and Tim Berners-Lee designed the World Wide Web to transmit data over the end-to-end architecture of the Internet. From these examples we can identify the historical dimensions of economic change, such as network externalities and bandwagon effects, that persist over time. This fundamental character of infrastructure—that it almost always builds on earlier infrastructures—sheds additional light on the process of infrastructure evolution. Where individuals making incremental innovations often seek to preserve backward compatibility, entrepreneurs pursuing radical innovations often make a clean break. But the most successful new communication networks of the late twentieth century—the Internet, cellular telephones, and the Web—struck a middle ground between a slavish dedication to the past and a wholesale rejection of it. They preserved valuable features of both. There is, I believe, an important aspect of technological change embodied in this experience—an aspect that historians miss when they try to make their subject appear to be unique, revolutionary, or unprecedented in world history.[1]

The technological and organizational critiques also indicate the flexibility of one particular organizational form, consensus standardization, that engineers devised and

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[1] These historical characteristics of infrastructure are evident in studies of different modes of transportation. See for example Mark H. Rose, Bruce E. Seely, and Paul F. Barrett, *The Best Transportation System in the World: Railroads, Trucks, Airlines, and American Public Policy in the Twentieth Century* (Columbus: Ohio State University Press, 2006); Alex Roland, "Containers and Causality," *Technology and Culture* 48 (2007): 386-392; and Susan Leigh Star and Geoffrey C. Bowker, "How to Infrastructure," in Leah A. Lievrouw and Sonia Livingstone, eds., *Handbook of New Media: Social Shaping and Consequences of ICTs* (Thousand Oaks, CA: Sage Publications, 2002), 151-162.

modified to set standards for the communication networks of the Third Industrial Revolution. This organizational form became both effect and cause of technical change during this revolutionary process. It was originally created in the late nineteenth and early twentieth centuries by scientists and engineers who sought to establish common specifications not through market power, but instead through impartial institutions such as engineering societies and trade associations. As they matured during the twentieth century, consensus standards bodies shared a common institutional feature: specialized committees and sub-committees to bring together scientists and engineers from private firms, government agencies, universities, and non-profit organizations. They also shared common ideological assumptions such as a belief in the rational methods of professional engineering, a progressive view of the power of science and technology to improve society, a conviction that cooperation among engineers within "industrial legislatures" was superior to adversarial conflicts in existing judicial and political institutions, and, especially in the United States, an assumption that the private sector should lead.

Consensus standards bodies were perpetually works in progress, organizations in flux, and sites of organizational experimentation that sustained technological evolution in new communications technologies. As the Bell monopoly matured in the 1920s and 1930s, its engineers learned to use the consensus standardization process to address problems, such as the "petty racket" of telephone slugs, that they could not solve within their extensive managerial hierarchy. During this period, engineers also learned that standards bodies could help them circumvent costly and time-consuming legal proceedings—a feature that Paul Gough Agnew promoted in his public advocacy of the

American Engineering Standards Committee (AESC), and that Bancroft Gherardi embraced when AT&T's telephone networks faced electrical interference from power and lighting networks.

As the technical and legal foundations of the telecommunications industry shifted during the second half of the twentieth century, the locus of control over standardization also shifted. In the new, decentralized industry structure that took shape in the 1970s and 1980s, consensus standards bodies assumed responsibility for the design of new standards and new networks that had previously fallen to the network architects at AT&T and IBM and regulators in government agencies. In the 1980s and 1990s, the telecommunications and computing industries converged around digital electronics. When we consider devices such as the Blackberry or the iPhone that were brought to market in the late 1990s and early 2000s, it is impossible—or rather, beside the point—to distinguish between a "telephone" and a "computer." The new devices were bundles of components, designed around consensus standards that allowed users to connect to any number of communication networks—the Internet, the Web, and cellular telephone networks—in a seamless and, one hopes, apparently natural manner.

The objective and impartial appearance of standard-setting organizations belies the contested circumstances under which these organizations established their authority. Because their standards were not backed by the force of law, consensus organizations needed to establish themselves as legitimate and effective organizations. Each of the institutions examined in this dissertation faced crises during which they could either demonstrate their legitimacy or risk losing their authoritative position. The initial construction of a new standards body usually occurred when trusted professional scientists or engineers—such as Elihu Thomson, Paul Gough Agnew, Vinton Cerf, and Tim Berners-Lee—led the way. But there was more to the history than heroic leadership: for the consensus method to be effective, standards bodies needed to reach out to new members with different points of view. Expansion led to controversy and, in many cases, reform. Expansion also revealed the limits of consensus standardization: new rules were necessary to ensure that agreements were fair and legitimate for all participants, but a preponderance of rules also dulled the speed advantages of the consensus method. This aspect of the evolutionary process could leave bloated bureaucracies in its wake.[2]

For the purposes of comparison, it can be helpful to step back and consider the variety of standard-setting institutions—engineering societies, trade associations, industry consortia, dominant private firms, and government agencies—as elements of a distinctive American system of standardization. To the extent that it can be understand as a coherent system, the American system of standardization is the most fragmented, decentralized, and pluralistic in the world. Much like the history of the American nation itself, this system has strong traditions of voluntarism, local control, meritocracy, rights to represent one's own interests, and a marked preference for private coordination of commercial activity.

Based on their experiences in the federal armories, their organizational innovations in the steel and railroad industries, and advice from British engineers,

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[2] Timothy S. Simcoe, "Delay and *De Jure* Standards: Exploring the Slowdown in Internet Standards Development," in Shane Greenstein and Victor Stango, eds., *Standards and Public Policy* (New York: Cambridge University Press, 2007), 260-295.

Americans created a loose network of organizations that set industrial and national standards during the late nineteenth and early twentieth centuries. The stable contours of an American system of standardization were in place by 1930, when the American Engineering Standards Committee was reconstituted as the American Standards Association and adopted rules and procedures that are still in place today. Where industrial powers such as Germany, Britain, France, and Japan relied on government authority to set standards, American regulators never established a centralized, overarching authority responsible for creating and enforcing standards. Instead, they consistently deferred to organizations and professionals in the private sector and created rules to encourage collaboration and experimentation. Tocqueville would not have been surprised at the persistent importance of self-government and voluntarism in support of commercial development.[3]

In the American case, however, the government was still an important actor. We should not interpret the deference of federal policymakers as a sign that the private ordering of standards was anarchic or a function of pure market exchanges. The history of consensus standardization in the United States demonstrates the important role of indirect government support of consensus standardization. Indeed, every organization and network discussed in this dissertation had the implicit support of government, and, in

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[3] Jay Tate, "National Varieties of Standardization," in Peter A. Hall and David Soskice, eds., *Varieties of Capitalism: The Institutional Foundations of Competitive Advantage* (New York: Oxford University Press, 2001); D. Linda Garcia, "Standard Setting in the United States: Public and Private Sector Roles," *Journal of the American Society for Information Science* 43 (1992): 531-537; Samuel Krislov, *How Nations Choose Product Standards and Standards Change Nations* (Pittsburgh: University of Pittsburgh Press, 1997), 83-133; and Andrew L. Russell, "Industrial Legislatures: The American System of Standardization," in *International Standardization as a Strategic Tool* (Geneva: International Electrotechnical Commission, 2006).

many cases, an explicit declaration from government officials that private bodies were best positioned to create legitimate and widely acceptable standards. Examples of this pattern include the AESC's creation of safety standards at the behest of the National Bureau of Standards in the 1920s; the Federal Communications Commission's endorsement of cellular standardization in industry groups such as the Telecommunications Industry Association in the 1980s and 1990s; and the relaxation of antitrust laws that encouraged the proliferation of industry consortia, such as the World Wide Web Consortium, in the 1990s and early 2000s.

At times—particularly in the 1920s and again in the 1980s—the preference for industry self-regulation appeared to be little more than a strategy to avoid political controversy. Advocates of private control, however, crafted rhetorical campaigns that emphasized the positive aspects of standardization through "industrial legislatures." These campaigns convinced regulators to rely on private standards bodies because of the leadership of trusted professional scientists and engineers, and because they fit well with prevailing preferences for private control.[4] This trend was evident as early as the middle of the nineteenth century, when elite scientists from England, Germany, and the United States met at World's Fairs to create standards for electrical technologies and telegraph networks.

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[4] Howard Coonley and P. G. Agnew, *The Role of Standards in the System of Free Enterprise: a study of voluntary standards as alternative to Legislative and Commission control. Prepared by Request of the Temporary National Economic Committee* (New York: American Standards Association, 1941).

Even as consensus standards bodies became increasingly dominated by agents of corporate capital, the foundation of trust remained, and was most visible in the activities of highly-regarded leaders such as Paul Agnew, Bancroft Gherardi, Vint Cerf, Robert Kahn, Jon Postel, Thomas Haug, Tim Berners-Lee, and Daniel Weitzner. In the 1920s, as in more recent times, the actions of these leaders and their liaisons in the standards process—those who ensure the smooth operation of voluntary consensus process, and those who cross over the boundaries of different organizations—were of crucial importance. Several of these individuals led standards committees while working for private companies; others were employed by universities or, in some cases, by the standard-setting organizations themselves. In all cases, these individuals made fundamental contributions to the commercial development of technology, but they did not channel their efforts exclusively to the proprietary gain of any one particular firm. The fruits of their labor was never considered for Nobel prizes, but they nevertheless performed important roles in the technical development of modern society by integrating novel scientific and technical advances into standard devices and networks. In this sense, the individuals in this dissertation provide examples that flesh out Greg Downey's concept of "protocol labor," and remind us of the immense amount of human effort required to create and sustain the communication networks built in the modern era.[5]

[5] Gregory J. Downey, "Virtual Webs, Physical Technologies, and Hidden Workers: The Spaces of Labor in Information Internetworks," *Technology and Culture* 42 (April 2001): 209-235. See also Gregory J. Downey, *Telegraph Messenger Boys: Labor, Technology, and Geography, 1850-1950* (New York: Routledge, 2002); and Amy Slaton and Janet Abbate, "The Hidden Lives of Standards: Technical Prescriptions and the Transformation of Work in America," in Michael Thad Allen and Gabrielle Hecht, eds., *Technologies of Power: Essays in Honor of Thomas Parke Hughes and Agatha Chipley Hughes* (Cambridge, MA: The MIT Press, 2001).

The inescapable irony of the history of standardization is that the organizations devised to create rigid and unchanging standards were themselves part of a dynamic and flexible system, one that evolved through a persistent state of controversy and conflict. To comprehend the contours of this system, one is pressed to reconsider fundamental questions about the tension between freedom and order, between the political desire for local control and the rational impulse for uniformity. The ultimate expression of the latter impulse led to the creation of international bodies that coordinated the various standardization initiatives that arose in diverse locations and industries. Thankfully, the desire for standardization did not—or has not yet—generated the dystopic social conditions feared by Aldous Huxley and George Orwell.

Engineers who work in standard-setting organizations seemed to be entirely uninterested in expanding their control over the whole of society. They were not the heirs of the technocratic vision articulated in the 1920s and 1930s. Instead, they sought to solve technical problems within their own limited domains. Over the course of the twentieth century, they devised progressively larger institutions—at first the AESC on the national level, and eventually the International Organization for Standardization (ISO) on the international level—to bring more order to industrial standardization. These organizations have, in some cases, enjoyed extraordinary success. According to historians JoAnne Yates and Craig Murphy, the formation of the ISO was a successful act of political entrepreneurship insofar as it provided a forum that "in all industrial sectors and in all parts of the world, [was] always available as an alternative to any other standard-setting mechanism."[6]

In recent years, however, engineers and corporate executives have rejected ISO and sought new alternatives such as industry consortia that they could control more easily and that could move more quickly. Groups such as the Internet Engineering Task Force and the World Wide Web Consortium provided sleeker alternatives to large, formal organizations such as ISO. These nimbler alternatives proved to be especially useful as the structure of the telecommunications and computer industries became more decentralized and market forces pressed for the rapid production of standards. However, as we saw in chapters four through six, consortia and other faster alternatives introduced a new set of administrative and legal problems that threatened to weaken their legitimacy claims and technical efficacy. These problems intensified as corporate managers began to abandon common technological goals and seek advantages by using standard-setting organizations as venues for advancing proprietary technologies and capturing monopoly profits.

Standard setting organizations thus continue to struggle with the contradictory demands of competition and interoperability. The proliferation of liaison arrangements indicate that these organizations are not isolated islands of activity. New arrangements, such as one recently announced between the Internet Engineering Task Force and the

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[6] JoAnne Yates and Craig Murphy, "Charles le Maistre: Entrepreneur in International Standardization," paper presented at the Business History Conference, June 2007.

CableLabs consortium, are justified as "an effort to avoid duplication of work."[7] We've been here before. In 1920, the first annual report of the American Engineering Standards Committee used similar language to justify its mission "to secure cooperation between various interested organizations in order to *prevent duplication of work* and promulgation of conflicting standards."[8] Engineers in the 1920s, much like their present-day counterparts, faced complex technical problems, constant jurisdictional conflicts, a competitive international economy, and the continual need to negotiate boundaries between government, market activity, and private collaborations. Standards change and organizations come and go, but the underlying tension between freedom and order remains.

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[7] Jean-Francois Mule and Mark Townsley, "CableLabs – IETF Standardization Collaboration," January 31, 2007, http://www.ietf.org/internet-drafts/draft-mule-ietf-cablelabs-collaboration-03.txt.

[8] *Annual Report of the American Engineering Standards Committee*, (New York: American Engineering Standards Committee, 1920), 1.

Appendix A: List of Acronyms

AESC American Engineering Standards Committee
AIEE American Institute of Electrical Engineers
AIME American Institute of Mining Engineers
ANSI American National Standards Institute
ARPA Advanced Research Projects Agency
ARPANET Advanced Research Projects Agency Network
ASA American Standards Association
ASCE American Society for Civil Engineers
ASME American Society of Mechanical Engineers
ASTM American Society for Testing Materials
AT&T American Telephone and Telegraph
BBN Bolt, Beranek and Newman
BESC British Engineering Standards Committee
CBS Columbia Broadcasting System
CDMA Code Division Multiple Access
CEPT Conference of European Posts and Telecommunications Administrations
CLNP ConnectionLess Network Protocol
CTIA Cellular Telecommunications Industry Association
DARPA Defense Advanced Research Projects Agency
DEC Digital Equipment Corporation
ECMA European Computing Machinery Association
ECSA Exchange Carriers Standards Association
EIA Electronic Industries Association
ETSI European Telecommunications Standards Institute
FCC Federal Communications Commission
FTP File Transfer Protocol
GE General Electric
GNU GNU's Not Unix
GOSIP Government Open Systems Interconnection Profile
GSM Groupe Spéciale Mobile (1982-1989)
GSM Global System for Mobile Communication (1989-present)
HTML HyperText Markup Language
HTTP HyperText Transfer Protocol
IAB Internet Advisory Board (1984-1986)
IAB Internet Activities Board (1986-1992)
IAB Internet Architecture Board (1992-present)
IBM International Business Machines
ICCB Internet Configuration Control Board
IEC International Electrotechnical Commission
IEEE Institute of Electrical and Electronic Engineers
IETF Internet Engineering Task Force
IMP Interface Message Processor

INARC Internet Architecture Task Force
INWG International Network Working Group
IPTO Information Processing Techniques Office
ISO International Organization for Standardization
ITU International Telecommunications Union
JTC Joint Technical Committee
LCS Laboratory for Computer Science
MHz Megahertz
MIT Massachusetts Institute of Technology
NBS National Bureau of Standards
NCP Network Control Protocol
NCSA National Center for Supercomputing Applications
NIST National Institute for Standards and Technology
NMT Nordic Mobile Telephone
NSF National Science Foundation
NTP Network Time Protocol
NWG Network Working Group
OASIS Organization for the Advancement of Structured Information Standards
OSI Open Systems Interconnection
P3P Platform for Privacy Preferences
PPWG Patent Policy Working Group
PRnet Packet Radio Network
RAND Reasonable and Non-Discriminatory
RCA Radio Corporation of America
RF Royalty-Free
RFC Request for Comments
SAE Society of Automotive Engineers
SATnet Satellite Radio Network
TCP/IP Transmission Control Protocol/Internet Protocol
TDMA Time Division Multiple Access
TIA Telecommunications Industry Association
UCLA University of California, Los Angeles
VoIP Voice over Internet Protocol
W3C World Wide Web Consortium
XML Extensible Markup Language

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Curriculum Vita

Andrew L. Russell was born on May 26, 1975 in Elmira, New York. He graduated with a New York State Regents Diploma in 1992 from Clinton Central High School in Clinton, New York. He holds degrees from Vassar College (B.A. History, 1996) and the University of Colorado at Boulder (M.A. History, 2003). From 1997 to 1999, he worked in the Harvard Information Infrastructure Project at Harvard University's John F. Kennedy School of Government.