When Innovations Meet Institutions: Edison and the Design of the Electric Light

Andrew B. Hargadon
University of California, Davis
Yellowlees Douglas
University of Florida

This paper considers the role of design, as the emergent arrangement of concrete details that embodies a new idea, in mediating between innovations and established institutional fields as entrepreneurs attempt to introduce change. Analysis of Thomas Edison's system of electric lighting offers insights into how the grounded details of an innovation's design shape its acceptance and ultimate impact. The notion of robust design is introduced to explain how Edison's design strategy enabled his organization to gain acceptance for an innovation that would ultimately displace the existing institutions of the gas industry. By examining the principles through which design allows entrepreneurs to exploit the established institutions while simultaneously retaining the flexibility to displace them, this analysis highlights the value of robust design strategies in innovation efforts, including the phonograph, the online service provider, and the digital video recorder.●

The pursuit of innovation increasingly drives organizations in rapidly changing environments, where risks are high and missteps have serious consequences (Brown and Eisenhardt, 1997; Drucker, 1999). Introducing change into otherwise stable social systems is a risky endeavor, but this is exactly what entrepreneurs with potentially significant innovations must attempt to do. To be accepted, entrepreneurs must locate their ideas within the set of existing understandings and actions that constitute the institutional environment yet set their innovations apart from what already exists. Recent research has highlighted the social embeddedness of such economic actions as innovation and entrepreneurship, in which value and significance are shaped as much by cultural as economic influences (Granovetter, 1985; Dacin, 1997; Dacin, Ventresca, and Beal, 1999; Lounsbury and Glynn, 2000; Ventresca et al., 2000). One cultural determinant of an innovation's value is how well the public, as both individuals and organizations, comprehends what the new idea is and how to respond to it. And it is the concrete details of the innovation's design that provide the basis for this comprehension, as well as for new understandings and actions to emerge, which then, in turn, change the existing institutional context.

When innovations meet institutions, two social forces collide, one accounting for the stability of social systems and the other for change. These moments provide opportunities to observe the shifts in collective understanding and action that throw the otherwise static institutional background into stark relief (Czarniawska-Joerges and Sevón, 1996). Because the changes that accompany innovations often occur over years and even decades, historical cases can provide the necessary distance to observe how an innovation both emerges from and reshapes its institutional environment (e.g., DiMaggio, 1992; McGuire, Granovetter, and Schwartz, 1993). By analyzing a specific moment in history when an innovation first begins to affect the landscape of existing institutions, we can identify the means by which innovations displace existing institutions and suggest how future innovations could be designed to exploit such means.

0001-8392/01/4603-0476/$3.00.

●

We are grateful to Robert I. Sutton, Steve Barley, Beth Bechky, Angelo Fanelli, Rodney Lacey, Mark Zbaracki, Reed Nelson, and three anonymous reviewers for their helpful comments on earlier drafts of this paper. This research was funded in part by a grant from the Center for Innovation Management Studies of Lehigh University.

We do this here by examining what is perhaps the prototypical example of innovation, Edison's development of his system of electric lighting, an innovative new technology that gained rapid and widespread acceptance and profoundly altered the institutional landscape.[1] We chose this case because it was not a simple story of one innovation's demonstrable technical and economic superiority over an incumbent rival. Rather, the evidence suggests that for its initial success, Edison's system of electric lighting depended on the concrete details of its design to invoke the public's familiarity with the technical artifacts and social structures of the existing gas and water utilities, telegraphy, and arc lighting. Although this familiarity provided the public with the means for quickly understanding the value of his new system and how to interact with it, Edison's system of lighting ultimately was able to displace many of those established institutions and become itself the model for successive ones. Our analysis of this case led us to focus on the nature of Edison's design, which exploited past understandings but also preserved the flexibility to evolve beyond them and build wholly new institutions. A careful analysis of the interplay among design, innovation, and institutions has the potential to enrich our understanding of innovation in contemporary organizations.

INNOVATION, INSTITUTIONS, AND THE LANGUAGE OF DESIGN

Explanations for the successful (and unsuccessful) introduction and diffusion of innovations typically focus on the inherent functional and economic advantages that new technologies provide over traditional ways of doing things. Innovations are variously differentiated from established institutions with such terms as revolutionary, radical, discontinuous, competence-destroying, or disruptive (e.g., Rosenberg, 1982; Abernathy and Clark, 1985; Tushman and Anderson, 1986). Tushman and Anderson (1986: 441) suggested that discontinuous technologies represent price-performance improvements over existing technologies so significant that "no increase in scale, efficiency, or design can make older technologies competitive with the new technology." As a result, the primary focus is on whether innovations enhance or destroy incumbent firms' existing competencies (e.g., Tushman and Anderson, 1986; Henderson and Clark, 1990) and on how organizations can overcome the barriers to adopting the new and inherently better technology (e.g., Leonard-Barton, 1992; Bower and Christensen, 1995).

While the promise of change is what drives adoption, such explanations neglect the social embeddedness of the process by which innovations are introduced to and accepted by the public (Granovetter, 1985; Dacin, 1997; Dacin, Ventresca, and Beal, 1999; Lounsbury and Glynn, 2000). Perhaps this is because research tends to treat innovations as abstract and indeterminate ideas—the automobile, the personal computer, the Internet, and genetic engineering—while, in daily life, the public confronts them in specific and concrete forms—the Model T, the Apple II, Yahoo!, and Dolly the sheep. To understand how individuals and organizations respond to such innovations, it is useful to consider how the

1
During the period of interest, Thomas Edison worked so closely with a small group of engineers in his Menlo Park laboratory that it is difficult to distinguish his actions from those of his colleagues. Francis Jehl, one of Edison's long-time assistants, once said, "Edison is in reality a collective noun and refers to the work of many men" (Conot, 1979: 469). It is with this understanding that we refer to Edison throughout this paper.

existing institutions of a social system shape those responses.

To interpret novel situations and craft responses, actors choose from their set of existing understandings and actions (Schank and Abelson, 1977: 67–68; Kintsch and Dijk, 1978; Rumelhart, 1986). Institutions shape behavior by constituting the set of acceptable interpretations and actions available to them (Goffman, 1959; Friedland and Alford, 1991; Barley and Tolbert, 1997; DiMaggio, 1997). To describe this constitutive nature, institutional scholars have used the language of schemas and scripts. Schemas are "knowledge structures that represent objects or events and provide default assumptions about their characteristics, relationships, and entailments under conditions of incomplete information" (DiMaggio, 1997: 269). Scripts, as more localized forms of schemas, direct individual action and understanding in highly particularized situations (Barley, 1986; DiMaggio, 1997). The presence of schemas helps us to see, the presence of scripts, to act. Most importantly for our purposes, schemas and scripts represent the means through which understanding and action are embedded in established institutional environments. Cognition at both the individual level (DiMaggio, 1997) and the organizational level (Weick, 1979; Levitt and March, 1988) takes place as concrete details in the environment cue actors' existing schemas and evoke appropriate scripts.

Our challenge is to understand precisely how an innovation invokes and exploits institutionally shaped understandings, because these are the very details that have tended to slip unnoticed as these innovations evolve into institutions of their own. The concrete details of an innovation evoke interpretations among potential adopters that are based on adopters' past understandings and experiences. So while innovations must appear novel to draw attention and suggest an advantage (Kiesler and Sproull, 1982), entrepreneurs must initially present the meaning and value of their innovations, including their novel features, in the language of existing institutions by giving them the appearance of familiar ideas (McKinley, Mone, and Moon, 1999). Paraphrasing Gombrich (1961: 4), there is no such thing as an immaculate perception. Purely novel actions and ideas cannot register because no established logics exist to describe them. Instead, such innovations fail to be adopted because they go largely unnoticed and unvalued. This presents a dilemma. Without invoking existing understandings, innovations may never be understood and adopted in the first place. Yet by hewing closely to existing institutions, innovators risk losing the valued details, representing the innovation's true novelty, that ultimately change those institutions. Success, then, requires entrepreneurs to locate their ideas within the set of understandings and patterns of action that constitute the institutional environment in order to gain initial acceptance, yet somehow retain the inherent differences in the new technology that ultimately will be needed to change those institutions.

Design, as the particular arrangement of concrete details that embodies an innovation, provides the means to mediate between innovations and institutions. The design process itself can be both intended and emergent. As Simon (1981:

55) argued, "Everyone designs who devises courses of action aimed at changing existing situations into preferred ones" (see also Liedtka, 2000). The result is the embodiment of previously indeterminate ideas in specific and concrete forms (Buchanan and Margolis, 1995), which may range from the physical form of an innovation, such as the look and feel of an artifact like the handle on an iMac computer or the leather seats of an automobile, to the characteristics and actions of those who promote it—the reputation of the individual or firm as innovative, for example, or their ISO-9000 certification (Cole and Scott, 2000). To the public, these details and their arrangement represent the sole means through which it can understand, appreciate, interact with, and, eventually, adopt an innovation. So what might seem like local concrete details can cue an entire raft of schemas that shape the understanding and adoption of an innovation. In this way, design grounds a particular innovation in its particular time and place by providing it with a set of meanings and values that are embedded in the existing institutional environment. Yet because people have multiple, overlapping, and often-contradictory schemas, their interpretation of any given situation depends on their selection of particular schemas, and their actions depend on their choice of particular scripts. Thus, while people make sense of the new only in terms of the old, the design of the new shapes *which* sense they make by determining *which* aspects of the old are invoked.

While Edison's development and introduction of the electric light has long been held up as both an icon of invention and a technological triumph, recently compiled evidence reflects that established institutions had a role in shaping electric light's form and presentation (McGuire, Granovetter, and Schwartz, 1993; Israel, Nier, and Carlat, 1998). This evidence suggests that Edison triumphed over the gas industry not by clearly distinguishing his new system from but, rather, by initially cloaking it in the mantle of these established institutions. Further, this case alerts us to a hidden value in the design of innovations, what might be called robust design. The notion of robust design comes from an insight Leifer (1991) had while analyzing the chess moves of masters and novices. Previously, chess masters were believed to select moves by mapping out the myriad possible moves and countermoves, predicting the future of the game and choosing those moves that achieved the player's strategic goals. What Leifer found was that players did not (and could not) rely on such detailed planning, which made them unresponsive to evolving conditions of the game. Rather, players chose moves that simultaneously advanced a particular strategic gambit yet preserved the flexibility needed to respond to their opponents' moves. Leifer described these moves as robust actions, and Eccles, Nohria, and Berkley (1992) generalized this concept to describe the effective actions of managers in organizations (see also Padgett and Ansell, 1993). Effective in the conditions of a relatively certain short run, robust actions remain adaptive in the face of uncertain and evolving conditions over the long run. In this sense, an innovation's design is robust when its arrangement of concrete details are immediately effective in locating the novel product or process within the familiar world, by invoking valued schemas and scripts, yet preserve the flexibility necessary for future evolution, by not constraining the potential evolution of understanding and action that follows use.

To strike this balance, prospective innovators must carefully choose designs that couch some features in the familiar, present others as new, and keep still others hidden from view. By designing the incandescent light around many of the concrete features of the already-familiar gas system, Edison drew on the public's preexisting understandings of the technology, its value, and its uses. At the same time, by structuring his system as he did, he also maintained its ability to evolve beyond that limited understanding and use. In the case study, we construct the role of robust design in examining the means by which Edison gained acceptance for his system of electric lighting.

Method

Historical case studies like Edison's introduction of electric lighting offer opportunities to examine social processes in ways that both cross-sectional and even current longitudinal research cannot. Paraphrasing Weber, Barley and Tolbert (1997: 93) suggested that "organizations, and the individuals who populate them, are suspended in a web of values, norms, rules, beliefs, and taken-for-granted assumptions." In this way, cognition, whether individual (e.g., DiMaggio, 1997) or organizational (e.g., Weick, 1979; Levitt and March, 1988), serves as the nexus between existing institutions and the actions they guide. Cultural elements shape both interpretation and action, and any analysis of the relationship between them must account for the context in which they are embedded (Geertz, 1973). Ultimately, the purpose of such an analysis is not to develop a set of general rules that apply across all cases but, instead, to look at the concrete details and actions of a particular situation to understand the larger systems of meaning reflected in them (Geertz, 1973). Exploring momentous innovations with a careful eye toward the social embeddedness of the innovation process highlights the reciprocal links between the concrete actions of innovators and the social forces of the institutions they overturn. As DiMaggio (1997: 280) suggested, the challenge is "to understand the cognitive aspects of major collective events in which large numbers of persons rapidly adopt orientations that might have appeared culturally alien to the majority of them a short time before." Careful analysis of moments in history when innovations rapidly change the landscape of existing institutions offers the opportunity to observe these larger systems of meaning.

Historical case studies also provide a perspective that covers the decades often necessary to observe an innovation's emergence and stabilization. Further, as Kieser (1994: 611) noted, historical analysis provides the ability to understand how existing actions and institutional structures are not determined by laws but, rather, are "the result of decisions in past choice opportunities, some of which were made intentionally and others more implicitly." In addition, while the "facts" of historical case studies are difficult to access and often depend on secondary sources, the "facts" of current events are often distorted by the necessities of impression management. Over time, as necessity wanes, different stories surface. Our understanding of Edison, for example, has evolved considerably from the image of a lone genius that Edison, his engineers, and his investors mutually sustained (Hughes, 1983). Recent histories have suggested that perhaps Edison's greatest invention was his organization of the invention process itself (Hughes, 1989; Millard, 1990), and credit for much of Edison's work in developing the system of electric lighting actually belongs to one of his engineers, Francis Upton, a "fact" that emerged only in memoirs written after the need for a mythological hero had passed. Similarly, the operating losses that nearly collapsed Edison's first commercial generating plant on Pearl Street in New York were kept secret for fear of dissuading investors or encouraging competing technological systems (Hughes, 1983; McGuire, Granovetter, and Schwartz, 1993).

The use of historical data may be problematic, however, because historical accounts often neglect the concrete details that shape and constitute actions, favoring instead the more abstracted implications that render those actions timeless. And they often neglect the spirit of the time that was an essential but mainly invisible background against which these events unfolded. Fortunately, for an attempt at understanding the relationship between innovation and institutions, few cases offer more recorded history or relevance than the development and institutionalization of the system of electric lighting. We were therefore able to draw on considerable data from a wide range of sources. We relied on recently compiled volumes offering primary data on Edison's early efforts at perfecting a commercial bulb and his early visions of the potential of electricity, as well as newspaper accounts that captured the expectations of investors and consumers alike as the public learned about the promises and realities of the evolving technologies (Israel, Nier, and Carlat, 1998). We also drew from secondary histories of Edison, which trace Edison's every move from childhood to retirement (Josephson, 1959; Conot, 1979; Millard, 1990; Israel, 1998), as well as histories that track the technological changes covering the demise of the gas industry and the concurrent rise of the electric industry (Silverberg, 1967; Hughes, 1983, 1989; Basalla, 1988; McGuire, Granovetter, and Schwartz, 1993). So while this analysis lacks access to the original details (and their socially shared meanings), few events in the history of technological innovation have been as well documented as Edison's introduction of incandescent lighting.

EDISON'S INNOVATION MEETS THE ESTABLISHED INSTITUTIONS

In 1878, Thomas Edison began designing an incandescent light bulb suitable for lighting homes and offices and, on September 4, 1882, formally unveiled to the public both his electric light bulb and the system of power generation and distribution that would support it. He chose the downtown New York offices of financier J. P. Morgan for his first public demonstration of electric lighting, locating the nearby generating plant at 257 Pearl Street. At the time, the well-established gas companies dominated the lighting of homes and offices, while new enterprises were scrambling to promote electric arc lighting for public spaces and isolated power plants for incandescent lighting of individual homes and offices.

By 1892, however, Edison's system of centralized generation and broad distribution of electric power would almost seamlessly displace a gas infrastructure that had been entrenched in the city physically, economically, and politically for more than a half-century. In those fifteen years, Edison's system of electric lighting was transformed from a mere innovation into an institution, with its network of electric utilities companies, manufacturers and suppliers, investors, and customers (Hughes, 1983; McGuire, Granovetter, and Schwartz, 1993). For this discussion, we are interested in the critical early years during which the system of electric lighting primarily followed the form presented by Edison, between the summer of 1878, when Edison began work on the new technology, and 1886, when competing systems (particularly the advent of alternating current) revealed the new technology had rapidly grown independent from the man credited with its invention. Table 1 provides a timeline of notable events that tracks Edison's presentation of his system of electric lighting during this eight-year span.

Edison's successful introduction of incandescent electric lighting provides a unique opportunity to study the interaction between the design of an innovation and the institutions of an established social system. While Edison is most often credited with inventing the electric light, this legacy better reflects his success at creating the first broadly successful commercial system of incandescent lighting than it does his technical accomplishments. Electric lighting first caught the public's attention in 1808 and, by 1844, lit the Paris Opera (Bright, 1949; Conot, 1979). This early light, by arcing electricity across a small gap between conductors, created a lamp that was both brilliant and relatively short-lived, as the conductors burned constantly. Development of a less intense and longer-lasting incandescent light was underway as early as 1838, forty years before Edison's work, and by 1859 Moses G. Farmer had already developed a promising incandescent light (Conot, 1979: 120). Edison did not invent the incandescent light, nor did he invent the generators or distribution system that powered such a light (Conot, 1979; Hughes, 1983). Edison's success lay in developing a system of electric lighting that adapted and integrated each of these components and, as important, that gained rapid acceptance and provided the model for subsequent development of the technology. Our history of Edison's electric light, then, focuses not only on the technical accomplishments of his time but also on the means by which he succeeded in gaining acceptance for his particular design of the new technology.

Looking back from our well-lit offices and homes, across a vast range of electrical appliances, Edison's successful introduction of his system of electric lighting seems an inevitability, another case of technological progress sweeping aside an inferior incumbent. In 1882, gas jets lit offices and parlors with a sputtering and yellowish flame equivalent to a 12-watt

Table 1

Timeline of the Introduction of Edison's System of Electric Lighting

1878	September	Edison begins working on incandescent illumination, recording in one of his notebooks: "Object, Edison to effect exact imitation of all done by gas, so as to replace lighting by gas, by lighting by electricity" (Basalla, 1988: 48). Announces to the press that he has solved the problem of electric lighting. Gas utility stocks drop on news.
	November	Edison incorporates the Electric Light Co., to develop and market "all the inventions, discoveries, improvements and devices of said Edison, made or to be made, in or pertaining to Electric lighting, or relating in any way to the use of electricity for the purposes of power, or of illumination or heating; or relating to improvements in Electric engines or to the developing of electric currents by machines or otherwise, for any use or purpose, except electric telegraphy" (Israel, Nier, and Carlat, 1998: 712).
	December	A British parliamentary committee of inquiry concludes that the commercial production of incandescent lighting is utterly impossible. Gas utility stocks gain back previous losses.
1879	Oct.–Nov.	Edison's Menlo Park laboratory develops carbon incandescent lamp.
	December	Residents of New York experience first use of arc lamps to light city streets.
1880	April	Edison forms the Lamp Manufacturing Company to build carbon incandescent lamps.
	December	Edison Electric Light becomes Edison Illuminating Company, organized under existing gas statutes, enabling Edison to lay power mains beneath the city streets.
1881		The Board of Underwriters passes a resolution that all buildings with electric wiring are to be treated as "extremely hazardous" after workers are electrocuted by thinly insulated high-tension wires.
1882	March–August	Edison crews struggle to lay mains despite high power losses, exploding circuits, and occasionally electrified streets.
	September	Pearl Street station begins operation, where Edison unveils both the light bulb and centralized electrification system by illuminating Drexel, Morgan & Company in the financial district of New York City. At this time, Edison Isolated Electric has sold 153 units and has demonstrated profitability. By 1882, the number will grow to 702, nearly equalling the number of lamps lighted by Edison central stations.
	October	New York's six gas companies enter a price war, driving the price of gas down sharply.
1883	February	Edison acquires 508 subscribers, using a total of 12,732 bulbs, each costing $1.00. Edison's First District customers receive their electricity for free, as Edison fails to develop working meters until spring 1883.
	March	U.S. Illuminating Company, an arc-lighting company, granted charter for illuminating Manhattan below 14th Street from a power station located only blocks away from Edison's Pearl Street station.
1884	November	Gas companies consolidate to form Consolidated Gas of New York, driving down prices from an 1860 high of $2.50 per thousand cubic feet to slightly more than $1.05. Lighting by gas is now markedly less expensive than lighting by electricity.
	November	The New York State Legislature orders all telegraph, telephone, and electric light wires and cables removed from above ground; utility and communication companies ignore the law until 1888.
	December	Edison Illuminating Company declares a net profit of 6%, after losses of over $12,000 during the first two quarters after the Pearl Street station opens.
1885		The gas lighting industry introduces the Welsbach mantle, increasing both the candlepower and steadiness of the flame of gas lamps.
1886		Thomson-Houston, producer of equipment for Edison Illuminating Company, begins producing hundreds of alternating current (AC) alternators and thousands of transformers that prove more efficient and able to transmit electricity better over distances than Edison's direct current (DC) system. Westinghouse introduces system of electric lighting that uses alternating current electricity, taking significant market share from Edison Illuminating Company and instigating the withdrawal of Edison from the management of operations.

bulb. Gas and associated acids eroded the rubber and leather burner diaphragms of the lamps with alarming frequency and tragic results. The smoke from gas lights scarred walls and paintings alike, and the threat of fire was substantial enough for Harvard to close its library, Gore Hall, every evening before sunset, since Harvard authorities had refused to introduce highly flammable gas anywhere in the building (Silverberg, 1967). To make matters worse, early in the century, New York City, where Edison chose to introduce his new system, had granted each gas company in Manhattan its own local territory and, hence, high profits from monopoly pricing. By comparison, the electric light promised both better performance, with its clean white light, and a lower cost than the incumbent system of gas lighting, and the benefits of the new technology were already highly visible in the public spaces now lit by electric arc lighting. While Edison was working the bugs out of his system of incandescent light for indoor use, gas stock prices were falling, and one newspaper reporter even rejoiced in the intense discomfort Edison's work caused the powerful interests of the gas monopolies, calling him the "benefactor of the human race" (*Brooklyn Daily Eagle,* 1 Dec. 1878; in Israel, Nier, and Carlat, 1998: 736). And, as early as November 1878, several gas companies had already discretely enquired about licensing the new system (Israel, Nier, and Carlat, 1998: 734). From the perspective of the new technology, the world was ready to beat a path to the door of Edison's Menlo Park laboratory.

But the story is not that simple. However bright the future of incandescent lighting appears to us now, in 1882 Edison's system still had to tackle a rather formidable rival. The existing gas industry was not only well established, gas was inextricably woven into the city's physical and institutional environments. New York first lit its streets using gas lamps in 1825; by 1878, gas companies in the U.S. had a capital investment of approximately 1.5 billion dollars. In New York, these companies had integrated themselves deeply within the city's social, economic, political, and physical infrastructure, from their many gas mains buried under the streets to their extensive corps of city-employed lamplighters, to their powerful influence over the aldermen and mayor of New York—the political machine of Tammany Hall (Hughes, 1983). When Edison introduced his competing system of electric lighting, gas lighting was more than an incumbent technology, it was deeply embedded in a web of suppliers, consumers, regulatory agencies, competing firms, and contributory technologies (Silverberg, 1967). From an institutional perspective it is difficult to understand how Edison was able to introduce his innovation and how he was able, in so short a span of time, to overthrow the existing system and institutionalize his own, yet he did.

The Established Institutions

The gas industry had become a highly institutionalized field in the half-century since it overturned oil lamps and candles as the dominant system of lighting. Like its successor, gas lighting technology faced early difficulties in displacing the existing institutions. Gas first lit the streets in New York in 1816 in an experimental effort that was soon banished by the established and threatened interests of candle makers and the whalers supplying whale oil (Granick, 1975). In 1825, however, it made a second and lasting appearance, and gas was soon manufactured in plants located on the edge of Manhattan, close to the coal barges that supplied them, and piped under the city streets, into buildings, and finally through walls and floors into lamps mounted on ceilings and walls, where residents used the sputtering yellowish light to read and work. This system divided the market into territories, creating monopolies supplied by a cadre of gas companies (Silverberg, 1967). The profits these monopolies provided, in turn, lined the pockets of the politicians of Tammany Hall who oversaw their regulation. In stable and more highly institutionalized fields, as Scott (1998: 129) argued, "there is a high consensus on the definitions as to who the critical players are, what activities and interactions are appropriate, and which organizations are included, marginal to, or outside field boundaries." The actors that participated in the production and consumption of gas for lighting, as both individuals and organizations, had all the makings of such an institutionalized field, extending from the coal manufacturers to the city-employed lamplighters, and including suppliers, customers, politicians, and investors alike.

Institutional theory suggests that the established interests of such an industry would not go softly into the technological night, and reactions to Edison's proposed system of electric lighting do reveal the institutionalized nature of the incumbent technology and its resistance to such change. Such resistance takes two forms: institutions constrain behavior through normative and regulatory environments that promote stability and suppress change through rule-setting, monitoring, and sanctioning activities (Scott, 1995) and by providing the very understandings, interests, and actions of actors that constitute behavior. The regulatory environment of utilities in New York, where Edison first introduced his system, was both developed for the existing gas-lighting industry and manipulated by those same interests. When Edison first applied for an operating license, the mayor of New York flatly opposed even granting the company an operating franchise. When that opposition failed, in large part due to Edison's backing by financiers from powerful Drexel, Morgan & Company, the Board of Aldermen proposed Edison pay $1000 per mile of wiring and 3 percent of the gross receipts (Conot, 1979: 184). Ultimately, however, the fee was reduced to $52.80 per mile. Gas companies, by comparison, were permitted to lay their mains for free and paid only property tax to the city.

Further, in ways reminiscent of Selznick's (1949) study of the Tennessee Valley Authority (TVA), Edison may have attempted to co-opt the established gas interests by bringing them in as investors in his own venture, but those co-opted in turn sought to control the development of the new system. William Vanderbilt, for example, was one of Edison's largest investors and also the largest owner of natural-gas stock in America, having bought Edison Electric Light Company stock as a hedge against this new technology (Freidel and Israel, 1986; McGuire, Granovetter, and Schwartz, 1993). Together with J. P. Morgan and other investors, Vanderbilt argued forcibly against Edison's design of the electric system after the centralized production model of existing utilities, preferring instead the alternative of isolated systems, which consisted of selling small generators, wiring, and lights to individual customers, who would produce electricity locally in homes, office buildings, and ships. Only by threatening to resign from the new venture did Edison retain his design choice, though this defiance significantly weakened Edison's future control of the enterprise (McGuire, Granovetter, and Schwartz, 1993).

Institutions also resist change by constituting the understandings, interests, and actions of actors, providing the institutional logics from which individual thought and action is constructed (Friedland and Alford, 1991; DiMaggio, 1997; Dacin, Ventresca, and Beal, 1999). These logics provide the cognitive models for interpreting situations, identifying valued ends and possible means, and initiating actions. In essence, they become the basis for defining the legitimate and illegitimate actions that inspire normative and regulative sanctions. The difficulty in overcoming this resistance, as Douglas (1986: 98) argued, stems from "the high triumph of institutional thinking . . . [in making] institutions completely invisible." These logics operate in part by identifying what is not possible, as Edison discovered when he initially unveiled his plans for a system of incandescent lighting. A British parliamentary committee of inquiry had concluded in 1878—several months after Edison publicly announced his intentions and after a lengthy set of consultations with Britain's leading scientists and physicists—that the commercial production of incandescent lighting was utterly impossible and that Edison demonstrated "the most airy ignorance of the fundamental principles both of electricity and dynamics" (Conot, 1979: 129–133). Closer to home, leading American scientists were expressing the same beliefs. Newly established arc-light inventors and manufacturers also publicly warned that Edison's plans were "so manifestly absurd as to indicate a positive want of knowledge of the electrical circuit and the principle governing the construction and operation of electric machines" (Conot, 1979: 162). In 1878, few believed Edison's system of electric lighting was even possible, let alone practical or commercially viable, and the early history of the innovation does little to dispel this view.

The Emerging Innovation

With Edison's new system, brown-outs and black-outs were frequent, along with breakage and, at times, sparking and fires from short circuits and poor wiring (Basalla, 1988). The new system was relatively low in complexity, however, and when it worked, users required little expertise to light their homes or offices. Moreover, potential users could easily observe Edison's invention operating in neighboring houses or in local businesses and experiment with the system at Edison's headquarters prior to subscribing. The simplicity of turning lights on or off and the still dim light emanating from Edison's 12-watt bulbs, however, scarcely differed at the time from users' intimate familiarity with the long-established gas system.

While the technology of electric lighting had existed for almost 75 years, commercial use of electric lighting had only been visible to New Yorkers in the few years before Edison threw the switch at the Pearl Street station. Two years earlier, in 1880, Charles Brush began using arc lamps to light New York streets. Less than six months after Edison began lighting the offices of Wall Street, the newly unveiled Brooklyn Bridge was lit with arc lights provided and powered by the U.S. Illuminating Company. Within a year, the U.S. Illuminating Company would light Lower Manhattan's parks and major thoroughfares, some of them from a central power plant situated mere blocks from Edison's Pearl Street station. This observability, however, worked both for and against Edison's innovation. Misunderstandings and real dangers surrounding the new technology were nearly its undoing. Press coverage of the competing systems of gas lighting, arc lighting, alternating current (AC), and direct current (DC) fueled newspaper accounts of "Electric wire slaughter," "Electric murders," and "Another corpse in the wires," causing New York City Mayor Abraham Hewitt to petition utilities to strip high tension wires from their poles (Nerney, 1934: 122). When ice storms felled telegraph poles and wires throughout the city, mounted firemen roamed the streets warning pedestrians about the danger of live wires. As observable as the benefits of electric lighting may have been in the early 1880s, its dangers, which included occasionally electrified streets and electrocuted workers, were still more visible. Such conditions would have obscured many of the relative advantages of Edison's innovative system that are so clear today.

Where the economics of his system were concerned, Edison's prospects for displacing the established systems seemed even worse. Centrally powered incandescent lighting required enormous capital investments for constructing generating stations and for laying wire around the city and into buildings. Strikingly, Edison's insistence on adapting to the role expectations of a utilities provider was not a reflection of advantages inherent in the new technology. While gas production could be located at a distance from its customer, under Edison's system, the distribution of electric power was limited to within a half-mile radius of each generating station. According to his own calculations for a generating plant the size of the Pearl Street station, the costs of the copper conducting lines alone came to over a third of the total capital investment needed for the entire plant (Hughes, 1983: 39). Later technical improvements, namely, alternating current, overcame these limitations but were so far from inclusion in Edison's plans that he would later sacrifice much of his market position, his role within the Edison companies, and, ultimately, his reputation to fight the shift to AC current.[2]

Further, many of the residences and offices in Edison's First District had been designed around the gas system: gas jets and lamps functioned as intrinsic fixtures in most buildings erected after the 1830s. And like any company proposing an entirely new system, Edison Illuminating faced enormous capital costs for each consumer it pried from the existing gas network (Silverberg, 1967: 193–194). To wire a building for electricity, Edison had to pull up floors and snake wires around doorways, a skill at that time known only, and incompletely, to installers of burglar alarms (Conot, 1979: 187). So short was the supply of qualified laborers that, over the first few years, Edison lobbied local schools to develop training programs in electrical engineering and, when that initiative fell short, started his own training program (Israel, 1998).

Less than a month after Edison first lit the boardroom at Drexel, Morgan & Company, the six gas companies of New York City waged a fierce price war, driving prices down sharply. Within two years, the six would join to form Consolidated Gas in a further effort to battle the encroaching threats from both arc and incandescent light companies, as well as

2
The competing technological standards of Edison's low-voltage direct current and Westinghouse's high-voltage alternating current began with Westinghouse's 1886 introduction of AC equipment. High-voltage AC sustained little power loss over great distances, making it an appealing design for the centralized production and broad distribution of electric power. While popular stories talk of Edison's resistance to AC, in fact he merely objected to its technical specifications, having himself patented an alternative AC design (Israel, 1998). Nevertheless, the battle between Edison's DC standard and Westinghouse's AC was waged in the court of public opinion. AC's victory, independent of technical merits, merely signaled that Edison no longer controlled the design of the system of electricity production and lighting.

from the emerging kerosene lamp industry. In 1885, as a response to the incandescent bulb, the gas industry introduced the Welsbach mantle, an asbestos bag that fit over existing lamps that changed the flickering of the faint, yellow glow into a clean, white light and provided a six-fold increase in the candlepower of gas lamps. As a result, early electricity was far more expensive than gas light, yet its superiority remained uncertain (Millard, 1990). To meet the challenges of both the technology and the powerful gas industry, Edison worked to develop a robust design.

ROBUST DESIGN AND THE ELECTRIC LIGHT

McKinley, Mone, and Moon (1999) described how organizational scholars must couch novel ideas within existing theories to gain acceptance by the academic community. Edison's strategy and its success suggest that innovators may similarly foster the adoption of their ideas by designing the concrete details of their embodiment to embed them within—rather than distinguish them from—the established social system they seek to change, creating a robust design. The risk in such a strategy is that presenting the new in terms of the old may encourage understanding and adoption but may constrain the public to only those existing understandings and uses and, by doing so, suppress the evolutionary potential inherent in the new technology. An innovation's design is robust when its arrangement of concrete details cues schemas and scripts that are immediately effective in the short term, by invoking preexisting understandings, but that do not constrain us to only those existing understanding and actions, instead allowing us to discover new ways to interact with the new ideas as our understandings evolve. So the challenge for developers of an innovation lies in pursuing robust designs—in deciding which details to present as new, which to present as old, and which to hide from view altogether.

To demonstrate the superiority of his new system, for instance, one might have expected Edison to present it in ways that distinguished it as much as possible from the existing gas system he aimed to displace, and, in ways, he did. For example, on September 16, 1878, within a month of turning his attention to the electric light, Edison exploited his existing fame as an inventor to announce publicly in the *New York Sun* that he had "discovered how to make electricity a cheap and practical substitute for illuminating gas" (Israel, Nier, and Carlat, 1998: 502). From the beginning, he presented the innovation as far superior to gas, in which "the same wire that brings the light to you will also bring power and heat—with the power you can run an elevator, a sewing machine, or any other mechanical contrivance, and by means of the heat you may cook your food" and all at "a fraction of the cost" (Israel, Nier, and Carlat, 1998: 505). He even incorporated his Electric Light Company with the broad purpose of developing and marketing any invention, except telegraphy, that could use electricity (Israel, Nier, and Carlat, 1998: 712). And four years later, when he finally offered a working system, he chose the offices of Drexel, Morgan & Company to demonstrate to the world his first commercial power plant. These offices were a highly visible feature of Manhattan's financial district and mere blocks away from the heart of New York's newspaper district, both sources of much-needed support for Edison's entrepreneurial endeavor (Conot, 1979; Hughes, 1983; Millard, 1990).

At the same time, Edison also strove to wrap his lighting system as tightly as possible in the trappings of the existing system. So while Edison's notebooks reveal that he envisioned an entire constellation of electric gadgets that would one day be powered by his burgeoning electrical system (Conot, 1979), he deliberately designed his electric lighting to be all but indistinguishable from the existing system, lessening rather than emphasizing the gaps between the old institutions and his new innovation. Closer examination of these design choices makes his decision to mimic gas seem more dependent on social than technical considerations.

To begin with, Edison chose to generate electricity centrally, like the established gas companies, and distribute it to individual homes and offices. The design decisions surrounding Edison's choice of centrally produced electricity were not the only ones available to him nor, by many accounts, the most promising. When Edison famously threw the switch to light J. P. Morgan's downtown offices with his new Pearl Street generating station, Morgan's uptown mansion was already lit with an Edison Isolated Electric system. The Edison Company for Isolated Lighting was by 1882 already a relatively successful business, manufacturing and selling isolated electric lighting systems to hotels, ships, factories, and large homes (McGuire, Granovetter, and Schwartz, 1993; Israel, 1998). As McGuire, Granovetter, and Schwartz (1993) argued, this alternative design held equal potential for development, avoided the need to lay main lines, or conduct centrally generated electricity over distances and was more attractive to Edison's investors, as it provided faster returns on less capital investment. But Edison chose instead to pursue the gas industry's system of centralized production and distribution. By supplying electricity centrally, Edison presented to the public a lighting system already familiar to them and hid from view the enormous capital resources and specialized expertise needed to negotiate the uncertainties of the emerging technology.

Edison's earliest sketches and pronouncements reveal that, in putting electricity into homes, he sought to exploit elements of the existing gas system as completely as possible. For example, he described how his new system would "Utilize the gas burners and chandeliers now in use. In each house I can place a light meter, whence these wires will pass through [existing gas pipes in] the house, tapping small metal contrivances that may be placed over each burner" (Israel, Nier, and Carlat, 1998: 504–505). While it proved impractical to embed his new technology within the physical artifacts of the old system, Edison pursued similarities with the existing system in other ways. According to Edison's notebooks, his object was "to effect exact imitation of all done by gas so as to replace lighting by gas with lighting by electricity . . . not to make a large light or a blinding light but a small light having the mildness of gas" (Basalla, 1988: 48). So although the glow shed by Edison's light was both steadier and clearer than gas, its brightness was the same. Gas jets produced the equivalent of a 12-watt bulb, one of the very inadequacies of gas lighting that had initially drawn inventors like Edison to the challenge of designing incandescent bulbs, and this dim light was made worse by the lampshades required to shield its guttering flame from drafts. Yet Edison's light bulbs provided a mere 13 watts—a light still not adequate for reading or office work—despite early prototypes that, according to Francis Upton, "gave a light of two or three gas jets" (Israel, 1998: 186). Crowned by a now-superfluous lampshade, Edison's incandescent lights created an overall effect so similar to gas lighting that, as the *Times* reported, scarcely anyone would realize rooms were lit by electricity (Silverberg, 1967).

For distribution, Edison insisted on burying his electric lines under the ground like water and gas mains, rather than overhead, as was the model for telephone, telegraph, fire-alarm, and arc-lighting companies (Silverberg, 1967: 173). Here, Edison was explicitly following the precedents of the utility companies, rather than existing electric technologies, arguing, "Why, you don't lift water pipes and gas pipes up on stilts" (Basalla, 1988: 48). Yet city statutes forbade the Edison Electric Company to lay its conducting mains in the ground, since only utilities companies were accorded the right to dig up city streets (Silverberg, 1967: 155–157). In response, Edison formed the Edison Illuminating Company, under New York gas statutes, as a gas company to obtain the necessary legitimacy and use the established practices of the gas industry. This system design was robust in that it triggered an existing and institutionalized response allowing Edison to dig in city streets while it also retained the flexibility to bury copper wire, rather than gas or water mains. Surprisingly, Edison's efforts to bury underground electric mains were not driven by immediate technical advantages because, when buried, the bare copper wires leaked electricity and blew out entire circuits. Even when Edison's crews encased the wire in wooden molding, they were unable to prevent high power losses.

Edison's careful masking of the new electric lighting system within the trappings of the old gas system also cost Edison Illuminating and its investors directly. Edison insisted on using meters to bill customers for usage, based on the easily read gas meters long used by the city's gas companies, despite the fact that he had yet to devise a means of measuring electricity usage with such devices. As a result, Edison's earliest clients enjoyed six months of lighting absolutely free (Conot, 1979: 198). Until Elihu Thomson's invention of the mechanical meter a decade after Edison Illuminating began business, Edison relied on zinc sulfate meters that remained a cipher to mistrustful consumers and froze whenever temperatures dipped below 40 degrees (Silverberg, 1967: 189). Monitoring usage was also a problem in the early days of the gas industry, when companies lacked effective means of monitoring usage and, instead, billed their customers by the lamp, a practice similar to the public's previous experiences with candles and oil lamps. While the option existed to charge customers by the lamp for their use of electricity, it is possible that such a solution might have conflicted with Edison's vision of the many other appliances that electricity might one day power.

Now, over a century later, Edison would likely still recognize the dominant technologies in the production of electricity (e.g., coal and gas-powered steam turbines driving dynamos) but would barely grasp the novel products that electricity now powers. Perhaps one way to recognize the robust nature of Edison's design is to juxtapose this environment of stability and change with the conditions that widespread use of isolated systems might have produced. McGuire, Granovetter, and Schwartz (1993: 218) described how J. P. Morgan's original vision "was an industry composed of scores of manufacturers, each producing its own line of electricity production and distribution equipment." Within such an alternative technological environment, we might find more evolution in the nature of the production systems themselves, yet more stability in the range of electric appliances available. Freed from the enormous capital investments required of central production plants, the technologies for locally generating and storing electric power would likely evolve through successive generations more rapidly. Conversely, bound by the plurality of production equipment that would exist, the evolution of electric appliances may have required, like today's personal computers and peripherals, considerably more attention to the requirements of integrating with other local components than we now experience. Despite such conjectures, it can safely be said that our understandings and patterns of use have evolved relatively significantly from the idea of electricity as a means for lighting parlors and streets. And it can be safely said that this evolution has happened more (despite our fleeting enthusiasm for nuclear power) in the means by which we consume electricity than by which we produce it. The direction of such evolution, it would seem, owes its roots in large part to Edison's design choices.

UNDERSTANDING DESIGN AS DESIGNING UNDERSTANDING

The need to ground innovations in the existing understandings of established social systems has existed long enough for anthropologists to have labeled the design details that result. Skeumorphs are those elements of a design that serve no objectively functional purpose but are essential to the public's understanding of the relationships between innovations and the objects they displace (Basalla, 1988). For example, many design features are merely vestiges of structural details once essential to the construction and function of earlier versions, including the carriage lights next to the doors of luxury cars that remain from the automobile's predecessor, the wood veneer detailing that covers the plastic surfaces of televisions and radios, and even the garbage can icon that sits upon computer "desktops"—not to mention the desktop itself. Within these elements lie insights into the cognitive mechanisms at work in robust design. Because they serve little objective function, skeumorphs also provide few objective constraints: they serve as subjective signposts that signal one possible interpretation of and one way to use a new technology without precluding others.

It is the job of architects and industrial designers to be good at understanding and manipulating these cultural symbols through the design of an innovation. The industrial designer Raymond Loewy always argued that design should be the "most advanced yet acceptable" form, recognizing implicitly that good design should neither deprive the public of the familiar features necessary for understanding and use nor bind the innovation too closely to established institutions. Similarly, J. Mays, designer of the reintroduced Volkswagen Beetle, insisted the car was new while admitting its exploitation of past meanings: "The design is new—not a single detail comes directly out of the past—but no one can mistake the shape for anything other than an allusion to a treasured icon" (Goldberger, 1999: 30). Likewise, the success of early postmodern architecture, like the buildings designed by Robert Venturi, succeeded in large part because they were "intended not to replicate history literally but only to allude to it" (Goldberger, 1999: 32). Edison succeeded by embodying his innovative ideas in designs that were robust enough to exploit the existing institutions of a social system without being confined by them. Lampshades, burners, gas statutes, and metered billing all presented the public with clear signals of how to interpret and interact with Edison's new technology, but none precluded the diverse evolution that would soon follow. To maximize understanding and use while maintaining future evolutionary flexibility, much of the signaling in robust designs should be invested in features that serve little or no objective function while retaining those objective features that provide the foundation for the envisioned future.

Skeumorphs reveal how design mediates between technologies in the abstract and the social systems in which their use is embedded. Understanding the role of design in mediating between innovations and institutions requires recognizing the interdependent relationship between the technical and social aspects that constitute an innovation. Embedded within every technological system is a set of technics—fundamental physical materials, their properties, and the details of their use (Mumford, 1934). For example, coal lies at the core of the system of gas lighting that Edison sought to replace. When heated, coal gives off a flammable gas that burns relatively cleanly and is easily transportable. By 1882, these materials and properties (and others) were embedded in a complex system of gas production, distribution, and use. For Edison to overthrow the existing system of gas lighting, he needed to do more than simply devise a way to produce light that was cleaner, cheaper, and more transportable than gas. He had to overcome the institutions—the existing understandings and patterns of action—that had, over the fifty years of the gas industry's existence, accreted around these fundamental physical properties and now maintained the stability of the gas system.

The technics and institutions of complex social systems like the gas lighting industry constitute a network of actors and physical objects whose relationships are given meaning by a set of surrounding understandings and actions (Callon, 1989; Law, 1989). When a new technology emerges, a social process follows, crystallizing understandings and actions around the technics at its core (Barley, 1986; Garud and Rappa, 1994). The longer the technology persists, the more embedded it becomes within a set of shared understandings and actions (Tolbert and Zucker, 1983; Giddens, 1984; Barley and Tolbert, 1997). On top of these shared understandings and actions, further layers of actors, interests, and opportunities accrete until a "technology becomes reified and institutionalized, losing its connection with the human agents that constructed it or gave it meaning, and it appears to be part of the objective, structural properties of the [larger social system]" (Orlikowski, 1992: 406). What embeds technics within the social systems surrounding them are the understandings and patterns of action that make up each individual and organizational relationship to those technical details and, through those details, to other individuals and organizations. At a certain point, these institutions become as real as the technics at their core.

Robust Design beyond the Electric Light

The role of design is then to arrange the concrete details that embody an innovation in ways that construct people's interpretations of novelty from pieces of what are old and familiar to them. What makes this process so perilous is that the novel and the familiar must merge together in ways that neither bury the novelty nor shed the familiar. Innovations that distinguish themselves too much from the existing institutions are susceptible to blind spots in the public's comprehension and acceptance, particularly those innovations viewed as radical or discontinuous. But innovations that hew too closely to particular understandings and patterns of use may incite resistance or assimilation into the current technological environment. Two examples of less successful innovations may illustrate these dangers; the first is Edison's own experience in developing the phonograph just prior to his development of the electric light.

When Edison began working on the electric light in 1878, he was at the peak of his efforts and fame as inventor of the phonograph. Edison's experience with the phonograph not only reveals the dangers of dealing with a truly novel innovation but may also have determined his subsequent strategy in designing the electric light. While the electric light had the gas lamp, the phonograph had few recognizable antecedents, and when Edison introduced the phonograph, he also provided a list of ten possible uses for the device. The uses, listed in order of descending importance, ranked Edison's own preference first—taking dictation without the aid of a stenographer—followed by talking books for the blind, teaching public speaking, reproducing music, and recording telephone calls (Basalla, 1988: 140). Despite its immediate reception as a marvel and, with it, the public's recognition of Edison as an inventive genius, the phonograph would languish all but unused for nearly twenty years before other inventors produced versions designed to achieve only the fourth use, reproducing music. Only as the beginnings of the lucrative recording industry took shape in the mid-1890s did Edison—who had once admitted to an assistant that his phonograph lacked "any commercial value"—stop insisting that its primary purpose was taking dictation (Conot, 1979). Edison rigidly presented the phonograph as an electric stenographer, an image that at the time exploited a limited set of established schemas and scripts. Baron S. M. Rothschild, a potential investor in the electric light, worried that the new idea would meet the same fate when he wrote, "It would greatly interest me to learn whether really there is something serious and practical in the new idea of Mr. Edison, whose last inventions, the microphone, phonograph, etc., however interesting, have finally proved to be only trifles" (Conot, 1979: 129). Perhaps Edison, too, was mindful of this experience when he designed his system of electric lighting in ways that clearly placed his ideas within a set of strongly established understandings and patterns of use.

The second, and more recent example concerns the design of Prodigy, the online service aimed at the "casual home users who are not computer types but have a computer at home" (Getts, 1990: 72). Sears and IBM invested $600 million to create the service, which debuted in November 1989, offering banner advertising, electronic bulletin boards (BBS), e-mail, and the first online Volkswagen and Mercedes showrooms. Yet while Prodigy had all the technical features of today's major Internet service providers, like America Online, Prodigy executives designed the system to match closely a particular set of understandings and patterns of use. For them, the service was a means of selling advertising, merchandise, and the online service itself (including surcharges for e-mail services). Unfortunately, advertising and online information proved obtrusive and annoying to users intent mainly on contacting others electronically via e-mail and BBSs. E-mail and online forums likewise annoyed Prodigy executives, who hoped to sell both advertising and online information to users.

The service may well have thrived but for Prodigy executives' insistence that users adopt their particular schemas and scripts for using the online service. In a well-publicized incident, Prodigy users who banded together to protest the e-mail surcharge via mass e-mailings and messages posted to one electronic forum had their subscriptions cancelled. Immediately after canceling the subscriptions, Prodigy issued guidelines that directly determined the use of its online services, including prohibitions against contacting merchants for anything other than questions about orders and e-mailing requests for members to contact other Prodigy members (Getts, 1990; Lee, 1990a, 1990b). In protest, 3,000 members immediately changed their online service to GENie. Prodigy, the online service that initially offered everything the most sophisticated services would take more than another half-decade to match, languished, enabling fledgling online services like CompuServe and America Online to flourish. The mismatch between the particular set of understandings and interactions that Prodigy executives had designed and what the users wanted ensured that Prodigy soon lagged at the back of a growing pack of competitors, evolving little from its original form.

Like Edison's phonograph, Prodigy's failure was made prominent by the successes of those systems that soon followed, suggesting that the relationship between an innovation and the institutions it seeks to change is a complex one. When innovations are designed to succeed only within a narrow set of understandings and patterns of use, the price is often failure. Even the most radical innovations, in terms of their impact on our understandings and our lives, may require humble origins to gain the public's acceptance. The changes that electricity wrought emerged only as the public's conception of the new technology shifted from understandings and patterns of use based on their existing schemas and scripts for gas lighting to new understandings and uses that emerged from the different details and possibilities of the new technology. Had Edison, like Prodigy's managers, insisted on shaping those new understandings or uses directly, his system might have met fatal resistance.

Robust design is also a challenge in emerging innovations whose ultimate evolution and impact are not yet appreciated, let alone known. In these situations, the value of a robust design perspective is not in the explanations it provides for what happened but, rather, the strategic design questions with which it frames an unfolding process. The digital video recorder offers one such example. In 1999, TiVo introduced the digital video recorder into the U.S. market.[3] This technology marries components and concepts from the personal computer and the videocassette recorder (VCR) and, initially at least, enables users to easily program, record, and replay television programs in digital format. This simple explanation belies a more complex interaction between the innovation and the existing institutions it currently faces, because TiVo's founders envision ultimately revolutionizing the ways that viewers, networks, and advertisers interact.

The original developers of digital video recorders face significant hurdles, however, in achieving their vision. In the short run, TiVo's products must generate rapid and widespread adoption to offset the considerable initial capital investments and ongoing costs to maintain the system that supports them. To gain rapid acceptance, TiVo must provide the market with a clear understanding of the purpose and value of its product. To do so, it can exploit the very well-established understandings and actions surrounding the VCR and television industry. In the long run, however, the founders of TiVo envision a system that does more than replace existing technologies while leaving old habits unchanged. Instead, they believe TiVo can fundamentally change the way viewers, networks, and advertisers relate to each other by giving more control of the content to viewers, greater knowledge of viewer habits to networks, and more accuracy to advertisers seeking target audiences. To achieve this vision, TiVo's products must retain the flexibility to evolve beyond the established understandings of the VCR if they are to accomplish their objectives. In this way, the TiVo case offers a useful counterpoint to Edison's electric light. While the Edison case reveals the need to ground novel technologies in existing institutions, the TiVo case reminds us that, despite this need, innovations must still be presented as novel and compelling. Robust designs must strike a balance between these competing needs, yet TiVo offers a technological innovation whose design so easily invokes our existing under-

3
At the same time, ReplayTV (known then as Replay) also introduced a similar version of the technology. In the spring of 2001, TiVo was awarded the patent for this device. So, while ReplayTV has an equal stake in the adoption and evolution of these devices, for the sake of simplicity this discussion focuses on TiVo.

standings about the VCR that it may be unable to set itself apart from and evolve beyond those established institutions, despite its potential to alter our relationship to the television dramatically.

The digital video recorder provides a very interesting case study for several reasons. First, the digitization of the VCR is not the overarching vision of the entrepreneurs who developed this technology, nor will it likely be the ultimate impact. On the one hand, digital video recorders do make it possible (by making it simpler and easier) for users to do what VCRs originally promised to do: recording and replaying television. This by itself significantly changes the habits of television viewers—as the notions of prime-time television, commercial breaks, and other tyrannies of television scheduling come under the discretion of the viewer. On the other hand, TiVo's technical capabilities enable considerably more opportunities to change the way television is broadcast and viewed than simply achieving what the VCR promised. TiVo offers a subscriber service to download local television schedules that users can peruse online, selecting particular shows to record once or each time they appear. This service links each TiVo box to a central database that is already evolving to provide "showcases" of particular networks or movie previews. Further, TiVo has formed alliances with Blockbuster Video and with AtomFilms (a maker of short films) to use this service to download movies and other content in ways that resemble the Internet more than the television. Finally, TiVo boxes track each customer's viewing patterns, data that will allow TiVo to offer customized advertisements and other content to particular viewers' interests, again, more like the activities of customized advertisements and offerings one might see at Amazon.com. TiVo's strategic vision, then, is to extend considerably beyond the existing understandings and actions surrounding the VCR. Jim Barton, one of the co-founders of TiVo, for example, hopes one day that the technical components—the digitizing hardware and software—will come integrated with television sets or cable boxes: "We'll know we've succeeded when the TiVo box vanishes" (Lewis, 2001: 168).

Second, TiVo is basically a computer and modem and, as such, has the technical capabilities to evolve beyond the VCR. Marc Andreesen, the founder of Netscape, described these new machines as "The Trojan horse for the computer industry to gain control of the entertainment industry" (Lewis, 2001: 169). TiVo runs on a Linux operating system, which is open-source software, meaning that the code is widely available, and a growing community exists that can contribute new features or revise and patch old ones. Already, there is an online community of TiVo hackers who discuss the changes and upgrades they have developed for their TiVo boxes. Also, TiVo uses many off-the-shelf computer components, enabling people to swap disk drives and other components. In many ways, these features enable users to participate in the evolution of functionality and features of TiVo and, to date, TiVo has not attempted to shut down or direct these avenues of exploration. So the technologies underlying TiVo carry with them significant potential beyond their use as a smart VCR.

Finally, TiVo follows a product that is very well understood and yet whose original intentions were never quite realized. The VCR was introduced to the market with considerable claims (and concerns) that it would overthrow the existing relationship among network television shows, the viewers that watched them, and the advertisers who sponsored them. The VCR made it possible for viewers to tape shows, skip commercials, and trade tapes in ways that undermined the economic relations that bolstered the system. Yet these concerns were misguided. Users never substantially changed their understandings and actions to make use of the "recorder" in videocassette recorder—the technology is used instead primarily for renting and viewing movies on television—and the blinking clock has become a well-worn example of how engineers' dreams often overshoot customers' abilities. For the digital video recorder, the VCR offers a set of preexisting schemas and scripts that provide instant recognition, yet a relatively limited set of uses. From the perspective of robust design, how the new technology locates itself relative to this predecessor and others becomes a critical design challenge for both its adoption and evolution.

Thus TiVo faces the issue of robust design, of determining which features of its new technological system to present as new, which to present as old, and which to hide from view altogether. Because widespread and rapid adoption is necessary to TiVo's strategy, TiVo introduced its product as an advanced generation of VCRs, a concept quickly and easily grasped by customers, network executives, and advertisers alike. Its boxes share the form, are manufactured by the same vendors (e.g., Sony and Philips), are sold in the same stores, and are intended to sit next to existing VCRs in users' living rooms. Further, public descriptions expressly evoke functions and values associated with the VCR. As TiVo President Mike Ramsay says, "TiVo gives people the control and convenience they need, so at the end of a busy day all they have to do is sit down in front of the television and watch what they want to watch, right when they want to watch it" (TiVo, 1999). Such words would just as easily describe the existing technology, or at least its promises.

In the same way that TiVo draped its innovation in the language of old understandings and actions surrounding the VCR, it also hid some potentially distinguishing features from view altogether. For example, because these new digital recorders require the cooperation of the television networks for the new services they offer (both providing scheduling to users and selling viewing data to networks and advertisers), TiVo chose to downplay some of the advances that might distinguish them from the old technology. For example, Lewis (2001) described how TiVo chose not to include the ability to skip commercials automatically in digitally recorded shows. TiVo's nearest competitor, ReplayTV, did include this feature but expressly promised the networks they would not advertise it. TiVo's Ramsay explained, "Advertising the ability to skip commercials is on the other side of the line. We designed the technology so that it doesn't infuriate the networks" (Lewis, 2001: 172). Additionally, TiVo's product's similarities to the computer are absent from its product design, its marketing material, and the public statements of its entrepreneurs.

The biggest challenge facing TiVo then appears to be presenting its product as new, setting it apart from the existing understandings and actions surrounding the VCR. One technology reviewer went so far as to welcome Microsoft's entry into the digital video recorder market as bringing the necessary resources to defray the cost of educating the public about what the new technology can do (Taylor, 2001). Because, while exploiting similarity with the VCR has provided TiVo with instant understanding for customers, network executives, and other powerful actors within the industry, it does not offer a compelling glimpse into the potential for change. It could be argued that TiVo's ability to track viewer behavior represents a critical design feature that sets it apart from the VCR and other components of the television industry and should offer both networks (and their advertisers) a compelling vision of new opportunities, but TiVo and its competitors have not yet succeeded in presenting their products to the general public in ways that suggest people should abandon their VCRs for the new technology (e.g., Taylor, 2001). TiVo's story reveals how institutionalized understandings and actions surrounding existing technologies serve as both opportunities and barriers in the innovation process. As of this summer, after four years, TiVo had 400,000 installed units, in contrast to the 21 million cable boxes now in homes. Unless TiVo and its current rivals can succeed in attracting customers, the future of TiVo may resemble that of other pioneering innovators who martyred themselves in educating the customer for the benefit of later entrants into the market.

CONCLUSION

By imitating the features of gas lighting, Edison sought to displace the technology of gas lighting without requiring dramatic changes in the surrounding understandings and patterns of use. Their preexisting schemas and scripts for gas lighting, after all, shaped how customers, regulators, even investors would quickly identify the new innovation and easily understand how to use it. So despite his vision of a new electric world of lighting and household appliances, Edison purposefully hobbled his innovation to fit cleanly within the technical roles currently given to gas. By mimicking virtually every aspect of the familiar gas system, save for its noxious fumes, Edison ensured his users would both recognize the purpose of his innovation at the outset and know without reflection how to use it in their everyday lives.

The battle between a new system for lighting homes and offices with electric lights and the established institutions that made up the gas industry may not have been won by virtue of an overwhelming and obvious technological superiority. While the promise of technological superiority may have loomed on the horizon, according to Edison's own notes and enacted strategies, the battle seems to have been won, instead, by minimizing the differences between the upstart technology of electricity and the existing system. Though incandescent light debuted more than a century ago, the dilemma Edison faced is a common one among designers of new products and processes. The old adage, "Build a better mousetrap and the world will beat a path to your door," may be more optimistic than realistic. Edison, for instance, might well have learned from the phonograph that the public is not interested in beating any new paths when confronted with an entirely novel innovation. Instead, entrepreneurs might find it more profitable to build their new enterprises on some already well-traveled paths.

For entrepreneurs attempting to introduce novelty within or outside organizations, this history suggests they should choose their designs carefully to present some details as new, others as old, and hide still others from view altogether. The challenge ultimately lies in finding familiar cues that locate and describe new ideas without binding users too closely to the old ways of doing things. As new technologies emerge, such as the Internet, entrepreneurs and innovations must find the balance between novelty and familiarity, between impact and acceptance. The early successes should arrive draped in familiar understandings and patterns of use. Over time, however, our understandings and patterns of use are changing, and those systems that retain the flexibility to change with us will persist. Ultimately, these will be the innovations we look back on as radical and discontinuous.

For organizational scholars, these ideas suggest we consider how existing meanings and behaviors are conscripted to make sense of and exploit novel ideas. The design process reflects both the construction of innovations by designers and their reception by the public. As a number of institutional scholars have found, builders of new organizational forms and fields often do so by importing the rationales of other organizations and industries (Swidler, 1986; Westney, 1987; Leblebici et al., 1991). The way entrepreneurs exploited these old rationales to construct new systems may also help to explain the ultimate success or failure of their innovations. In both the construction and reception of innovations, then, it is not only useful but necessary to consider the particulars of the design process if we are to understand how any single innovation unfolded within a particular institutional context. Theories of change that seek to explain how innovations emerge within and ultimately displace stable social systems, whether those theories are descriptive or prescriptive, must recognize the significance of the concrete. Profound changes in both technologies and social systems may hinge on robust design and subtle differences in the arrangements and understandings of their details.

REFERENCES

Abernathy, W. J., and K. B. Clark
1985 "Innovation: Mapping the winds of creative destruction." Research Policy, 14: 3–22.

Barley, S. R.
1986 "Technology as an occasion for structuring: Evidence from observations of CT scanners and the social order of radiology departments." Administrative Science Quarterly, 31: 78–108.

Barley, S. R., and P. S. Tolbert
1997 "Institutionalization and structuration: Studying the links between action and institution." Organization Studies, 18: 93–117.

Basalla, G.
1988 The Evolution of Technology. New York: Cambridge University Press.

Bower, J. L., and C. M. Christensen
1995 "Disruptive technologies: Catching the wave." Harvard Business Review, 73 (Jan.–Feb.): 43–54.

Bright, Arthur, Jr.
1949 The Electric-Lamp Industry: Technological Change and Economical Development from 1800 to 1947. New York: MacMillan.

Brown, S. L., and K. M. Eisenhardt
1997 "The art of continuous change: Linking complexity theory and time-paced evolution in relentlessly shifting organizations." Administrative Science Quarterly, 42: 1–35.

Buchanan, R. , and V. Margolis
1995 Discovering Design. Chicago: University of Chicago Press.

Callon, M.
1989 "Society in the making: The study of technology as a tool for sociological analysis." In W. E. Bijker, T. P. Hughes, and T. J. Pinch (eds.), The Social Construction of Technological Systems: 83–103. Cambridge, MA: MIT Press.

Cole, R. E., and W. R. Scott
2000 The Quality Movement and Organization Theory. Thousand Oaks, CA: Sage.

Conot, R. E.
1979 A Streak of Luck. New York: Seaview Books.

Czarniawska-Joerges, B., and G. Sevón
1996 Translating Organizational Change. New York: de Gruyter.

Dacin, M. T.
1997 "Isomorphism in context: The power and prescription of institutional norms." Academy of Management Journal, 40: 46–82.

Dacin, M. T., M. J. Ventresca, and B. D. Beal
1999 "The embeddedness of organizations: Dialogue and directions." Journal of Management, 25: 317–356.

DiMaggio, P. J.
1992 "Nadel's paradox revisited: Relational and cultural aspects of organizational structure." In N. Nohria and R. G. Eccles (eds.), Networks and Organizations: Structure, Form, and Action: 118–142. Boston: Harvard Business School Press.
1997 "Culture and cognition." Annual Review of Sociology, 23: 263–287. Palo Alto, CA: Annual Reviews.

Douglas, M.
1986 How Institutions Think. Syracuse, NY: Syracuse University Press.

Drucker, P.
1999 "Beyond the information revolution." Atlantic Monthly, 284 (Oct.): 47–57.

Eccles, R. G., N. Nohria, and J. D. Berkley
1992 Beyond the Hype: Rediscovering the Essence of Management. Boston: Harvard Business School Press.

Freidel, R., and P. Israel
1986 Edison's Electric Light: Biography of an Invention. New Brunswick, NJ: Rutgers University Press.

Friedland, R., and R. Alford
1991 "Bringing society back in: Symbols, practices, and institutional contradictions." In W. W. Powell, and P. J. DiMaggio (eds.), The New Institutionalism in Organizational Analysis: 232–263. Chicago: University of Chicago Press.

Garud, R., and M. A. Rappa
1994 "A socio-cognitive model of technology evolution: The case of cochlear implants." Organization Science, 5: 344–362.

Geertz, C.
1973 The Interpretation of Cultures: Selected Essays. New York: Basic Books.

Getts, J.
1990 "Prodigy plows ahead." PC World, 8 (July 1): 72.

Giddens, A.
1984 The Constitution of Society. Berkeley: University of California Press.

Goffman, E.
1959 The Presentation of Self in Everyday Life. Garden City, NY: Doubleday.

Goldberger, P.
1999 "Detroit tiger." New Yorker, July 12: 28–33.

Gombrich, E. H.
1961 Art and Illusion: A Study in the Psychology of Pictorial Representation. New York: Bollingen Foundation.

Granick, H.
1975 Underneath New York. New York: Fordham University Press.

Granovetter, M.
1985 "Economic action and social structure: The problem of embeddness." American Journal of Sociology, 91: 481–510.

Henderson, R. M., and K. B. Clark
1990 "Architectural innovation: The reconfiguration of existing product technologies and the failure of established firms." Administrative Science Quarterly, 35: 9–30.

Hughes, T. P.
1983 Networks of Power. Baltimore, MD: Johns Hopkins University Press.
1989 American Genesis. A Century of Invention and Technological Enthusiasm, 1870–1890. New York: Viking.

Israel, P. B.
1998 Edison: A Life of Invention. New York: Wiley.

Israel, P. B., K. A. Nier, and L. Carlat
1998 The Papers of Thomas A. Edison: The Wizard of Menlo Park, 1878. Baltimore, MD: Johns Hopkins University Press.

Josephson, M.
1959 Edison: A Biography. New York: McGraw-Hill.

Kieser, A.
1994 "Why organizational theory needs historical analysis—And how this should be performed." Organization Science, 5: 608–620.

Kiesler, S., and L. Sproull
1982 "Managerial responses to changing environments: Perspectives on problem sensing from social cognition." Administrative Science Quarterly, 27: 371–381.

Kintsch, W., and T. A. van Dijk
1978 "Toward a model of text comprehension and production." Psychological Review, 85: 363–394.

Law, J.
1989 "Technology and heterogeneous engineering: The case of Portuguese expansion." In W. E. Bjiker, T. P. Hughes, and T. J. Pinch (eds.), The Social Construction of Technical Systems: New Directions in the Sociology and History of Technology: 111–134. Cambridge, MA: MIT Press.

Leblebici, H., G. R. Salancik, A. Copay, and T. King
1991 "Institutional change and the transformation of interorganizational fields: An organizational history of the U.S. radio broadcasting industry." Administrative Science Quarterly, 36: 333–364.

Lee, Y.
1990a "Prodigy cancels CDC's accounts." Info World, 12 (Nov. 19): 35.
1990b "New Prodigy guidelines raise questions of privacy." Info World, 12 (Nov. 27): 5.

Leifer, E.
1991 Actors as Observers: A Theory of Skill in Social Relationships. New York: Garland.

Leonard-Barton, D.
1992 "Core capabilities and core rigidities: A paradox in managing new product development." Strategic Management Journal, 13: 111–125.

Levitt, B., and J. G. March
1988 "Organizational learning." Annual Review of Sociology, 14: 319–340. Palo Alto, CA: Annual Reviews.

Lewis, M.
2001 Next: The Future Just Happened. New York: W. W. Norton.

Liedtka, J.
2000 "In defense of strategy as design." California Management Review, 42 (3): 8–30.

Lounsbury, M., and M. A. Glynn
2000 "Cultural entrepreneurship: Stories, legitimacy, and the acquisition of resources." Working paper, School of Industrial and Labor Relations, Cornell University.

McGuire, P., M. Granovetter, and M. Schwartz
1993 "Thomas Edison and the social construction of the early electricity industry in America." In R. Swedberg (ed.), Explorations in Economic Sociology: 213–246. New York: Russell Sage Foundation.

McKinley, W., M. A. Mone, and G. Moon
1999 "Determinants and development of schools of organization theory." Academy of Management Review, 24: 634–648.

Millard, A.
1990 Edison and the Business of Innovation. Baltimore, MD: Johns Hopkins University Press.

Mumford, L.
1934 Technics and Civilization. New York: Harcourt Brace.

Nerney, M. C.
1934 Thomas A. Edison: A Modern Olympian. New York: Thomas and Haas.

Orlikowski, W. J.
1992 "The duality of technology: Rethinking the concept of technology in organizations." Organization Science, 3: 398–427.

Padgett, J. F., and C. K. Ansell
1993 "Robust action and the rise of the Medici, 1400–1434." American Journal of Sociology, 98: 1259–1319.

Rosenberg, N.
1982 Inside the Black Box. New York: Cambridge University Press.

Rumelhart, D. E.
1986 "Schemata: The building blocks of cognition." In R. J. Spiro, B. C. Bruce, and W. F. Brewer (eds.), Theoretical Issues in Reading Comprehension: Perspectives from Cognitive Psychology, Linguistics, Artificial Intelligence, and Education: 33–59. Hillsdale, NJ: Lawrence Erlbaum.

Schank, R., and R. P. Abelson
1977 Scripts, Plans, Goals, and Understanding: An Inquiry into Human Knowledge Structures. Hillsdale, NJ: Lawrence Erlbaum.

Scott, W. R.
1995 Institutions and Organizations. Thousand Oaks, CA: Sage.
1998 Organizations: Rational, Natural, and Open Systems, 4th ed. Upper Saddle River, NJ: Prentice Hall.

Selznick, P.
1949 TVA and the Grass Roots. Berkeley: University of California Press.

Silverberg, R.
1967 Light for the World: Edison and the Power Industry. Princeton, NJ: Van Nostrand.

Simon, H. A.
1981 The Sciences of the Artificial, 2d ed. Cambridge, MA: MIT Press.

Swidler, A.
1986 "Culture in action: Symbols and strategies." American Sociological Review, 51: 273–286.

Taylor, C.
2001 "TiVo or not TiVo." Time.com, May 30. Retrieved November 5, 2001 from www.time.com/time/business/article/0,8599,128435,00.html.

TiVo, Inc.
1999 Press release: Philips Personal TV Receiver with TiVo Service named "Best of What's New" and "Product of the Year." Sunnyvale, CA: TiVo, Inc.

Tolbert, P. S., and L. G. Zucker
1983 "Institutional sources of change in the formal structure of organizations: The diffusion of civil service reform, 1880–1935." Administrative Science Quarterly, 28: 22–39.

Tushman, M. L., and P. Anderson
1986 "Technological discontinuities and organizational environments." Administrative Science Quarterly, 31: 439–465.

Ventresca, M., M. Washington, D. Dialdin, and R. Lacey
2000 "Form Entrepreneurship in Online Database Services, 1972–1992." Working paper, Kellogg Graduate School of Management.

Weick, K. E.
1979 "Cognitive processes in organizations." In B. M. Staw (ed.), Research in Organizational Behavior, 1: 44–74. Greenwich, CT: JAI Press.

Westney, D. E.
1987 Imitation and Innovation: The Transfer of Western Organizational Patterns to Meiji Japan. Cambridge, MA: Harvard University Press.