INTRODUCTION

You ask people in a burning house, what are you going to take out?
After the kids and the dog, the answer is the family photo album.

— Peter M. Palermo, GM of Kodak's Consumer Imaging Division (Burgess 1991)

Statement of the Problem

In 1888 George Eastman and his associates launched the original roll-film camera. Customers purchased a "Kodak" loaded with one hundred exposures of Eastman's newly invented, celluloid negatives. After photographing families, friends, and homesteads, they sent the camera back to Eastman Company headquarters. In Rochester, workers developed the film with Eastman chemicals and ultimately made prints on Eastman's dry photographic paper, itself only a few years old. Customers received their prints, negatives, and a freshly loaded camera through the mail. What in the first decades of photographic history had been an intimidating, time-consuming activity was suddenly one of utmost simplicity. People the world over fell in love with the contraptions, making more and more photos—and pouring, eventually, billions of dollars into Kodak's coffers.

Eastman Kodak was the one company that controlled all of photography's critical components: cameras, film, chemicals, paper, photofinishing, personnel, and technical knowledge. When people talked about amateur photography, they talked about Kodak. The company's logo and yellow-and-black boxes symbolized convenience, quality, and leading-edge technology for enthusiasts and snapshooters throughout the twentieth century. In the United States, Eastman Kodak entered the high court of corporate divinity, earning blue chip status as a Dow Jones Industrial with staggering market valuations. Like Edison and Ford, Eastman became a symbol of American technical ingenuity and business

acumen, donating millions to university research departments to encourage industrial and military science.

For most of the century following the Kodak's introduction, Eastman continued to grow steadily, entering new overseas markets and expanding existing ones. Sales everywhere correlated nicely with operational simplicity and attractiveness. A succession of innovations made cameras smaller, more automated, and more powerful to satisfy those demands. Likewise, in the 1940s and 1950s the introduction of color film boosted photography's vernacular appeal. Except for 35mm cameras—which Eastman Kodak abandoned altogether in the 1960s, the first of its concessions to rivals from Japan—the company played a largely singular role in the evolution of the photographic process.

When digital technologies emerged in the 1980s, however, Eastman Kodak began losing its market edge, and by the 1990s the losses had turned into a rout. Although the film-based conventional system remained the everyday imaging technology, Kodak's advantages largely evaporated: in technical superiority, in consumer's perceptions, and consequently in market shares here and especially abroad. Furthermore, Kodak faced an onslaught of competitors in every relevant digital battleground. In storage media, for example, several hundred innovators scrambled for technical advantages. Practically all of them were more nimble, more familiar with new technologies and innovation techniques, and perhaps more motivated than Kodak.

Eastman Kodak managers acted conservatively between 1980 and the beginning of 1996, when the company relaunched its first wholly digital products. They failed to recognize or to act on fundamental changes in the imaging business. For decades they had achieved magnificent profits by protecting the core of their technological system, conventional photography. But the company's competitive environment changed drastically during this period, and senior executives wavered on strategic decisions. Rather than strengthening Kodak's hold on the photographic system, these defensive actions ensured that it would not evolve with the changing circumstances. Events near the end of the period

under consideration (1996) suggest that new decision-makers, though not abandoning the conventional system, began marshaling their resources differently to compete in a less centralized system. Through analysis of these final acts, one can infer what deeper troubles haunted the company throughout the 1980s and 1990s.

This thesis attempts to analyze, using STS interpretive strategies, the technological and competitive changes in Eastman Kodak's world. In the first period, Kodak had significant advantages that its managers could leverage against competitors to preserve their control of the system. The company relied on its research and development units to stay a step ahead of its rivals and to simultaneously make photography easier, expanding its potential market. Having been unquestionably successful with this strategy for well over half a century, Kodak executives became convinced it was their sole, best course. As a result they acquired a mindset that undervalued alternate technologies and business tactics, leaving Kodak's system managers ill-equipped to maintain their dominance of the photographic system in the 1980s and 1990s. To examine this thesis, I employ the systems approach elaborated by Thomas Hughes, described by John Staudenmaier, and filled in by Richard Hirsh and Adam Serchuk. Institutional histories by Alfred D. Chandler, Jr. and Richard Rosenbloom exemplify the traditional model and an emerging consensus, framing hypotheses about changes in the goals, processes, and management of industrial R&D advanced elsewhere in STS scholarship.

Thematic Framework & Literature Review

Photography, especially the mass consumed kind, is more than just a single box camera. It also involves film, paper, and the related production equipment; photofinishing facilities; trained personnel; knowledge of chemistry and engineering; and a variety of organizations and management specialists. Because it encompasses technical, business, and contextual factors, the systems approach advanced by Thomas Hughes is an appropriate

methodological framework with which to study Eastman Kodak and imaging. Reese Jenkins alludes to the necessity of such a holistic methodology in the conclusion to *Images and Enterprise*: "here *technology is seen not as an independent causal factor but as an interdependent element* in the conceptualization, formulation, and implementation of those business strategies that ultimately shaped the character of the [photographic] industry" (p. 340, emphasis added). Subsequent elaboration and formalization of the systems approach can be applied to imaging technologies consistent with this earlier work. In particular, the concepts of technological momentum, conservative innovation and radical invention, critical problems, and external stress receive extensive treatment, as I will define and outline in the following pages.

According to John Staudenmaier's 1985 survey of the Society for the History of Technology's journal *Technology and Culture*, the systems approach evolved as historians moved away from the established tradition of purely technical, or "internalist," histories. Staudenmaier describes a decided shift towards "contextual" styles that cast technology as central to history, as much so as economics, politics, and social factors. These styles integrate technical analysis with broader concerns. Thus, technology is not apart from mainstream history; it is bound up in it. This style became formalized as the systems approach through the work of many historians, both implicitly and explicitly.

In their historiographies of the history of technology and STS, respectively, Staudenmaier (1985) and Bijker (1995, p. 250) cite Thomas Hughes as providing the most complete statements on technological systems. Hughes's approach evolved through his studies of large-scale technological systems like railroads and electricity generation, the latter serving as the subject for his magnum opus, *Networks of Power* (1983). Since that time Hughes has acted as a *de facto* spokesman for the systems approach in essays (Hughes [1987]) and subsequent books (Hughes [1989]). Many scholars have used the systems approach as a starting point, successfully applying and adding to it in different contexts.

Key to the systems approach is its formulation of technology as a *system*—an interconnected web of components, physical and non-physical. A system includes not only the obvious hardware, devices, end products, transmission networks, and production machinery, but also organizations, managers, workers, researchers, regulations, and "scientific" components. None of the components function in isolation; change in one causes change elsewhere. A camera without film, factories, and photofinishers is just a box with intricate internal mechanisms. System builders (corporate managers) try to forge a system from disparate elements, to turn chaos into order. A successful system consolidates control in the hands of managers, making it easier to preserve and defend against alternatives. Since Eastman had already ordered the photographic system in exactly this fashion, the systems approach is an appropriate methodology for this study.

Hughes argues that system evolution is contingent on any number of factors, especially human ones, thus rejecting the deterministic tone often associated with internalist histories. In the determinist view, the end result follows as a logical consequence of earlier conditions. Hughes instead suggests that from a systems perspective, successive technical and contextual developments restrict the paths available to system managers without foreclosing human responses: "systems . . . do not become autonomous; they acquire momentum" (Hughes 1987, p. 76). This *momentum* appears in other contexts as "vested interests, fixed assets, and sunk costs" (p. 77), as well as psychological affections or social attachments that manifest themselves in the marketplace. Once a system develops around a core technology, the system appears autonomous because handlers and consumers alike cannot afford—or believe they cannot afford—to alter the system. Managers pursue protective strategies, such as vertical integration, to control the physical components, stave off competition, and secure predictable profits. Consumers dislike changing systems because they perceive that the security and predictability of the established technology outweighs the putative benefits of any others. (Corporate marketing can reinforce this tendency.) For example, chemical factories are a physical asset that photographic firms are

reluctant to replace. Conversely, a family that has purchased a camera will tend to buy film for it rather than switch to a camera of a different format.

Breakthroughs can either supplement or mitigate the technological momentum of a system. Momentum-enhancing inventions are called *conservative innovations*. Corporations and others with a stake in the system pursue this type because they do not necessitate a reordering of the system, which involves costs, dislocations, and so forth. Indeed, such innovations reinforce the system and impede alternatives. *Radical inventions*, on the other hand, come from external sources. Until World War I they were primarily the product of independent inventors like those described by Hughes (1989), such as Thomas Edison and Alexander Graham Bell. They challenge the existing technology, offering an alternative that delivers a similar (or somehow improved) product while circumventing the system. Their breakthroughs threaten corporations, investments, careers, and privileged knowledge, provoking harsh, conservative responses from system builders and managers.

In the pursuit of conservative innovations, system builders define *critical problems* that impede the establishment or growth of the system. Solutions may improve operating efficiencies, lower production costs, or introduce appealing features to the core technology. Managers focus on these problems, directing development towards breakthroughs that resolve the difficulties. Problem choice iterations fuel technological momentum. Put bluntly, managers elevate the virtues of conservative innovations and condemn the perceived shortcomings of radical inventions; the former are problem-solving victories, while the latter cannot be measured against the accepted norms. Research pursues those problems and innovations which ultimately uphold the status quo, and neglects those which do not. Hughes (1989) argues, in particular, that "[t]he values of order, system, and control that [technologists and managers] embedded in machines, devices, processes, and systems have become the values of modern technological culture" (p. 4). Eastman Kodak—which rose to dominance in the peak years of what Hughes terms the age of

"technological enthusiasm" (1870 to 1970)—embodied exactly these values for a century. They developed products and a system that resolutely enforced order and control; all breakthroughs were gauged against the problems deemed critical.

While the above concepts set forward a kind of internal logic, changes in the system's environment influence it as well. Richard Hirsh and Adam Serchuk (1996) call these changes "*stresses*," signifying their potential to alter the course of the system. The authors expand on the conclusion by Hughes (1989) that "a confluence of contingency, catastrophe, and conversion" (pp. 470-71) can break the momentum of a technological system. More specifically, this confluence can include "rapid shift[s] in consumer inclinations" (Hirsh and Serchuk 1996, p. 285), system failures such as environmental disasters (p. 285), and the embrace of alternative values (pp. 285-86). These pressures help explain why, during the period under consideration, the Kodak-dominated conventional system began to give way to an alternative.

Business historians long ago demonstrated that companies pursued integration strategies to increase their size and assume dominant positions in their industries. Alfred D. Chandler, Jr. provides the authoritative account of "big business" in *The Visible Hand*. He argues that vertical integration required trained, capable managers to "command" the expanded enterprises. These large corporations "came to compete in the modern oligopolistic manner, by means of product improvement, product differentiation, service, and improved coordination, rather than by price" (p. 402). This description of competitive strategy parallels that set forth by Hughes and advocates of the systems approach. Chandler lists managers' motivations as "improvement," "differentiation," and "service," which Hughes finds at the margins, in conservative innovations. I employ these themes of integration and motivation to contextualize Eastman Kodak's position in the modern photographic industry, one which relied on the construction of mass distribution (Chandler, ch. 7) and mass production (ch. 8) organizations. Not surprisingly, many of Chandler's propositions about management activity are applicable, especially that the

administrative bureaucracy became a self-preserving entity (p. 8) through the pursuit of predictable growth strategies (p. 10).

Chandler's theme of managerial control describes Kodak executives' characteristic behavior up through the 1980s. Thus, his insights form the basis for understanding managers in the conventional system, and his propositions aid my interpretation of their actions as Eastman Kodak shifted into the second period: the traditional organization and strategy of the company's administrators influenced their choice of problems, and so forth. Much of Chandler's work applies to the case of Eastman Kodak through the present. Importantly, the definitive history of early photographic technology, by Jenkins, conspicuously lists Chandler as a scholar of organizational and structural change that occurred during photography's earliest days, although it then adds that "distinctive product technologies [seem] to provide a more fundamental interpretive tool for understanding the marketing changes and the history of the industry generally" (Jenkins 1975, p. 4). I have kept Jenkins's assessment in mind, while also understanding that Chandler's analysis of American management concludes with the 1970s, before the more recent changes in which I am most interested.

For the state-of-the-art in technology management research, I turn to Richard Rosenbloom, a management scholar who has studied the technology issues facing contemporary businesses. His recent subjects include computer disk drives, videotapes, and semiconductors. His work impinges on the present study in two ways. First, an STS subtext pervades his articles, hinting at a conceptual overlap with this thesis.[1] Rosenbloom frequently invokes Thomas Kuhn's *The Structure of Scientific Revolutions* and the paradigm concept to help explain product success and decline in the technological marketplace. For researchers studying management and commercial R&D, this insight is

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[1] Richard Hirsh has reminded me that Rosenbloom was an early SHOT contributor, a member of the STS community writ large, as it were. See Richard S. Rosenbloom, Some 19th-century analyses of mechanization: Men and machines. *Technology and Culture* 5:4 (Fall 1964): 489-511.

helpful, but the systems approach offers more sophisticated analytical tools for dealing with technology. It strengthens Rosenbloom's basic premises that technologies and companies form "networks" (systems) and that corporate tactics seek to protect market position. Together with Clayton Christensen (1995), he concludes in the case of disk drives

> that the manifest strength of established firms in component innovation and their weakness in architectural innovation—and the opposite manifest strengths and weaknesses of entrant firms—are consequences not of differences in technological or organizational capabilities between incumbent and entrant firms, but of their positions in the industry's different value networks. (p. 242)

Here, "component innovation" translates to conservative innovation, "established firms" to system participants, and so forth. A first reading may leave the impression that Rosenbloom rejects the role of either technology or management, in sharp opposition to much of my argument. In fact he reaches a conclusion very similar to mine, because arguing that competency differences arise from "value networks" amounts to pointing to "technological systems," as I do. Let me amend, then, the definition of "radical inventor" to include Rosenbloom's "entrant firms"—small groups and so-called micro-capitalized companies possessing the special knowledge, imagination, and investment capital to create the "architectural innovations" that seed alternative systems. These contemporary radicals, then, appear in the form of Apple Computer, which constructed the home computer in the late 1970s, and Seagate Technology, which created the PC hard disk drive in the 1980s (see Christensen and Rosenbloom 1993, pp. 246-248). In this way, Hughes fills out Rosenbloom's analysis of technology, and Rosenbloom updates Hughes's (and Chandler's) description of technological management.

Rosenbloom's second area of influence is on the larger theme of this project. In "The Transformation of Industrial Research," written with William J. Spencer, the authors describe a number of changes in the way corporate labs have operated in the 1990s, and they foresee change continuing into the future. Alliances, precompetitive development (i.e. close to production), division-level projects, and risk management have supplanted the highly centralized, pioneering research that constantly strove to discover "home run"

products, like nylon and Teflon. This thesis attempts to peel layers off of this onion, to find examples of these phenomena in an everyday—yet research-driven—corporation. Rosenbloom and Spencer attribute the changed corporate course to increased competitiveness, and rightly so. But why is it so, and how did such a change come to pass in the photography business? Why during the period under consideration instead of earlier, or later? It is my hope that this work will use the case of Eastman Kodak to at least begin to answer questions like these.

Some further works fill in the backdrop for the particular case I shall present. For while Eastman Kodak's actions in the face of radical changes in their business are interesting, they became generally significant to STS when considered in the context of broader change. Robert Reich comes to similar conclusions and places them in the context of a fundamental shift towards the much-heralded global economy. Using anecdotal evidence of corporate struggles (mentioning Eastman Kodak more than once), he finds companies unable to control markets and relying increasingly on partnerships and virtual products (e.g. applying corporate logos to products made by others). At the most fundamental level, knowledge itself has changed, as Michael Gibbons, et al. suggest. They argue that traditional, disciplinary knowledge is being overrun by a new "mode" of knowledge and knowledge production, one which favors transdisciplinarity, organizational diversity, social accountability, and site- or project- specific expertise.

Using the systems approach allows me to create a nuanced description of the conventional and digital photographic technologies. Because it is inclusive, my analysis incorporates diverse components, such as retailers and scientific knowledge, ordinarily overlooked by industry commentators. As such, I can locate stresses in and challenges to the conventional system which Eastman Kodak's managers neglected or ignored in their defense of a highly profitable, seemingly impenetrable market. Interpreted in conjunction with the themes and methods of Chandler and Rosenbloom, I show that Kodak's mistakes

contributed to a loss of system control that may ultimately leave the company at the mercy of its competitors.

Overview

This thesis is organized into three chapters. In the first, I review the consolidation of photographic technologies into what I term the conventional system. I focus first on the interconnected technical features of the system and the dominant position Eastman Kodak achieved through strategy and research. In the remainder of the chapter, I discuss the momentum of the system and the value mindset which crystallized at Kodak. In chapter two I describe the digital breakthroughs that formed the basis for an alternative system, as well as the problems, values, and stresses which arose. I conclude in chapter three that Kodak's intense involvement in the conventional system made the company ill-prepared to deal with radical change.

ONE: THE CONVENTIONAL SYSTEM

The problem was, Kodak felt it could do what it pleased.

— Peter Ueberroth, president of the Los Angeles Olympic Organizing Committee (1984), explaining why Fuji Photo Film won a sponsorship instead of Eastman Kodak (*Business Week* 1982)

Introduction

When parents memorialize a child's first steps with a photograph, or a business creates pictorial documentation or advertising, or a newspaper prints a stunning photo above the fold, they tap into a century-old technological system. Early photographic processes made plate images that photographers chemically treated one by one, confining their use mostly to professionals working in portrait studios. This technical limitation prevented photography from consolidating into a widely practical technological system until the 1880s. At that time, a small firm led by George Eastman began building a photographic process for the masses—inexpensive, operationally simple, and batch-processed. He and his partners substituted uncut celluloid film for plates, constructed the machinery to make it, and invented a mechanism to advance the film and hold it in place behind the shutter. At the same time, they established factories to photosensitize film and paper, facilities to develop film and make prints, and an organization to accept exposed film from consumers, transport it to the processing plants, and return the finished product. In 1888 the Eastman Company introduced the Kodak box camera to the world (see Figure 5). With it came the famous advertising slogan "you press the button, we do the rest," alluding to the infrastructure hidden away in Rochester, NY (Hedgecoe 1986, pp. 18-25; Jenkins 1975, chs. 1-3; Newhall 1982, chs. 3-5).

In this chapter I examine the key components of the photographic process that Eastman Kodak used to dominate the conventional system. To do so, I describe the

artifacts, organizations, and critical problems of the system. In the first section of the chapter, I describe the consolidated system in terms of its characteristic innovations and organizations. I depict next the critical problems that system builders tried to solve in the period under consideration, and the increasing momentum of the system.

Having shown in general terms how the system consolidated and expanded, I then outline the technical and production dominance that Kodak, in particular, obtained by accumulating scientific knowledge and human expertise. I argue that the company's decision-makers, including executives and researchers, developed a conservative mindset that viewed their system as a technological crown. I conclude that the internal critical problems highly influenced, and were influenced by, the values of the conventional system. At the same time, pressures from Kodak's broader corporate context began to threaten the traditional structure.

Consolidation: Standardization and Management

Many variations on George Eastman's roll film system appeared in the twentieth century. The 35mm film format was widely used for much of that time, but others also enjoyed great popularity. Each system involved several interdependent components. Firms developed the basic elements of the 35mm system roughly between the two World Wars. Other formats followed. These refinements consolidated what had been disparate parts into an orderly whole. This evolution satisfied managers' desire for control and growing sales. In particular, it enabled Eastman Kodak to sell enormous amounts of film, photographic chemicals, and photofinishing services.

The Ernst Leitz Company initiated "modern" still photography when it began selling Osckar Barnack's "Leica" camera in 1924. The Leica is notable because it used the same 24mm motion picture film that manufacturers already produced in large quantities for Hollywood. The ingenious use of standard film stock delighted enthusiasts and

photojournalists, who found supplies readily available. Leicas doubled the standard frame widths from 18mm to 36mm, making enlargements of up to the standard portrait size, eight-by-ten inches (2032x9144mm), acceptably crisp. Barnack's design used a ratchet that matched sprocket holes in the movie film, advancing one frame with every pivot of a lever (Newhall 1982, ch. 12; Busselle 1988).

But users had to load film onto an intricate spool apparatus by hand in a darkroom, a chore that intimidated all but the most heroic photographers. Kodak simplified loading with the familiar factory-loaded cartridge, patented in 1934 (Schneider, Keppler, and Lothrop 1998). The cartridges made 35mm photography more attractive to experts and novices alike: sales of compatible cameras exploded following the introduction of the cartridges, creating additional demand for Kodak products. Though the company had not created the 35mm format, this conservative innovation cleverly differentiated Kodak's 35mm film. Moreover, the convenience of factory-loaded cartridges enticed consumers, especially the novice masses, to purchase film by the roll instead of in bulk—allowing the company to maintain higher profit margins. Leitz's camera had begun a trend towards making film an undifferentiated commodity; Kodak's cartridges reversed it.

Another Kodak innovation further differentiated the company's film products. In 1936 Kodak began selling Kodachrome for transparencies (slides), launching the first commercially successful color film. It remained Kodak's flagship slide film for decades, exciting generations. Kodacolor, first sold in 1941, and Ektacolor, in 1947, initiated amateur color print photography (Jenkins 1975, pp. 303-4; Newhall 1982, ch. 16; Hedgecoe 1986, p. 32). The film's vibrance generated even greater sales to family photographers, and still more so as Kodak refined the process, reducing prints' graininess and improving the fixing process.

Patents on cartridges and color technology gave Kodak several competitive advantages. Challengers could not offer the same easy-to-load cartridges or duplicate the quality of Kodak's color process, and thus they could not dent Kodak's film sales. In

addition, consumers had few alternatives to Kodak photofinishing. Complex color processing prohibited amateurs from doing the work themselves, and commercial labs were at Kodak's mercy because of the company's patents. Finally, the innovations resolved critical problems of simplicity and color, boosting overall revenues. Although it used a film widely available from Kodak, the Leica circumvented Kodak's traditional distribution channels. Through refinements of that technology, Kodak was building a system which it could control (see Figure 1).

But Kodak managers recognized that their dominance would last only as long as their technical, patent-protected advantages persisted. To spur demand and ensure their superiority, Eastman Kodak repeatedly created new film and camera formats. Although new and potentially threatening to sales of 35mm film, they were conservative innovations expected to expand the overall amateur photographic market, and for film specifically. The Instamatic 126 (introduced in 1963) and Pocket Instamatic 110 (1972), and later the Disc format (1982), compressed camera components into the smallest possible devices, and some even fit into a pocket. Novices could use them right out of the box. Self-contained, double-ended cartridges (or circular discs) promised worry-free loading, taking factory-loaded cartridges one step further, removing all but the step of putting the cartridge into the camera. Most had fixed-focus lenses and no more than rudimentary exposure control. Kodak and other manufacturers developed some more sophisticated versions, but the best-selling models required little more than a push of the shutter release and a turn of a dial.

The formats were smaller than the 35mm standard, but that meant greater magnification in the enlargement stage. As a result prints seemed noticeably grainy. Designers ignored these problems as long as consumers would tolerate them, content to sell film however they could. The periodic success of these alternatives hinted at the potential market for convenient photography. But these innovations were conservative because they did not threaten the status quo. Processors and retailers alike generally supported each new format. Indeed, the nature of the design changes suggests a conservative approach. The

formats introduced new frame sizes and new cartridges, but nothing beyond the conventional system as we have seen it.

Commercial photofinishers gave consumers the fullest advantage of the photographic system. In the original roll-film system, consumers delivered their Kodaks to Eastman's Rochester facilities, where the film was unloaded, developed, and enlarged, and prints were then returned to the Kodak agent. Together with film manufacture, photofinishing was the most centralized part of the conventional system. Not surprisingly, it occurred under Kodak's roof (Jenkins 1975, pp. 104-120). Antitrust litigation eventually restricted how Eastman Kodak could market photofinishing, somewhat "decoupling" film sales from processing. Still, Eastman maintained the nation's largest photofinishing centers. The company continued to invest in photofinishing, increasing its own commitment to the system. At the same time, consumers grew dependent on them. Amateurs could not match professionals' services, especially in color processing.

Kodak and other firms constructed processing machines to facilitate the large volumes of unexposed film. By the late 1970s, automated machinery handled developing and printing for all but very specialized tasks. These units provided a much more precise chemical and temperature balance for processing, essential for the special sensitivities of color film. They also constantly filtered the chemicals to remove impurities. "Dip and dunk" units (Figure 6) processed film or prints by suspending the exposed materials from a rack. The rack would intermittently raise, advance to the next tank or drying section, and then lower the film or prints into the next stage of the process. Large volumes of film could be batch-developed, although part or all of the machine had to be situated in a light-tight room to safely load the materials. Supply tanks replenished the chemicals without halting development (Gallistel 1977, pp. 496-506).

"Macrolabs," such as Eastman Kodak's and Fotomat's, processed enormous volumes of film, thousands of rolls daily. They had either a single or a few regional processing locations fitted with many pairs of film and print processing equipment.

Consumers dropped off film in a drop-box or at a commercial dealer, and distribution channels funneled unexposed rolls to the nearest (or only) processing facility. By operating several processors at one site, photofinishers minimized both capital expenses and labor costs, as one technician oversaw several machines at one time. The large volume processed with the lowest possible fixed costs yielded classic economies of scale. Qualex was the largest contemporary macrolab photofinisher, and the largest American photo processor. Kodak owned a 51% majority stake in the 1990s, a significant remnant of their processing dominance. Qualex and other macrolabs have long featured Kodak chemicals and processing equipment (See *Discount Store News* 1992).

By the late 1970s Eastman Kodak had driven from the market competitors like Bell & Howell in equipment, GAF in film, and Berkey Photo in wholesale (macrolab) photofinishing (Hayes 1981). Although Kodak was not viewed as a monopolist—Japanese firms made 35mm cameras and several domestic and foreign companies produced film—it had consolidated photographic technologies into an ordered system from which it derived steady profits. The company had that most enviable of positions: reputation as the best of the best, even among most experts, while simultaneously being the film for Everyman. Its managers sought not more control or market share but rather a larger overall market.

Innovation and Momentum: Pocket Zooms, T-grains, and Minilabs

Having consolidated photographic technology into conventional formats and created the basic chemical standards, the system builders devoted time and resources to cultivating the growth of the system: to getting cameras and film into the hands of every consumer, to making the system and its products ubiquitous. The company had been producing enormous volumes of film and paper since early in the century. For economic reasons Eastman Kodak managers wanted to maximize this capacity, and the potential capacity they could add at comparatively low cost. They could afford to think big. In the early 1980s,

Eastman Kodak controlled about 90% of the color film market, a business that yielded gaudy pretax earnings of up to 60% of sales (Business Week 1982, p. 48).[2] Kodak's researchers knew better than anyone in the world how to make photographic film, and the company already controlled a majority of the market. Production did not limit Kodak's prior expansion; consumption did. A confluence of innovations furthered the convenience of photography by reaching specific technical goals. Automation and sophisticated optics made photography easier, and eventually habitual, for casual consumers. Yet these innovations ultimately encouraged results the managers had not foreseen.

Nikon and Zeiss introduced the single-lens reflex (SLR) camera shortly after World War Two, ushering in an era of increasingly sophisticated designs (see Figure 7). Powerful cameras and lenses gave photographers greater versatility. With the exception of Zeiss, Leitz, and a few other European firms, these features were all developed by manufacturers in a Japanese oligopoly. Pentax introduced the first through-the-lens light meter in 1960, allowing photographers to not only see the exact images passing through their lenses but to calculate more precise exposures for them. Before long, engineers began linking these meters to the controls themselves, and in 1976 Canon introduced the popular AE-1 model that coupled meter functions with shutter and aperture settings (Busselle 1988, pp. 31-39; Keppler 1996).[3]

Designers automated other features starting around the same time. Nikon designed motor drives into its F series cameras in the late 1960s, and they quickly found favor with war correspondents in Vietnam. At about the same time, zoom lenses debuted, offering variable focal lengths, or fields of view. Photographers could better crop their images and reduce the number of lenses they carried in their equipment bags. In 1981 Pentax introduced the first SLR with through-the-lens autofocus, i.e. it focused on the actual

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[2] By most accounts, double-digit pretax earnings are admirable; over 20% are outstanding. Film, as many industry insiders have commented over the years, is money.

viewfinder image, not using sonar or other artificial measuring means. As one author has described, the development of electronic meters needed the invention of the transistor, while the development of autofocus needed the invention of the integrated circuit to practically process image data (Busselle 1988, pp. 31-39; Keppler 1996).

Under Chairman Walter Fallon, who presided from 1972 to 1983, Kodak decided to get out of the 35mm camera business to focus on its inexpensive, proprietary formats. The film giant could not keep up with the advances in camera design as well as it could in its core business, and more importantly, the new technologies did not yield the lofty profit margins which managers demanded; competition in integrated circuits and the like was too fierce. Left to themselves after Kodak's exit in 1975, the Japanese manufacturers fashioned a 35mm system that utilized their electronics expertise, concentrating on automation problems. These cameras became widely known as "auto-everything" wonders (see Figure 8; Schiffres 1986). Consumers applauded the new developments, making the 35mm format the fastest growing sector of the photographic industry after 1975 (Buell 1986; Hayes 1981, p. 78). Kodak engineers made one lasting contribution to 35mm photography in the early 1980s when they added conductive "DX codes" to film cartridges, from which compatible cameras read the film speed and other information (Goldsmith 1983). This conservative innovation eliminated yet another step from camera handling.

A few companies had timidly competed with Kodak for short periods over the years. But either they were too small, like GAF, or they lacked the heart for prolonged skirmishes with Kodak, as with DuPont. In the late 1970s firms like Fuji Photo Film, Konishiroku (Konica), and 3M began establishing amateur film brands that approached the quality of Kodak's, and at lower prices (*Business Week* 1982, p. 49). Fuji, especially, upstaged Kodak on several occasions, beating it to market with a high-speed (i.e. greater sensitivity, 400 ASA) color film in the late 1970s, even though Kodak quickly followed

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[3] Richard Hirsh has informed me that the 1968 Konica Autoreflex featured auto exposure controls, long before the AE-1.

suit (Busselle, 1988; Chakravarty and Simon 1984). Kodak then did Fuji one better, creating a high-speed emulsion that did not sacrifice resolution.[4] The "T-grain" emulsion oriented flat silver halide crystals parallel to the imaging plane so as to gather more light, whereas standard emulsions contained randomly oriented, irregular crystals. In October 1982 Kodak introduced a super high-speed color film rated at ASA 1000; it was not only more sensitive to light, it yielded less grainy prints. Its potential was not lost on investors: Eastman Kodak stock price promptly shot up to a six-year high (*Time* 1982).

Faster film benefited others as well as Kodak. With more sensitive film on the market, "lens designer[s] [were] under less pressure to increase maximum apertures and … design [shifted] towards lighter, smaller zooms with a greater focal-length range" (Busselle 1988, p. 37). Zoom lenses, whose variable focal lengths allow photographers to change the magnification and field of view for an image, had features desired by professionals and amateurs alike. But they had an unexpected impact on the inexpensive end of the camera spectrum.

So-called "point-and-shoot" (P&S) cameras made use of these breakthroughs, generally at the more inexpensive end of the spectrum (see Figure 9). Supreme ease of use distinguished them from SLRs; novices could use them within minutes. Whereas SLRs offered multiple controls and options, including autofocus and auto-exposure, P&S models had only a few. Consumers took to them quite rapidly, multiplying 35mm camera sales several-fold (see Watson 1991-94).

A derivative of this camera type was the disposable or single-use camera, introduced by Fuji in 1986. No more than a plastic box camera, disposables stripped away all design frills in a small package. They did, however, come at a cheap price, allowing consumers to make use of the conventional system with a minuscule capital investment. Kodak's interests in Japan were well aware of Fuji's innovation and its quick success in

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[4] Generally speaking, the "faster" the film, the "grainier" it is: bigger silver halide crystals have greater surface areas and thus are more sensitive to light.

Asian markets, and similar ideas were already being developed at Kodak. However, the disposable camera concept was initially responsible to the film group, whose managers feared that single-use cameras would "cannibalize" the lofty profits of film sales. They also had introduced a single-use 110 camera earlier in the decade, one which was quickly discontinued after disappointing sales (Wheelwright and Clark 1995, pp. 105-108). Only after senior executives, cognizant of Fuji's potential windfall in the American market, stepped in and removed the project from the film group's control did a competitive product emerge (pp. 109-110). Once Kodak executives had embraced the concept and backed it with a forceful marketing campaign, a whole family of "FunSaver" products emerged. Along with Fuji, Kodak had more film to supply (and process) than ever before.

Photofinishing expanded to accommodate growth in the rest of the system.[5] New, smaller labs gained significant market share by placing the site of processing closer to the consumer. The Noritsu Koki Company (Noritsu) introduced compact "minilab" equipment to the United States in the late 1970s but a trend did not accelerate until 1983. In 1982, only 600 such minilabs existed nationwide; in 1984, there were over 2,000, and they serviced 11% of the market; by 1986, Kodak estimated that there were over 8,000 (Business Week 1984). Most were specialty shops, photographic retail chains, and occasionally drug stores. With one film processor and one automated enlarger operating on-site, a minilab could offer one-hour processing or less, limited only by the duration of the chemical processes; even the most efficient macrolabs could do no better than overnight service.

The spread of small photofinishing labs forced longtime regional macrolabs like Fotomat out of the business by the mid-1980s (Business Week 1984). Kodak, which had maintained its macrolab mastery, entered the minilab equipment business in 1986 (Buell

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[5] See yearly entries by Watson (1991-94) for periodic sales figures and usage surveys. In 1989 American photographers made over 20 billion photos and paid over $9 billion for photofinishing, including professional markets (1991).

1986). Within a few years, unable to gain a foothold in the sector, the company stopped making minilab equipment.

Equipment manufacturers like Noritsu continued to make processing machines that were smaller, less expensive, and much simpler to operate. They continued to saturate the market, giving rise to "microlabs" in drug stores, grocery stores, and department stores (see Figure 10). Though they were slower than larger units, topping out at about twenty rolls per hour (Discount Store News 1992), the sheer number of microlab outlets reduced the average volume for each one, making one-hour service possible and nearly universal. Typical was the case of Newport Beach, California (1998 population: 70,000). In 1983, 3 minilabs running Noritsu equipment opened, and by the late 1980s, there were 12. Six microlabs appeared in the early 1990s, all in drug stores and supermarkets (Purves 1998). Stores marketed photofinishing as a commodified convenience to be bundled at one-stop shopping centers. This strategy capitalized on economies of scope rather than of scale,[6] allowing microlabs to undercut prices charged by macrolabs like Qualex, while simultaneously providing faster, more personalized service. The momentum of the conventional system increased and gradually displaced Kodak, which was locked into its regional macrolab concept.

Seattle Filmworks and others succeeded with a modified macrolab concept starting in the mid-1980s. Rather than delivering film to a retailer who contracts with the lab, SFW's customers deliver film and receive finished products directly—via standard U.S. mail service (Fryer 1995). These mail-order businesses offered further convenience to customers; they correctly perceived a market for door-to-door convenience, predating and

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[6] So as not to confuse the subtle difference: *economies of scale* exist as an enterprise produces ever greater volumes of a good while holding fixed costs (factories, administration, etc.) constant, reducing the average unit cost; *economies of scope* exist when an enterprise increases the variety of goods produced or services rendered to minimize the same variable. Kodak managers mastered photofinishing scale economies while constructing the conventional system, an advantage they wielded against competitors for much of the twentieth century. Kodak's enormous volume made it virtually impervious to assault via scale. Department store managers, like those at large grocery store chains, brought under one roof photofinishing, flower arranging, fast food, and their traditional packaged goods.

evolving with microlabs. At the end of this period, Fuji entered the macrolab business as well, purchasing Wal-Mart's six wholesale processing labs (Desmond 1997, p. 186).

Microlabs and mail-order macrolabs flourished because innovations in the size and operation of 35mm cameras appealed to a broader audience. As the artifacts became more handy, organizations were forced to offer convenience. They especially sought to decrease the amount of time between the initial exposure and delivery of the final product. Likewise, the increased sales of film offered more opportunities to process it: 70% more between 1980 and 1990 (Nulty 1991, p. 39). New photographers included increasing numbers of non-hobbyists and photophobes who wanted pictures but would not make an extra trip to the photo store just for photofinishing. Service became more convenient.

The One Best Way: Managing Technical and Production Superiority

Throughout the post-War era, at least until the 1980s, Eastman Kodak controlled an overwhelming majority of the film market, and its managers believed that they had a stranglehold on their industry. Just as Thomas Hughes finds in Frederick Winslow Taylor's "search for the one best way of working" (1989, p. 191) a possible motto for system building, it may be just as true that a functional system becomes synonymous with "the one best way." Absent crisis, Panglossian managers fancy that theirs is *the* best way. In Kodak's case, managers chose conservative problems to sustain the momentum of the conventional system. A century of market dominance nurtured a rigid management bureaucracy and operational arrogance.

Company managers generally viewed the conventional roll film system as a finished product; they just needed to make it sell. New formats accomplished that task, as did constant improvements in film resolution, sensitivity, and vibrancy. To generate these innovations Kodak accumulated the necessary technical and production expertise. Chemists and engineers filled the ranks of Kodak's research staff. They also claimed most

managerial positions: Chairmen Walter Fallon (1972-83), Colby Chandler (1983-89), Kay Whitmore (1989-93), and all of their predecessors were technical graduates.

Researchers defined problems in emulsions and processing. Kodak's research chemists created the C-41 and E-6 processes which became the standards for automated development of color negative and color slide film, respectively. The standards resolved a critical problem in the automation sequence, making films interchangeable with processors carrying the proper chemicals. Kodak, of course, would supply these chemicals to their own and independent photo processors. The company could better ensure the quality of the finished product; they also assured sales of another product line to complement film. Although Kodak was not the first to achieve a 400- or 1600-ASA color film, its researchers did develop the T-grain technology that significantly redefined the parameters of design. And the company also maintained subsequent technical superiority in many areas, including color, black-and-white film, and paper. Stanley Morten, an industry analyst, praised T-grains as a significant technological leap: "this is not something that could have come out of a basement or a garage. The product re-establishes Kodak's superiority in all types of emulsion film after a decade in which the Japanese and other foreign competitors had started producing some film as good as Kodak's" (*Time* 1982). These conservative innovations—after all, they were simply standardizing existing chemicals and processes—reflected Kodak's own values and reaffirmed system managers' faith in chemical research and development. Through R&D, the company continued to raise the bar of photographic quality and force competitors to keep up. Simply put, the system momentum followed this basic pattern: market share yielded generous profits, which in turn were invested in R&D that ensured future market superiority and share, and so on.

Managers put in place certain defensive mechanisms that solidified the status quo and, ultimately, established the tendency to react very slowly to change. At Kodak, rather than working in tandem to achieve imaging successes, independent units and work teams

acted defensively. Stephen Frangos, a retired Kodak manager, describes the "silver curtain" tradition of protecting information that

> began with a legitimate need for guarding our proprietary emulsion formulas—the recipes for making emulsion would have been a delicious plum for our competitors. Unfortunately, people began applying this line of thinking to virtually all of our processes, creating an information blackout that worked against teamwork and openness. (Frangos and Bennett 1993, pp. 72-73)

The Kodak way remained the best way. As long as the research staff could stay two steps ahead of its photographic competitors, whether it be with Instamatics or T-grains, the system remained more or less a safe haven for Kodak's staff. They certainly believed that they were ahead. Another manager, looking back on Fuji's "advanced technology" films that hit U.S. shelves in the late 1970s, "I don't believe it was superior to Kodak's products, but for people who were price conscious, the film was very appealing" (Frangos and Bennett 1993, p. 10). Again, Kodak's management defined critical problems narrowly. Technical superiority, as selected by the company's managers and researchers, was of utmost concern; price optimization, based on decades of experience, was not.

Eastman Kodak also achieved a superior position in manufacturing. Alfred Chandler writes of continuous-process producers, such as Kodak, "that production for the national and global market became concentrated in just a few plants, often only one or two. In all cases it was the massive increase in output made possible by the new continuous-process, capital-intensive machinery that caused the manufacturers to build large marketing and purchasing networks" (1977, p. 297-98). The economies of scale thus achieved engender a huge cost advantage. Explained analyst Ty Govatos, "Once [Kodak] gets enough volume to overcome large, fixed selling and administrative costs, much of the incremental gain rolls right to the bottom line," with gross margins of approximately sixty percent (Rudnitsky 1982, p. 109). In a 1988 speech, CEO Colby Chandler praised the virtues of manufacturing and decried the trend towards a service economy, stating that one job making a car (or film) was worth ten service positions (or minilab jobs) (Associated Press 1988). Only at the end of the period studied did other companies, especially Fuji,

produce similarly huge production runs that enabled them to compete on nearly equal footing. Kodak Park had meanwhile become bloated and inefficient, “the antithesis of the sleek factory” championed by Kodak’s Japanese competitors (Frangos and Bennnett 1993, p. 46).

Kodak’s dominance in technology and production fostered a stifling bureaucratic structure. As vertically integrated companies mostly do, Kodak depended on layers of professional managers since before the turn of the century (Jenkins 1975). Eastman’s successors continued to direct the company in the way the founder had. One appraisal surmised that “Kodak CEOs tended to be aloof and autocratic” (Maremont 1995, p. 65). This management style suited Eastman Kodak well as system builders consolidated chemical technologies and built a vertically efficient production structure. But the security of an almost impenetrable market dominance, the managerial structure petrified, maintained almost unchanged into the 1980s.

At a managers’ workshop in 1987, Don Delwiche, manager of motion picture film processing, revealingly argued that “The decision to ‘give up’ the high-tech 35-mm market simply led to more demand for film. And we’re not about to hand over the core business to anybody” (Frangos and Bennett 1993, p. 45). It is not clear from his words or the context why Kodak should have sold more film without selling cameras than it had while peddling them. One can only infer, based on the description of him as “a perennial Kodak defender,” that he believed the company could do no wrong, a common—and fatal—flaw among system managers. As with the manager who frowned on Fuji’s “advanced technology” products that provided that rival’s foothold in the U.S. market, Delwiche appears to have internalized the goal of selling more film as an end in itself. He displays an organizational commitment to film, more film, film always and forever. Like soldiers forgotten after an armistice, Delwiche and other managers guarded the ramparts against old enemies.

The insular mentality created an unreserved commitment to the components of the conventional system, including personnel. Indeed, the commitment was almost fanatical in

its faith in the one best way. Gerald Zornow, an executive at Kodak in the 1970s, explained that "They tried some people from the outside before and it never worked out. Kodak is like an old family that grows up together, and it is tough for outsiders to fit in" (Moore 1983, p. 128). The company, like other American businesses of the era, fostered a commitment to Kodak in return for secure employment. Once employed, managers and researchers could expect a lifelong career with the company. Workers and Rochester natives evoked the image of a family in describing the company, affectionately referring to it as "Mother Kodak" (Frangos and Bennett 1993) and "Father Yellow" (Taylor 1983). Chairman Walter Fallon pointed with pride to Kodak's "parochial" charms, claiming that its centralized organization made for a beneficial "*esprit de corps*" (*Business Week* 1982, p. 53). Yet this spirit would not always prove desirable.

Kodak managers' entrenched commitment to the inherited system and their zealous faith in Kodak became arrogance by the early 1980s. In the late 1970s Japanese film manufacturers, especially Fuji, nearly cut Kodak's share of the photographic paper market in half (from over 70% to around 40%) by offering significant discounts to photofinishers. Kodak marketers responded with a campaign that encouraged consumers to ask for Kodak paper by name, hoping to pressure independent labs from switching to the imports. The blitz worked, bumping Kodak's share back up to 65% (Hayes 1981, p. 80). Marketers continued using this strategy throughout the 1980s and into the 1990s by instituting the "Kodak Colorwatch System," whose trappings photofinishers displayed to flaunt their alliance with Kodak. This technique again proved successful as long as the momentum of the conventional system held—that is, as long as consumers shared the Kodak faith and distrusted the alternatives.

More glaring was the company's mishandling of sponsorship negotiations for the 1984 Summer Olympics in Los Angeles. Organizers actively sought American sponsors, but Kodak balked at a relatively $4 million sponsorship fee. One Kodak lawyer even haggled over "standard contract language" and complained that "After all, this is Eastman

Kodak." Astonished, organizers broke off the negotiations and eventually awarded the honor to Fuji—who eagerly agreed to put up over $7 million. Peter Ueberroth, president of the organizing committee, scornfully responded to questions about his patriotism by saying that "Kodak felt it could do what it pleased" (*Business Week* 1982, p. 51). Kodak managers extrapolated past dominance into future strengths and dismissed its competitors. As a result, they opened the door to what would prove its most nagging rival.

Viewing their competitive environment very narrowly, Kodak personnel believed that marginal superiority, in both technology and production, made their company impervious to competition. They believed that neither consumers, nor photofinishers, nor even the Olympics had legitimate alternatives to Kodak's conventional system. Kodak had discovered and still controlled the market for a product that yielded spectacular margins—and its managers planned to keep it that way.

Old Problems, New Stresses

Since inventing the conventional photographic system in the 1880s and 1890s, Kodak researchers worked on a few well-identified critical problems. Improving system performance in each made photography more convenient, in turn boosting sales of Kodak film, paper, cameras, and chemicals. Managers faced new stresses in the 1980s and 1990s. Increased competition hurt Kodak's market share and margins, forcing organizational decisions than executives had avoided for years. Environmental anxiety cast a pall over the company's film and chemical operations, threatening nightmarish public relations troubles for the future. These stresses, and other ones stemming from managers' actions, undermined the ability of Kodak executives to control the system they had long dominated.

Fuji's sudden success challenged Kodak's dominance most directly. Many industry watchers have analogized the conquest to that unleashed on U.S. automobile makers in the late 1970s and early 1980s. Fuji and others—in some cases, with the backing of their

governments—competed more aggressively on price than prior rivals, and their products approximated the quality of Kodak's. Even after the "price wars" and marketing campaign discussed in the previous section had restored much of its market share, Kodak was earning less off film and paper than it had in the early to mid-1970s. When Kodak controlled 90% of the domestic film market, managers set a price that returned 60% margins; by the mid-1990s, when their share was just 75%, market pressures often pushed margins below 50% (see Desmond 1997; Hayes 1981; Rudnitsky 1982). While impressive compared to shares and profits in other manufacturing industries, the difference was akin to that between Easy Street and the gutter. Meanwhile, the photographic market evolved from a "mass market" to a "class market" that all but ignored Kodak's no-frills Instamatic and Disc models in favor of sophisticated SLRs and point-and-shoots (Chakravarty and Simon 1984), making Kodak's development expenditures in them worthless.

Shocked by Kodak's losses and the evaporation of supposedly secure investments, shareholders demanded that the company boost earnings. Executives responded along three courses of action. For one, they laid off workers—eight separate times between 1983 and 1996 (Desmond 1997, p. 188). CEO Walter Fallon announced the first wave at Kodak's 1983 annual meeting. Insular Rochester reacted with alarm. "People are really scared for their jobs for the first time in their lives," said one resident (Taylor 1983). Job insecurity narrowed employees' already protectionist mindsets.

Another course involved reorganization—changing the organizational chart. Most intent on this strategy in the 1980s was executive vice-president J. Phillip Samper, the youngest of Kodak's top three executives in the middle of the decade (Colby Chandler and Kay Whitmore were the others). He replaced Kodak's traditional bureaucratic structure with seventeen "entrepreneurial units." One executive managed each and had authority over everything from conception to production and marketing (Buell 1985). Within a few years, the Photographic Products and Information Systems Divisions were showing remarkable improvement under his guidance (Chakravarty 1988). However, the initiative failed to

effect any lasting change in Kodak's culture. Manufacturing and administration functions proved difficult to coordinate, dividing the company into a number of sluggish "fiefs" (Frangos and Bennett 1993).

Lastly, Fallon and especially Chandler and Whitmore pushed the company to diversify. Their strategies intended to transform Eastman Kodak into an imposing conglomerate, a form of the large managerial corporation that evolved in the 1960s and 1970s. According to Alfred Chandler (1977, pp. 480-482), rather than expanding existing operations, conglomerates grew by purchasing other firms. They even purchased businesses in unrelated industries, in which case their "managers . . . became almost pure specialists in the long-term allocation of resources" (p. 482). They became investment gurus and, if they pursued this strategy to an extreme, resembled Warren Buffet.

Security analysts, troubled by collapsing market shares and shrinking earnings, vocally encouraged Kodak executives to venture into additional product lines as insurance against further losses (Taylor 1983). While Walter Fallon publicly rebuffed the notion, saying "one thing we don't want to be is a conglomerate going in directions that have nothing to do with photography," he drew up plans to make Kodak a major actor in health science (Hayes 1981, p. 86). Whitmore spearheaded the $5.1 billion dollar acquisition of Sterling Drug, a company whose pharmaceutical resources were expected to complete the visions of the executive staff. He and other managers wanted to take advantage of the health industry's strong showing in the 1980s (Ansberry 1988; Fraser 1990b). Sterling was a sector bet, a resource allocation decision as Chandler described. And it was a bad one at that. The takeovers as a whole brought Kodak mountains of debt—eventually totaling about $10 billion, according to Maremont (1995, p. 65)—and few positive results. Belying Fallon's expressed fear, managers diverted precious resources towards almost everything but photography.[7]

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[7] The corporation also plunged funds into electronics companies, which I detail separately in chapter two.

Meanwhile, environmental groups began to take notice of pollution stemming from the manufacture and use of photographic products. As the momentum of the conventional system increased during the twentieth century, firms intensified production to meet growing demand. Managers paid little attention to the consequences as they pushed the system harder. As they did so, they generated a veritable laundry list of waste chemicals—silver bromide crystals, complex hardening agents, developers like hyrdroquinone and gallic acid, acetic acid, sodium and ammonium thiosulfates, bleach, and aluminum salts (Henn 1977). The National Wildlife Federation placed Kodak on its list of top toxic chemical producers, and a study reportedly labeled it "the nation's largest user of methylene chloride . . . a possible carcinogen" (Frangos and Bennett 1993, pp. 15-16, quote on p. 16). Packaging wastes, especially plastic disposable camera shells, raised further concerns.

Already burdened by flat sales, Kodak managers endeavored to clean up their practices. A massive reclamation program begun in 1990 motivated photofinishers to return single-use camera casings to Kodak, who reused or recycled the pieces. Kodak also collected salvageable elements from film rolls (Watson 1991, 1994). By 1996 these efforts "diverted 500 million pounds of materials from landfills," including "materials from more than 1.3 billion rolls of film" (Fisher 1996, p. 9; see also Kohrt, 1997). A 1992 sustainable development study by Poduska et al. gave Kodak generally high marks. The company had reduced its chemical integrants by 90% and was transmitting only 1% of its silver inputs as waste. A few years later the company announced that one of its manufacturing plants no longer produced any wastewater whatsoever (Fisher 1995, p. 14). The system managers generally heeded environmental warnings in order to maintain a positive public image.

But while they concentrated on "sustainability," Kodak managers were distracted from other problems. The recycling program required Kodak to build channels for plastic on the same order as it had for distribution, adding costs at a time when Fuji was constantly lowering prices and stealing market share (late 1980s, early 1990s). Engineers scrambled

to invent new emulsion recipes and production flows that reduced both the consumption and waste of raw materials.[8] While the reorganization of the flows undeniably helped profitability of many product lines, time and resources were expended. Fuji was slashing prices, and Kodak was reinventing the wheel. Although the environmental stress itself did not upset the system, it occupied the attention of the system managers while deeper crises gestated.

These combined stresses destabilized Eastman Kodak's environment. Belligerents like Fuji had more resolve than Kodak managers had ever seen. Their strategies deflated Kodak's traditionally lofty profits, undercutting the financial security which allowed its engineers to spend almost unlimited resources and time on traditional research problems. Strategy responses like layoffs and reorganization temporarily boosted earnings, yet they created further anxiety within the corporation. Attempts to find new growth businesses through diversification added debt, which aggravated managers' need for reliable cash flows. At the same time, environmental concerns forced managers to overhaul their core products and services. Managers consigned funds, manpower, and intangibles to subdue internal convulsions. Thus, as Eastman Kodak confronted technological change, adversity threatened to unsettle its technological system.

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[8] On redesigning production flow in black-and-white film, see the extended treatment by Frangos and Bennett (1993, pp. 41-59 and 145-61).

TWO: THE DIGITAL SYSTEM

It's one thing to compete against GAF,
and another against Sony.

— Photographic industry analyst, 1982 (*Business Week* 1982)

Introduction

On January 28, 1996, the Dallas Cowboys won Super Bowl XXX, defeating the Pittsburgh Steelers, 27-17. Cornerback Larry Brown intercepted a pass late in the game, setting up Emmit Smith's clinching four-yard touchdown run. A worldwide television audience joined the seventy-six thousand spectators at Sun Devil Stadium for the pre-game entertainment, a Vanessa Williams rendition of the National Anthem, player introductions, Diana Ross's halftime show, and The Game. They relived the high points Monday morning through the newspaper photographs that captured the key moments. What they didn't see were the NC2000e cameras, Macintosh computers, editing software, disk drives, fiber optic cables, and all the other components that marked a photographic milestone.

For twenty-nine Super Bowls—not to mention World Wars, presidential elections, historic flights, and countless smaller news stories—photojournalists had used roll-film cameras. They plied the conventional 35mm system for decades. But no longer. That January day Associated Press staff photographers relied on digital technology exclusively; it was the first time a national news service had done so at a major event (Alabiso 1996). Although it remained dominant among consumers, conventional photography was no longer a monopoly.

In this chapter, I explore the digital system's components and the momentum changes that dissipated Kodak's dominant position. I describe the breakthroughs which first offered alternatives to the chemical technology which undergirded the conventional system. Next I outline hardware advances that reshaped the market environment in a way that was increasingly receptive to digital photography. These were market and technological "contingencies" to which Kodak managers did not react well.

I then outline some inventions whose features radically differed from conventional ones, undermining the conventional system's predominance. Combined with the contingencies already mentioned, these features incited conversion to a digital system.

The final two sections detail Kodak's handling of changing conditions in the system it long controlled. The first examines the competency crises in the face of these changes. One final section summarizes the external pressures on the conventional system's structure and the new values of the emergent system that spelled doom for the prevailing system. These final analyses highlight Kodak's conservative reluctance to compete in unproven technologies and then to project the mindset developed in the first period onto the conditions of the second.

Challenges to Film: The Beginnings of Disorder

As I showed in the first chapter, Kodak managers conceived of photography as a closed system that they alone controlled. They dismissed alternatives out of hand. Two technologies, however, set the precedent for non-photographic processes.

The first was the advent of workplace photocopiers in the 1950s and 1960s. These machines ushered in new approaches to document creation. They reproduced reports and memos at will, and could duplicate black-and-white photos, albeit crudely. Photocopying did not require any photographically skilled operators or darkroom facilities. Designers could conceive of a largely automated photographic process. Significantly, Eastman Kodak

did not. The company developed much of the technology but did not perceive a commercial market for it. Having passed on it, Kodak's Rochester neighbor, Xerox, turned photocopying into an industry.

Edwin Land's Polaroid system was a more direct threat. First unveiled in the 1940s, instant photography enjoyed commercial success starting in the 1960s. By the 1970s it was a significant threat to the conventional system. In 1978 over 13 million instant cameras were sold, outnumbering their conventional counterparts (Nulty 1991, p. 40). Instant cameras compressed the photographic process into a single step: pressing the shutter release. No one had to "do the rest"; it just happened. Consumers did not have to wait a day or a week to see their finished prints, just minutes. The process threatened all photofinishing services, and it challenged the century-old dominance of negative-positive systems. Despite its shortcomings, especially in quality, many consumers liked its advantages. Land had openly balked at the industry's deference to Kodak. His system nurtured the very values that most threatened Kodak's position, initiating a consumer mindset that proved receptive to unconventional photographic technologies.

Analog video was the final precedent to digital technologies. In 1975 Sony introduced the first video recorder. The company gained "an advantage in reputation if not in actual design" with its Betamax system, despite the eventual success of the rival VHS format. Sony furthered its reputation again in July 1983 when it added the first consumer camcorder, which combined imaging and recording components in a single unit. Both the VCR and camcorder became consumer electronics hits. Again, consumers simply pressed a button to record and another to play back on their home televisions; little technical skill or training were required. They could also record over unwanted scenes and reuse tapes. As with instant photography, video systems offered poorer resolution than film, but the illusion of motion convinced consumers' eyes otherwise. From a competitive standpoint, video manufacturers constructed an alternative to film. Family photographers that had

previously photographed children's' birthday parties, now took only a few, taping the events with a camcorder as well.

Remarkably, Eastman Kodak had developed much of the necessary technology, patenting an 8mm video recorder and single-unit camcorder in the 1970s, but again failed to imagine (or construct) a market for it. Retrospective managers have recalled widespread internal resistance to the video project for fear that it would "cannibalize" the film market. They feared that the radical system would obsolete the conventional one, taking personnel and expertise with it. From the perspective of this paper, the momentum of the conventional system within Kodak itself prevented potentially valuable research from entering the development for production phase. Problem choices led decision-makers to view these breakthroughs very negatively, either to downplay their significance or to fear them—to label them failures, in a sense. Thus, while radical inventions did indeed arise from independent sources, the system participants had in fact already accomplished the same ends, but they suppressed them in the name of the system.

Seeing an opportunity to further enter the photography market, Sony gave the first American demonstration of an electronic still camera at a trade show in October 1981. Called the "Mavica," the camera used 279,300 photoconductors to create black-and-white images, storing them on crude magnetic disks. A standard television set displayed the pixelized picture (see Drukker 1982). Although the prototype did not reach commercial production until 1984, the showmanship shook the video and conventional film industries. Many thought that if Sony could rush a still video camera to the market, they could overrun chemical film just they had dogged and surpassed home movies. Demand for VCRs and camcorders convinced Sony and others that consumers wanted to see their pictures on their TVs.

Just days after the stunning Mavica demonstration, Eastman Kodak's president and second-in-command gave it a cold reception in a presentation to security analysts. Aware of the sensation a still video camera would cause, then-president Colby Chandler emphasized

the technical superiority of existing film technology, his company's in particular. Entitled "To Hit a Moving Target," his speech emphasized the sparse resolution of the Mavica when compared with Kodak film and used eighteen projectors (presumably displaying the best contemporary photography) to illustrate his argument. Chandler explained,

> An electronic sensor with one million individual elements (pixels) could produce an acceptable [3x5 inch] print. That's almost four times the number of elements in currently available sensors, and even that falls far short of current film standards. . . . [A] 35-mm frame of . . . Kodacolor II film offers the equivalent of more than 10 million sensor elements. . . . We have on the drawing boards new products that have the potential to increase those numbers by 50 percent. (Leavitt 1982, p. 126)

Chandler's interpretation of the Mavica entirely in terms of his company's system and its established specifications is striking. This is not surprising, of course; everyone was talking about the Mavica in precisely those terms. What else could they do, after all? But his defense of film reveals the conservative mindset at Kodak. Chandler and other managers took the new technology—apparently any radical technology, if photocopiers and video recorders are any indication—and matched it up against chemical film. This is classic momentum by way of problem choice. Kodak's main critical problem was improving imaging resolution. When an innovation failed to surpass film's technical specifications, the technology was rejected as inferior and the company moved on. Though understandable, the self-congratulatory posturing (Kodak will "increase those numbers by 50 percent," don't you worry!) should not have reassured shareholders.

This kind of response was typical of those in the photographic industry. In the early 1980s Hitachi had developed a camera similar to the Mavica and unsuccessfully offered its rights to Polaroid. Said one Polaroid scientist, "A true photographic company can't come out with a product that mediocre" (Beam and Port 1985, p. 151).

Of course, Kodak was no ostrich. The company did eventually enter the photocopier business, and the instant photography business, and even the video business. It also set about developing a response to the Mavica. Kodak marketed an industrial video system capable of capturing more than 2,000 frames per second, showing that it already

had some convertible technology ready (Galluzzo 1981). Its first attempt, like many of its successors, conserved Kodak's superiority in film. A year after Sony showed off the Mavica, Kodak used another major industry exposition to demonstrate a film/television device. It displayed negatives in the recently-unveiled disc format on a standard television. Quality was hardly better than Sony's product, although passable for TV images. Again Kodak exhibited a conservative attachment to the conventional system (the model displayed used disc negatives to showcase the new format, not for any obvious technical reasons). The display unit was little more than a frill. It seems as though Kodak was learning the wrong lessons from the Mavica's excited reception. Believing that all consumers wanted was to see their pictures on TV, that's all the company offered. The company may have even believed that the threat was a thing of the past, as research director Leo J. Thomas commented that even Sony's engineers at the show "were very impressed," causing one journalist to declare Sony's still video intentions dead (Moore 1983, p. 126). Even recognizing that many significant capabilities did not exist anywhere in the world at that time, it seems that Kodak was dedicated to video technologies only to the extent that they could increase film sales. The display device was hardly revolutionary, and Fuji unveiled its "Fujix" machine that did the exact same thing in 1985 (Beam and Port 1985, p. 154)

In 1986 Kodak introduced what it called the "Still Video System." It made prints of television images. Thus, users could use a camcorder to record images, pause them on playback, and output them using the Color Video Imager (Andrews and Miller 1986; Leavitt 1985). They could also use it in conjunction with the Kodak 7000 Modular Video System, described above, to record and exchange images on proprietary floppy disks. Hitachi and others added dedicated TV printers of their own within a couple of years (Nulty 1991). The stakes were raised further still with the unveiling of Kodak's revised still video system at the International Conference on Consumer Electronics in June 1987. The $4,800 SV6500 Color Video Printer could make images from many different input standards, printing at 512-by-512 pixel resolution on 4-by-5.2-inch thermal paper sheets (Goldberg

1987). These products were significant because they began to move electronic photography toward the established mode of visual communication, the printed image. In this arena, Eastman had to make its mark or lose the market to the camcorder makers.

Despite the acceleration of advances in electronics, Kodak did not leap into the business. Instead, the company concentrated on developing measured responses of its own. For some time, corporate insiders tantalized the imaginations of industry watchers by leaking information about what would become the Disc product. Some speculated that the Disc would incorporate magnetic and still video technologies as a kind of hybrid product; others that its primary feature would be the television display of negatives rather than using prints (Hayes 1981, pp. 79-80). Both Wall Street whispers proved unfounded. Instead, the Disc turned out to be a relatively conservative film format.

Clearly Kodak saw that video technology could be captured as an addendum to their established system. Consumers would still use conventional film and photofinishers, putting their film on TV using the new device. They continued to take this attitude throughout the 1980s.

Beyond Control: Digital Hardware Outpaces Film

Electronic devices such as the VCR and Mavica demonstrated the possibility of filmless photography, but only when computer technology advanced did they directly threaten the conventional system. Kodak managers were aware of these possibilities but dismissed them as either inconsequential or too threatening to the core business. They fell into a defensive mindset that neither protected their film products nor engaged the emergent system. In this section I will describe the digital breakthroughs that exacerbated the threat to conventional photography and illustrate Kodak's response to them.

When Sony first publicly demonstrated the Mavica, many realized that it could be used in conjunction with computers as part of a digital system. Home computing was still a

speculative venture as the 1980s dawned, however. In 1975, for example, Digital Equipment's founder confidently foresaw "no reason anyone would want a computer in their home" (Collens 1998, p. 20). Colby Chandler's presentation, already discussed, came at a most inopportune moment, just ahead of tidal advances that forever redefined how consumers viewed computers. Confident in the divine superiority of film, he skeptically calculated that "If you were to calculate the storage capacity of today's Kodacolor II film in terms of 'bits of information,' you would find that one 35-mm frame of film can store more than the maximum internal memory capacities of 100 home computers" (Leavitt 1982, pp. 75, 126). Developments in at least five categories quickly shook his assumptions.

First, computers became everyday appliances faster than anyone at Kodak imagined. Within a year of Chandler's speech, IBM introduced its first "personal computer." The "PC" launched a relentless colonization of the office and home. Contrary to earlier predictions, consumers did want computers, lots of them. Kodak could only watch as the core component of a potentially radical system found its way onto millions of desktops.

Second, computers' memory capacities and processing speeds grew exponentially. Whereas the average machine handled a few million calculations per second in the mid-1980s, it handled tens of millions by the early 1990s, and a hundred million or more by the mid-1990s. Likewise, its memory increased more than a hundredfold (Historical Computing Society 1998). Indicative of the trend, IBM in 1990 forecast that "computers' speed will double, storage requirements will triple, and memory will quadruple" every three years (Larish 1992, p. 373). Even achieving Chandler's promised 50% increase in film resolution through T-grain emulsions, computer technology advanced far faster and more consistently. A computer at the end of the period under consideration could store data for not only "one 35-mm frame of film," but several.

Next, electronics manufacturers designed dedicated computer monitors that replaced standard televisions as display units. Because they were manufactured for much more forgiving viewing situations, televisions limited the maximum resolution, sharpness, and color range of a still video image. Better onscreen clarity allowed computer users to capitalize on the processing improvements already mentioned. Late in the 1980s Apple introduced a Macintosh computer with 24-bit color graphics—16.8 million hues—making realistic photographic reproduction available on a home computer (Historical Computing Society 1998).

Fourth, graphical user interfaces and mouse devices made computers valuable tools for handling images. The Apple Macintosh popularized this combination by pixelizing all onscreen images, including text, as did Microsoft in successive versions of its Windows operating system. Apple further simplified photo handling with a 1992 operating system extension that introduced routines to import and manage photographic images (Dambrot 1992b). At the same time, the computer mouse made manipulation and editing practical. Using the device to control an onscreen pointer was far easier than using keystrokes. Not coincidentally, “paint” programs and other desktop publishing applications flourished soon after mouse-controlled computers hit the market.

Finally, computer companies engineered vastly improved printers to work in tandem with the other advances. Dot-matrix printers replaced typographic machines in the early 1980s, and they in turn were supplanted by inkjet and laser printers a decade later. Color versions of these devices became affordable and popular in the 1990s (Verity 1993). Although they did not replicate the minute details captured by chemical emulsions, these printers made color hard copies quickly and conveniently. An inkjet print of a photo sufficed for many users just as laser-printed text substituted for professionally typeset documents.

Consistent technical improvement made computers sophisticated, graphics-intensive workstations by the early 1990s. Chandler and other managers underestimated not only

their memory capacities but also their appeal to consumers. Computers' novel features distracted many, if not most, from inferior reproduction values. Accustomed to the slow, steady improvement of chemical film technologies, Kodak managers had no quick response in hand. With only a diffuse interest in electronics, the company could not achieve the same production and research efficiencies that consumer electronics firms enjoyed.

Chandler defiantly challenged critics who said that Kodak could not compete with the likes of Fuji and Sony, saying "competition is nothing new to us" (Taylor 1983). In the early 1980s Kodak instituted a more substantial presence in electronics, spending the majority of its research funds in the category. Top executives showed sudden interest in recent research acquisitions, and they hired ten times as many electronics technologists as chemical engineers. Said president Kay Whitmore, who initiated the company's first strategic plan in 1983, "We clearly have to attract people into the company who don't exist here now" (Moore 1983). Facing threats from computers and video products, Chandler and Whitmore created Kodak's first Consumer Electronics Division in January 1985 (Beam and Port 1985).

The push into electronics yielded sporadic, if not downright disappointing, results. Despite throwing money, personnel, and superficial tactics at the problem, no one took the lead in forcing change. Kodak invested millions in small computer firms like Sun Microsystems and Interleaf, and acquired floppy disk maker Verbatim (Buell and Aikman 1985). Besides establishing a "presence" in computers, the moves had little strategic purpose. As a result, Kodak spent time and money developing colossal white elephants that lagged behind their competition. For instance, in May 1985 Kodak introduced an electronic publishing system for corporate users that wanted to print their own reports (Buell and Aikman 1985). The system came along well after word processors had become essential office products and just as desktop publishing was taking root on the Macintosh and other computers. Eastman Kodak's device was too little, too late.

Kodak's approach was the same in electronic imaging. Guided by the principles handed down by Eastman himself, Kodak's managers clung tightly to the conventional system. The disc negative TV viewer already discussed was one example. Another was the Still Video System envisioned by Kodak designers. Introduced in June 1987 and never sold commercially, the System combined conventional film, motion video, and computer components. Users could input their film prints via a Video Transfer Stand, or connect their PC or VCR to a Still Video Recorder. A direct capture Still Video Camera featured a 280,000 pixel CCD with a sensitivity equivalent to 100-200 ASA (Goldberg 1987).

The Still Video System conformed to Kodak's ingrained values and expectations. It tried to give Kodak maximum control, as the company would dominate transfer, recording, camera imaging, communications, and printing components. Even the storage medium, a proprietary floppy disk design, could be controlled by Kodak. At the time, Kodak had little expertise in any of these technologies. Befuddled by the acceleration of research throughout the electronics industries, Kodak managers fell back on their traditional notion of what their company did: it dominated the photographic system. Kodak managers would accept nothing but the highest quality photographs. "We didn't want to make television sets or recorders," Kay Whitmore affirmed later (Flanigan 1993). By creating a new system, they hoped to carry on the same.

An opportunity to redefine Eastman Kodak's management arose in 1989 when Colby Chandler announced his retirement as chief executive officer. Chandler's two vice chairmen, J. Phillip Samper and Kay Whitmore, vied for the position. Whitmore had a chemistry background and abundant manufacturing experience, as had every Kodak high executive since George Eastman. Samper, on the other hand, was a marketer by trade—the highest-ranking marketing manager in the company's history, in fact. Samper proudly told an interviewer that he was an outsider in Rochester and not locked into its stodgy mindset. "I'm an agent of change," he beamed, and went on to emphasize the many years he had spent overseas. Under pressure from stockholders, security analysts, and

employees—who all wanted Kodak to focus on its traditional strengths and achieve safe profitability—Kodak's directors picked Whitmore. Samper immediately resigned (Chakravarty 1988; Fraser 1990b; Holusha 1989).

Around the same time, Kodak researchers began work on an imaginative electronics project. As computer memories and users' demands grew, the industry had begun converting audio compact disc (CD) technology into a computer storage medium. Libraries and corporations needing high-volume data storage drove the innovation of these "CD-ROMs." The Kodak team believed that it could use the technology to store photographic images. The general manager of the Consumer Products Division, which had initial responsibility for the project, described Kodak's motivation as wanting to "take the best of silver halide technology and marry that with the best of electronic imaging technology" (Fraser 1990b).

Photo CD, as it came to be known, was announced to the public in 1990, a full two years ahead of its scheduled availability, to give other companies time to create compatible products. Kodak hoped it would be a new standard. "What we've done is create a new photographic medium," crowed one excited researcher. "It's as elemental as a roll of film" (Associated Press 1991). This comment hints at Kodak's expectations. The company expected its "digital film" to become the standard for the emergent system, just as roll film had been for the conventional system. Kodak's decision-makers still viewed the digital system much as they had the conventional one, as a consolidated, linear system which one company could dominate if it could get the system right first.

To handle the Photo CD product line, Whitmore shuffled Kodak's organizational chart at the end of 1991, about a year before the official debut. He formed a new Imaging Group from the existing Photographic Products, Commercial Imaging, and International Groups. Loyal managers with decades of experience in the conventional system assumed all of the primary leadership positions. Leo Thomas, the longtime research director who had been overseeing pharmaceutical and life sciences research, became its first leader.

William Fowble, the former head of Photographic Products, was named to head the Imaging Development unit , which would have primary control of Photo CD development. A new Electronic Imaging Platform Center was also created to develop hardware and software to handle photographic images (Holusha 1991).

The new organizations were clearly intended to identify problems critical to Photo CD development. By resolving them Kodak hoped to overcome the obstacles to a digital system as dominant as the conventional one. These goals were relics of Whitmore's—and others'—training in technical and manufacturing matters. Some two hundred engineers worked on the project. They refined existing technologies, isolating several obstacles. They created a faster scanning method that would allow photofinishers to input a roll of film in a reasonable time, and at sufficient resolutions. With help from Intel Corp., engineers invented a new compression formula that stored image data in a smaller space. And they conceived a method of "multi-session" recording that would allow consumers to add scans again and again, rather than in just a single stamping. "The whole writable CD concept is going to be really big business," gushed Scott Brownstein, Photo CD project leader. "We'll sell those scanners, we'll sell some printers, we'll sell blank CDs, and we'll sell software for image manipulation and graphics systems" (Gardner 1992, pp. 64-65).

Despite generous attention to the electronics details of Photo CD, the Group's early strategic actions are notable mostly for their passivity. Rather than actively tying Photo CD to other companies' products as well as their own, Kodak managers believed that their brand name alone would make it a standard in the digital system. They hoped demand would create a "bandwagon" effect that would solidify its market position (Grundberg 1990). Kay Whitmore expected that Photo CD would "open new business opportunities in itself" (Burgess 1991). The technology would be so good, the pictures so sharp and versatile that—like 35mm cartridges, Kodacolor, and T-grain emulsions—the rest of the industry would have to take notice.

Kodak continued on as planned, designing Photo CD as a product akin to a VCR. Photofinishers would return both prints and a Photo CD at the time of processing. Consumers would then view the CD on a special Kodak player attached to the family television. Company officials were publicly excited that they had the next video recorder on their hands, believing that yearbooks would publish CDs rather than hard cover annuals, and that wedding photos would come on a CD rather than in an album (Bernstein 1992). Some industry observers were already amused at those aspirations. Said Larry White, an electronics writer for *Popular Photography* magazine, "[as a consumer product] I think it falls through the cracks" (Burgess 1991).

Inventing Imaging: Digital Darkrooms and Digital Publishing

While acceptably sophisticated hardware components were in place, the digital system won only sporadic acceptance. Sony's Mavica hinted at things to come, yet it failed to even approach the success of the camcorder. Personal computer makers incorporated high-quality graphics about as quickly as they could, but mostly to accent video game software. Only when software packages and some other innovations justified it as a legitimate alternative to the conventional system, offering features that went beyond the linear chemical process, did the digital photography begin to evolve as a technological system with momentum. In the context of the computer industry they may not have been blatantly radical, since they simply programmed or refigured extant components. But what is conservative in one system can be anything but in another; Hughes refers to this effect as "soft determinism" between systems (1987, pp. 54-55). For Kodak, these uncharted breakthroughs disrupted their more conservative entries into digital photography.

Word processors and spreadsheets began fostering the computer-based editing ethos in the late 1970s and early 1980s. Programmers transferred these same values to "paint" programs (Adobe Illustrator, Corel Draw, MacPaint, etc.) throughout the 1980s

(Marshall et al. 1992), capitalizing on the improved graphics capabilities of home computers. Aldus Corporation packaged some of these same concepts in its “PageMaker” software, introduced in 1985. Together with an inkjet or laser printer, computer users produced magazine-style layouts that included graphics and even photographs. “Desktop publishing” was born (Historical Computing Society 1998).

Dedicated photo-editing software arrived around 1990. In the late 1980s, advanced paint programs began handling high-resolution photo images, and programs like PageMaker included some image-manipulation features. Meanwhile, scanners gave home and office users the ability to input their photos into their computers. Thomas Knoll and John Knoll owned such a unit and wrote a program to control scanning and edit images. They sold the rights to their program, called “Barneyscan XR,” to typeface and publishing systems giant Adobe, who released the software as “Photoshop” in 1990 (Salgado 1997). Similar programs from Fractal Design Corporation, Data Translation, and Letraset appeared at nearly the same time. Together with Photoshop they gave birth to computerized image manipulation (Eherenmann et al. 1993; Milburn 1990). By 1993, just a few years after obtaining the prototype, Adobe had sold more than 300,000 Photoshop units with a retail value of more than $200 million (Callahan 1993, p. 63).

These programs radically redefined the photographic image. Previously, managers at Kodak could rightly defend their system as “the one best way.” Chemical film had the highest resolution of any medium, hands down, and it was also durable, convenient, and inexpensive compared to any of the alternatives. Photoshop and its imitators challenged that momentum. The software did not outperform the conventional system on film’s technical merits; it defined new values that lay outside the conservative mindset of firms like Kodak. These are the familiar strengths of computers: unlimited editing, infinite reproduction of a digital original, immediate viewing, and (theoretical) compatibility among different programs.

Photoshop's features satisfied problems from both the conventional and emergent systems. It originally ran only on Macintosh computers, which were better suited to the graphics-intensive work. Many ingenious routines powered its usability. Photoshop worked around memory limitations by using hard disks as "virtual memory," storing the dormant image portions and displaying the visible ones on screen. It maintained 24-bit image data—enough to track the millions of colors that near the tonal discernment of the human eye—even on hardware that could not . Just as importantly, Photoshop operated in both the computer-standard RGB (red-green-blue) and publishing-standard CMYK (cyan-magenta-yellow-key/black) color separation modes. This, too, enabled the program to gain momentum. Able to convert their image data from mode to mode, photographers and graphic artists could store pictures as the CMYK data with which they were trained, and conventional publishers could print them without reprocessing the data (Parascandolo 1990). Computers were now speaking photographers' language.

Adobe also designed its product as a natural seed for a system. Photoshop included features called "filters," alluding to the colored- or special effects-filters of the conventional system. The digital versions twirled pixels or changed the color balance to resemble pastels, and additional filters from Adobe or third-party venders could be added to enhance the program's versatility. This feature carried momentum of its own, as users built filter libraries and Adobe encouraged tacit endorsements through products like Aldus Gallery Effects and Kai's Power Tools (McClelland 1994).

Despite these niceties, Photoshop's market was limited. Costing $895 in 1990, it was hardly a modern Brownie. The average consumer had little need for many of its features, and even many professionals decried the lack of stripped-down but functional editing software. In the mid-1990s Adobe began offering a scaled-down version of Photoshop called "PhotoDeluxe," including the simplest features, like crop and zoom. At only $89 and occupying far less memory, the program fit the needs of home hobbyists and laptop-dependent professionals. Good enough to let users get a taste of the flagship's

popular features, like cutting out a person's face and pasting it someplace else, as demonstrated in Figures 12a and 12b (Burgess 1995; *Petersen's Photographic* 1996).

Kodak managers appear to have consciously passed on commercial software development for two reasons. First, they remained committed to the idea that Eastman Kodak could only pursue state-of-the-art technologies. Although it eventually became the standard editing program among professional photographers and graphic artists, Photoshop did not meet Kodak's standards. Second, the company's research personnel just were not Silicon Valley types. Kodak possessed significant hardware and software talent, but their mission was not to design everyday software. They were drafted to develop high-end workstation software for industrial use, not for the mass market.

Over the same period of time it became far easier to digitize a photograph, or capture a scene directly, and import it into a home computer. Following the Sony Mavica and the Hitachi model offered to Polaroid, many Japanese camera and electronics manufacturers developed their own analog video and digital still cameras. Casio fabricated what it called the "first still camcorder" in 1987. The camera (VS-101) substituted metal oxide semiconductors (MOS) for CCDs. The new imaging component, though not as sharp as average CCDs, were much easier to produce and could therefore be sold more cheaply, listing at a svelte $899 (Sherman 1988). In contrast the Konica KC-400, introduced in the same year, sold for an unfriendly $3,870 (Schaub 1987, p. 70). Semiconductor manufacturers developed new forms of camera memory that were less expensive, more standardized, and smaller—some no bigger than a credit card—that made digital cameras less cumbersome in the 1990s (Elphick 1997).

Although still pricey and clumsy compared to conventional models, electronic cameras were suitable for use in specialized settings. Digital cameras always intrigued news photographers, whose work was limited by deadlines more than by overall picture quality. Associated Press photographers experimented with a (motion) video camera at the 1988 Democratic National Convention and a Nikon still video device at the 1989 Presidential

Inauguration (Foss 1992, p. 61). By the mid-1990s some regional newspapers used digital cameras exclusively, both for its time advantages and to save money ordinarily spent on film and processing (Rosenberg 1995; Smith and Rosenberg 1995). A few, such as the *San Francisco Examiner*, creatively used camcorders to tape breaking stories and selected individual frames for publication (Dvorak 1993). At the Super Bowl in 1996, the Associated Press followed suit (Alabiso 1996).

Eastman Kodak continued to refine its own digital camera technologies. The company had some of the world's best CCDs in 1987 (Sherman 1988), but they struggled to find an appropriate use for them. In the 1990s Kodak partnered with Nikon to create the DCS (digital camera system). Kodak attached a CCD and memory unit to a standard Nikon SLR body, making the camera as familiar as Nikon's flagship cameras.

Scanners and printers evolved as well. Desktop flatbed scanners became popular in the late 1980s as a way to import prints into page-layout software. Further improvements in CCDs, artificial intelligence, and scanning software allowed office models to capture images at a quality that rivaled that of professional scanners just a decade earlier (Sharples 1995). Film scanners did the same for negatives and slides. Desktop units emerged from the experimental stage around 1990 (Fraser 1990a). A new printing technology called "dye-sublimation" produced results that resembled conventional prints in resolution, color, and even the familiar glossy finish (Heid 1993). They allowed photojournalists and amateurs to capture images from processed negatives—omitting the chemical printing stage and a steady source of income for Eastman Kodak.

When the Internet and World Wide Web exploded in popularity in the early to mid-1990s, they powered a surge in demand for digital images. Corporate and casual Internet denizens craved the visual appeal of photographs for their web pages. The growing use of presentation software like Microsoft's PowerPoint had a similar impact. In most cases speed and convenience outstripped the importance of resolution and overall quality. Without having to worry about wasting film, "the sociology of picture-taking" changed

drastically. Commented one columnist, “with electronic cameras, you just want to keep shooting. You don’t care how things turn out. You can erase the really bad shots and fix the ones you want to keep using Adobe’s Photoshop” (Dvorak 1995). As the importance of electronic Web publishing increased, consumers had a growing need for digitized photos—and for scanners, digital cameras, and video capture programs. This new purpose, or overriding problem, for photography enhanced the momentum of the digital system while reducing that of the conventional system (see Figure 4a).

Accustomed to operating in a high margin business, Kodak’s managers shied away from computer accessories throughout the 1980s and into the 1990s. They meticulously focused only on products that had the potential to be big money-makers, and that consequently required enormous time and resources to develop: near-photographic quality cameras ($20,000) and Photo CD, for example. Electronics companies operated under different assumptions. A marketing executive at Minolta explained that they viewed the typical 1980s consumer as “a television person,” one who “might accept a lower level of quality than even we think.” As a matter of course at Sony, price was never a consideration for new products. Said one executive, “there’s always some segment of the population that will buy it, regardless of cost. Then we can refine it and bring down the price” (Beam and Port 1985, p. 151-154). These managers obviously had a mindset very different from those at Kodak. They took risks, pushed products into the marketplace and sought feedback, and worried about price-tags only after the “final” product had been developed. By inventing first and analyzing the merits last, computer and electronics companies defined much of the shape of the digital system.

In contrast, Kodak designers had always operated with a one-shot mentality. They would meticulously design a new format over several years and then bring it market, never to revisit it. Kodak researchers labored to develop Photo CD after licensing the core compact disc technology from Philips Electronics. The 1990 prototype was demonstrated to the press. The device took little advantage of its digital nature. It did not display full

frames and had no zoom feature, even though programming such a routine would be as easy as displaying the cropped image (Grundberg 1990). When Kodak personnel reached out to professional photographers for support, they got a cold and sometimes hostile reception. Fearing that copyright infringement would thrive on the new medium, photographers demanded that Kodak incorporate protection mechanisms (Walker 1991). And as the official debut neared, many photofinishers remained skeptical. One minilab owner who declined to jump to the new system explained that most consumers "are not aware of it yet," and without a groundswell of support he could not justify investing in "untested equipment" (Bernstein 1992).

Bemused by the criticisms, Father Yellow zeroed in on the consumer market. A series of Photo CD players designed to sit beside the family VCR hit stores' shelves in 1992 (see *Television Digest* 1992). Shortly after consumer sales began, a Kodak spokesman reported palpable "excitement" for the players. He went on to cite a San Diego stereo store that sold dozens within one hour of going on sale (Bernstein 1992).

What fanfare existed was short-lived. Kodak had recognized in 1988 and 1989 that digital photography would someday become a reality, perhaps very soon. Managers, from CEO Whitmore to project leader Brownstein, intended Photo CD to establish itself as *the* medium for the digital era, just as Kodak film had done so in the conventional system. But by early 1992, when the engineering team began fashioning the final product, a digital system different from Kodak's conception had meaningful momentum. Rather than wholeheartedly supporting Photo CD, photofinishers generally adopted a "wait and see" attitude. Without them generating consumer demand, the system would inevitably flounder. At three dollars per scan, consumers certainly did not clamor for it (Dodge 1995). Confronted with other digital choices—zip disks, personal scanners, and the like—consumers generally opted for alternatives.

By Christmas 1992, security analysts began declaring Photo CD a boondoggle. At a New York "Nobody Beats the Wiz," a consumer electronics store where Kodak expected

Photo CD players to sell well, only one unit sold in the first two months despite conspicuous displays and demonstrations. The same San Diego stereo store that had sold dozens the first day saw the pace drop from over 125 sales in August to less than fifty in November. Business, academic, and museum presentation designers, along with professionals in art, journalism, and entertainment all embraced the technology. With corporate resources available, they could afford new computers, software, and training. But because they used “high-tech photo labs,” the labs profited far more than Kodak (Burgess 1995; Rigdon 1992).

Kodak made other egregious miscalculations. Planners expected earnings to come from the sale of Photo CD players to casual photographers and computer users. But these users were already purchasing external CD-ROM drives for their PCs, and computer makers quickly made internal drives standard by the mid-1990s. Already in 1993 the electronics industry sold almost 5 million CD-ROM drives and analysts projected that to grow to more than 13 million yearly (Schroeder 1993). This trend made Photo CD players superfluous, particularly when they cost several hundred dollars and could only display pictures and play audio CDs. One flaw negated some of the intrigue among professionals. Image files created by digital cameras could not be written directly to Photo CD; they had to be printed and then scanned like a conventional photo (Dodge 1995). Intentional or not, the oversight frustrated digital photographers who might otherwise be some of Photo CD’s more loyal customers.

Kodak followed through on its promise to provide Photo CD software packages. They ranged from $40 programs that imported and displayed Photo CD images on a home computer, to a $695 page-layout package (Guglielmo 1993). But the inexpensive ones did too little, too late, and the page-layout package retraced ground broken by PageMaker, Quark Express, and Photoshop, which were already enmeshed in the digital system and standards across several industries. Finally, Kodak provided little or no support for Microsoft’s operating systems, preventing the majority of computer users from accessing

Photo CD on their PCs. Also, despite publicly declaring support for "the open systems movement" (Eastman Kodak 1991), the company kept Photo CD's file format and compression algorithm a proprietary secret based on the assumption that digital photography, like conventional film, would flow in a chain dominated by a single medium. Software vendors seethed at having to pay royalties just to support Photo CD (Grunin 1994); in effect, Kodak asked them to pay to help make its product an industry standard. Together with near exclusive support for the Macintosh, this strategy caused anguish when Kodak needed terms of endearment.

While Photo CD provided paltry earnings, Kodak's conventional film business continued to lose market share to upstarts like Fuji and 3M. Disaster loomed. On January 11, 1993 Kodak looked outside the company for the first time in decades and appointed Christopher Steffen as chief financial officer. Steffen was well-regarded on Wall Street for improving the bottom lines of Chrysler and Honeywell, and after he was hired Eastman Kodak stock jumped 36% within two months, a valuation increase of about $5 billion. Shareholders and analysts hoped that Steffen would wake Kodak from its sleepy ways. One admiring analyst described him as being "very good at picking sharp young guys in an organization and putting them in positions of responsibility," precisely what the analyst most desired to undo Kodak's insularity. The kind words were short-lived: Steffen stayed only 79 days, and Kodak stock plummeted 11% the day he left (Jones and Schneidawind 1993).

The prominent resignation hastened the end for the Kodak orthodoxy. Having watched the company plummet into the red and lose goodwill almost daily, the board of directors finally followed investors pleas and fired Kay Whitmore as CEO in the middle of the year. Rather than turning to another Kodak lifer or bringing in a cost-cutting specialist, the board hired George M. C. Fisher, who had run Motorola for several years (see Maremont 1993). The board wanted to bring an "external perspective" to the company,

according to the search committee's chairman, Roberto Goizueta of Coca-Cola (Knowles 1993).

Fisher, a veteran of the electronics and cellular phone industries, relished the opportunity to lead Kodak into the digital era. In contrast to the rigidly conservative mindset of his predecessors, Fisher claimed at his introductory press conference to have "lain awake for the past two nights thinking about the possibilities" (Dickson 1993). While just a claim, this hint of imagination contrasts sharply with the dread with which Fallon, Chandler, and Whitmore looked at computerized photography.

Fisher directed efforts to redirect the evolution of Photo CD, recognizing that Kodak's initial assumptions had proven misguided. Kay Whitmore had lumped digital technology research together with other projects under the "Imaging Group," which became a kind of catch-all. The arrangement discouraged decision-makers from breaking their attachment to chemical film. Development occurred across myriad divisions and working groups; dozens of independent teams worked simultaneously on scanner projects, for example. Potentially radical breakthroughs withered as they passed through layers of conventionally-minded managers. Fisher rearranged electronics research once more, creating a Digital and Applied Imaging Group, and he emphasized that digital awareness had to saturate all of Kodak's businesses if the company were to succeed in the new era. In the new structure Photo CD, printers, and software were all developed in a single, self-contained division. Fisher placed in charge Carl Gustin, an advertising-minded manager. Cognizant of the original failure, engineers tweaked the product, adding PC viewing software to each CD to make it easier for computer users to access. Fisher kept a close eye on progress himself (Dickson 1994; Holusha 1994; Maremont and McWilliams 1993, pp. 66-67). Kodak would procrastinate no longer.

Although Kodak did not suddenly dominate digital imaging as it had the conventional system, noticeable changes did occur. Colby Chandler and Kay Whitmore grudgingly paid lip service to competing with imports and developing viable digital

technologies, but Fisher, perhaps understanding better the nature of consumer electronics and the momentum of the digital system, instituted a wholesale commitment to reducing Kodak's insularity.

What Best Way? Kodak's Competency Dilemma

Product categories in the conventional system were well-defined, and Kodak's managers, dominating film and benefiting from its high margins, could justify an internal faith in theirs as "the one best way." The company had an advantage in the critical technical knowledge necessary to build the conventional system. Its research and development staff maintained that superiority by constantly innovating. But, by definition, the research staff concentrated on the problems critical to the conventional system, especially chemical film. This served Kodak well until the late 1970s, but conservative and radical challenges exposed the company's competency shortfalls.

The conventional system rested on several technical fields, mainly chemistry, optics, mechanics, and engineering. Clearly, the digital system made use of others. Electronics, computer science, and even mathematics displaced chemistry, while the contributions from optics and mechanics changed. One writer stated the threat to conventional system participants this way:

> What is happening is potentially far beyond just another step in the mechanics of camera manufacture or the chemistry of film emulsion. Digital photography is a leap into the science of signal processing, software engineering and microelectronics, disciplines with which most photographic manufacturers have little experience (Callahan 1993, p. 46)

Almost overnight, Kodak's chemical well had gone dry.

Electronics had been designed into conventional devices for years, automating camera exposures and photofinishing equipment. Kodak created a small electronics division in 1976. Its efforts were not entirely in photography, however; electronics research included instant photography, magnetic recording electrostatic photocopiers, and

support for the health sciences division. By the early 1980s Kodak was surreptitiously planning for wide-scale electronics research. Said Leo J. Thomas, Kodak's research director, "We have a mandate to integrate electronics into the fiber of this company over the next five years" (Moore 1983, p. 121).

Indeed, Eastman Kodak made strides in electronics, but they were not of the kind that could ensure system control. In the mid-1980s Kodak launched its 8mm full-motion video system, but it was a belated refinement of a technology governed by other firms. Kodak's "Vydek" CCDs were the world's best when announced in the 1980s, containing more than 1.4 million pixels (Sherman 1988, p. 68). But with only a few on hand, each was priceless. Even the commercial CCDs in the digital backs of the Kodak-Nikon cameras were prohibitively expensive—well over $20,000 apiece. And the still video systems which appeared in the mid- to late-1980s failed to go into production. Even Photo CD, an innovation well-regarded by industry-watchers, could not cut it with consumers. Producing top-of-the-line five dollar rolls of film was one thing; prohibitively expensive electronics were another thing altogether.

Without the proper expertise, Eastman Kodak's ventures in electronics were doomed from the start. Trained in the ways of the conventional system and the single dominant actor in that system, employees resisted change. Kodak managers, nearly all of whom rose through the ranks as chemists and chemical engineers, had a stake in the film business that they would not easily relinquish. Executives continued to look at the emergent system with a conservative mindset. One advertisement, for instance, stated that "image quality is a critical differentiator" between digital devices and their conventional predecessors (Eastman Kodak 1991, p. 144). Unfortunately for Kodak, consumers were beginning to think differently.

Additional stresses emerged under Kay Whitmore's leadership. As president, he had been a leading proponent of the Sterling Drug acquisition and initiatives into the pharmaceuticals business. Early in his tenure as chief executive, he admitted that Kodak

had spread its resources too thin. He pledged to concentrate only "on the sectors we want to be in," which he listed as "imaging, chemicals, and health" (Holusha 1989). Far from resolving Kodak's tangled research interests, his diversification strategies further muddled Kodak's confrontation with a changed environment. At a point when the company could have intensified ongoing digital research (and aggressively countered Fuji's inroads), Whitmore took on the twin responsibilities of integrating two very different companies and paying off billions in new debt. Kodak had to be too many things to too many people. Even Leo Thomas, the research director and a longtime proponent of health sciences research at Kodak, admitted that "we're a very complicated company. . . and we can't afford that. We need to be simple" (Associated Press 1991).

As a manager, the genial Whitmore was easily swayed by his colleagues—who, again, wanted to preserve the status quo. Shortly after becoming CEO he commissioned a strategic plan. Eighteen months later it was presented to the top-tiers of Kodak management. According to one second-hand report, the plan advocated that Kodak "give up its ambivalence about replacing traditional photography with digital imaging and . . . invest heavily in key electronics technologies, as well as the associated manufacturing and marketing structures." Initially, Whitmore enthusiastically supported the findings. If faithfully applied throughout the company, the strategies may have moderated the momentum of the conservative system within Kodak and opened the door to more imaginative thinking. As it was, managers issued a "silent veto" on the plan and simply ignored the directives. Whitmore himself eventually "downplayed" its importance and chose more risk-averse options like layoffs (Maremont and McWilliams 1993, p. 31). The wild goose chase for short-term profitability continued.

Whitmore also inherited the Kodak faith—or arrogance—of his predecessors. Flaunted at the top of the organization, these attitudes pervaded the company's culture and encouraged system-preserving behavior. Although he conceded that Kodak's partial monopoly would not survive, Whitmore predicted Kodak would lead the competition in

digital photography. As he explained it, “the fact you can make a television set or a computer doesn’t mean you know anything about how to make a color picture and move it around. That’s the part we know” (Appelman 1991). Yet Thomas Knoll and John Knoll knew enough to contrive the program that became Photoshop, the software that did just that. Meanwhile, Whitmore had covertly forced out two more visionary executives—J. Phillip Samper and Christopher Steffen. Whitmore’s actions mollified internal worries without attending to the underlying quandary.

George Fisher brought to Kodak the skills, experience, and vision of an electronics manager. Holding advanced degrees in electrical engineering and applied mathematics, he had directed Motorola’s development of cellular telephones and supervised the modification of conventional telecommunications. His charge was to do the same for Kodak. Having worked for so long in a monolithic system, Kodak personnel had lost their bearing under assaults from the likes of Fuji and Sony. Engineers’ problem choices diffused. “My challenge and goal will be to develop a clear strategy against which every Kodak employee can drive,” Fisher resolved (Knowles 1993).

To a large extent, Fisher concurred with Whitmore’s belief that color pictures was “the part we know,” but he used that insight to different ends. In his first major act at Kodak, he unloaded the pharmaceutical and health business. Analysts applauded the move because it sold for more than expected and allowed Fisher to reduce the company’s debt from $8 billion to $620 million (Maremont 1995, p. 63). This move freed Kodak from short-term obligations and made funds available. But Fisher’s action had deeper impacts within the organization. The research staff, including managers like Leo Thomas, was no longer distracted from the core problems in imaging. They could better integrate their efforts into the broader digital system without the tangential burden of biochemical research.

Tangible realignment followed. Leveraging his network in the electronics industry, Fisher forged myriad alliances and partnerships with other firms. Kodak could not hope to

keep pace with, let alone consistently surpass, the breakthroughs made in semiconductors, computers, storage, printers, and software. Fisher admitted that “this is a much bigger world with a lot of very sophisticated players.” His best course was to “select carefully who we will work with” (Wiseman 1994). The digital system had momentum, and Fisher knew it firsthand. He envisioned a system in which Kodak would provide critical technical expertise and public validation, but they could be no more than one component among many. “We used to try to do it by ourselves,” he poignantly explained, but “in this digital world, the opportunities are just too massive for any one company to do it on its own” (Bounds and Rigdon 1995). This conviction controverted a century of strategy at Mother Kodak. Heresy was now creed.

Colby Chandler and Kay Whitmore had formed partnerships previously. Nikon had developed the Digital Camera System jointly with Kodak in the late 1980s and early 1990s. Agfa, Fuji, Konica, and others had pledged support for the Photo CD format. Fisher was more active, allying Kodak with firms who accentuated his company’s strengths in the emergent system. Linotype-Hell, a manufacturer of publishing equipment, stuck an agreement with Kodak to develop and test jointly all overlapping products, ensuring their compatibility (American Printer 1994). Microsoft lent its expertise in software to a jointly designed, inexpensive program, “Picture It!,” that was similar to Adobe’s no-frills PhotoDeluxe but added the option to send images to Kodak’s Qualex macrolabs for printing (Eastman Kodak 1996). Video game maker Sega, a once unlikely partner for Kodak, consented to incorporate Photo CD technology into its new game system (Advanced Imaging 1995). Fisher even closed ranks with Hewlett-Packard, a competitor in printing devices, to develop high-quality dye-sublimation printers (Bounds and Rigdon 1995).

Kodak marketers designed a red, yellow, and blue variation on its familiar trademark to distinguish its digital products. As the momentum of the digital system increased, Fisher hoped to wield the symbol as an imprimatur. Though he knew the

company could not design, manufacture, and control all of the digital hardware, Kodak possessed scientific knowledge valuable to firms more established in electronics. For instance, colors had to be matched across scanners, monitors, and printers, and among organizations and users. Agfa's J. DeClippeleer identified this as one of electronic photography's critical problems, saying "despite serious standardization efforts, the problem of communication remains when speaking of color" (Jaspert 1992). Again, Whitmore was partially correct about "the part we know"—Kodak scientists did know color, filters, differences between daylight and tungsten lighting, and so forth. But rather than rushing to unilaterally impose a product on the market as he had done, Fisher joined with digital players like Adobe, Pantone, and Sun Microsystems to support Apple Computer's more practical and popular ColorSync system (Staten 1994).

While all these moves improved Kodak's digital outlook and clarified persistent competency questions inside the company, Fisher's actions dismayed others with stake solely in the conventional system. Photofinishers, especially independent or small-chain minilab owners, feared that the film giant was undercutting traditional photography. Kodak engineers created free-standing "CopyPrint Stations" from existing components—an Apple Macintosh or Sun Microsystems processor, an Epson scanner, and Kodak printer—that allowed consumers to enlarge and to enhance prints without a negative. The machines generated significant additional sales, increasing the number of frames enlarged by a factor of four or five (Jackson 1995; Maremont 1995; McNamara and Myers 1995). However, precisely because they did not depend on photolab facilities, Kodak could sell the units not only to minilabs but also to department stores, toy stores, and other non-photography retailers. Kroger's gain was the Photo Barn's loss, and the latter could not avoid resentment.

More galling was Kodak's newly announced ventures with Kinko's, whereby Eastman set up digital photography units with Photo CD access, digital cameras, and dye-sublimation printers (Advanced Imaging 1995). These "document creation centers" posed a

direct threat to the photolabs who had done much to make the conventional system more convenient, increasing film sales and profits. One chain president declaimed angrily, “they are introducing brilliant technologies, but are also saying drop dead to all the photo labs worldwide” (Bounds and Rigdon 1995). In essence Kodak had to mortgage its past to have any shot in the future.

Old Burdens, New Values

The company George Fisher stepped in to lead was clinging to an earlier era. Many burdens that first disturbed Kodak’s dominance in the 1980s still remained as its executives contemplated the digital age. Rivals eroded Kodak’s market share and profits, even in its home market; shareholders clamored for improved returns; layoffs and reorganizations continued. Some new difficulties hampered the company as well. To combat these pressures Fisher set out to realign managers’ (and employees’) values with those of the digital system, values he had mastered in his years at Motorola. These values resemble characteristics sketched by Richard Rosenbloom and William Spencer in “The Transformation of Industrial Research,” and they reflect the profundity of the changes that caused managers to lose control in the 1990s.

Kodak continued to lose market share to cagey competitors like Fuji. Managers projected huge additional sales to consumers in so-called “emerging markets,” especially in Asia. Based on assumptions about the conventional system’s predictability, they made plans to increase production capacity by 50%, boosting capital spending by 60% in 1981 alone (Hayes 1981). Fuji, however, had a better base in these markets. They captured a greater share than Kodak planners had figured, causing the Rochester giant to support expensive excess capacity. At the same time Fuji stole enough of Kodak’s previously impenetrable domestic film and paper markets to tatter its financial foundation (Desmond

1997). Besieged, Kodak managers resorted to legal maneuvers to protest what they viewed as Fuji's unlawful aggression.

Kodak's culture remained a lifeless bureaucracy. With earnings depressed, employees feared for their jobs and fought to protect them. Often this anxiety manifested itself in a covert loyalty to the conventional system. Making matters worse, CEOs Fallon, Chandler, and Whitmore had all balked at making a bold strategic change, preferring instead to make piecemeal moves designed to cut costs and make the company's stock attractive. Dragging the process out over more than a decade, they emboldened protectionist thinking and preserved the Kodak culture. When Whitmore's ousting was announced, one employee despaired because Whitmore "was a real people person" who understood "loyalty." Another stiffer, on hearing that the board intended to bring in an outsider, skeptically predicted "this is not good news for us. Things will get tougher" (Randall 1993).

Administratively the company had an inertia that resisted change. Kodak's management exemplified Alfred Chandler's propositions that "hierarchy itself became a source of permanence, power, and continued growth" (p. 8) and that "career managers preferred policies that favored the long-term stability and growth of their enterprises" (p. 10). Formulated by Eastman and his managers when Kodak's success derived from size (economies of scale), sprawl, and scientific prowess, the bureaucracy grew and added layers as the conventional system expanded. Total employment ballooned to well over 100,000 in the 1980s, and haphazard conglomeration pulled managers in competing directions. But the barriers-to-entry were much lower in the digital system, and its progress much less predictable. New companies and products appeared apace. For instance, some six hundred companies were at work on image storage systems that could potentially compete with Photo CD (Maremont 1995). Smaller and uncommitted to the conventional system, these firms valued radical innovation, brisk research on narrowly defined critical problems, and cooperative development when necessary. Until at least the initial failure of

Photo CD, Kodak operated on a development model that promised blockbuster successes like the Instamatic.

Heightened public awareness of environmental conditions threatened to bring Kodak, an intensive user and consumer of chemicals, into disfavor. Kodak managers reduced the consumption of raw materials by making manufacturing processes more efficient. Generally, Kodak averted any major stress on the conventional system. However, environmental concerns provided another reason for consumers to abandon it in favor of the digital system. The latter allowed users to photograph a subject, manipulate it endlessly, and make it almost universally available without using any non-renewable resources, except perhaps energy.[9] From the time of its invention until Sony unveiled the camcorder, Kodak's system was the only way. In a marketplace increasingly attentive to these issues, traditional chemical photography—an inherently industrial enterprise—found itself fighting an uphill battle. Again, the system managers had defined problems narrowly, and the new system mitigated ones they had not considered.

George Fisher recognized that he had to do more than cut costs and spend money on trendy projects. His predecessors had procrastinated and applied bandages to their conventional business. Managers retained the values of the conventional system; they tried to preserve their control. Fisher set about not only streamlining the company but fostering a sweeping change in the these values. As he put it, "you cannot get the hard parts of a company working well until you get the soft parts working well. . . . If you don't get a value system well established and well communicated to employees, you can end up with a company that is schizoid" (Jacobson 1994). Many Kodak watchers agreed, having believed for some time that the company needed a new approach.

Fisher instinctively knew that he had to reprogram the mindset of Kodak's managers, the people who clung to the conventional system. The values of which he spoke

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[9] My argument assumes that consumers are generally less attentive to the energy

put in to action the prescriptions advised by Rosenbloom and Spencer (1996). Their article deals specifically with the general 1990s decline of centralized industrial laboratories and "fundamental research,"[10] a model popularized by "organizations . . . whose dominant market positions cushioned budgets from the pressures of narrow margins and facilitated the fullest appropriation of profits from new technologies" (p. 69). Eastman Kodak typified this kind of corporation, in both its heyday and subsequent decline. By listing four of Rosenbloom and Spencer's major points and then recounting George Fisher's implementation of similar principles, I will bring into relief some of the main reasons Kodak managers lost control of the photographic system.

First, the article cites over-management of research as a source of financial and development inefficiencies. In a governmental context—maybe an unfair comparison, but maybe not—the Department of Energy's Galvin task force found that "micromanagement" inflated management costs by 30% (p. 72). At Kodak the momentum of the conventional system preserved an organizational structure that pondered radical inventions to death. Bureaucratic layers also encouraged redundant projects. Fisher consolidated digital R&D in a separate division, encouraging informed oversight and decisive decision-making. To this end he replaced managers of the conventional system with electronics-industry veterans like Carl Gustin, an Apple Computer veteran. Previous CEOs, coerced by analysts and investors, recognized the symptom—excessive costs and no successful new products—but pursued an incomplete treatment—cutting away at the bureaucracy without fundamentally changing its methods.

Second, Rosenbloom and Spencer found that firms no longer chased "home run" products (like nylon) with academic thoroughness but instead sought low-risk commercial successes (see pp. 69-71). Fisher was well attuned to this difference, having built the wildly popular paging and cellular telephone businesses at Motorola. The momentum of the

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[10] The term is theirs and, STS objections aside, I hope clear from the context.

conventional system steered Kodak's managers to pursue proprietary schemes along the lines of the Instamatic format, as they did with the Disc cameras and the Still Video System. These products would preserve their control and their company's dominance. Photo CD, too, was originally conceived of as a tightly-controlled product. Fisher shelved the project and retooled. When Kodak relaunched it in 1995, Photo CD was as an open format with widespread hardware, software, and user support in industries that could benefit from Photo CD themselves. That is, Fisher intended Photo CD to be not just a self-standing system but an efficient component in a much larger technological system.

The recognition of one product's interdependence on other technologies leads directly to Rosenbloom and Spencer's third argument, that corporations in the new era relied increasingly on alliances with strategic partners in industry, government, and academia (p. 71). Firms did so because "deregulation and the rise of global competition" squeezed profits, making managers eager to "coordinate their [R&D] activities and find ways to share the costs and benefits" (p. 69). Kodak obviously felt this pressure on two fronts, from Fuji in film and from the photographic, electronics, and software industries in digital products. Over-confident managers did not change their ways, however, believing that consumers recognized the innate superiority of the conventional system and Kodak's products, in particular. When Fisher arrived he understood his company's potential but also realized he could not go it alone. His predecessors had occasionally held hands with outsiders but they did so only as a last resort, as when Whitmore had licensed the core technology for Photo CD from Philips Electronics because of patent restrictions. Fisher sought partners with a larger purpose in mind, building a digital system comprised of many actors (see Figure 3); the right alliances would minimize risk and ensure that Kodak would be a primary player.

Finally, while Rosenbloom and Spencer see alliances as an appropriate means to all these ends, firms "must be prepared to identify and capitalize on research breakthroughs wherever they occur" (p. 73). They caution that lingering industrial laboratories and allied

research projects notwithstanding, “a hollowed-out corporation will find it difficult to make use of external sources” of new technology (p. 71). In other words, firms still needed experienced, internal research staffs to exploit the technological fruits of strategic partnerships. Kodak managers violated this advisory in reverse: they began with a sparse electronics staff at best. Although electronics became a central part of 35mm photography in the late 1970s, Kodak managers were committed to a conception of the conventional system that was contained no such frills and was, above all, cheap and profitable. Without the vital knowledge component, they could not avail themselves of new innovations no matter what their mindset and strategy.

This was the point on which Fisher diverged furthest from Kodak’s established ways. Rather than lamely hiring a score of electronics technologists or acquiring companies like Atex and Verbatim aimlessly, Fisher overhauled Kodak’s research mission. The consolidated Digital and Applied Imaging Group was a valuable knowledge base which could better exploit newly minted alliances and emerging technologies. It was more than symbolic. Fisher, well-respected throughout high-technology fields, brought in Carl Gustin and former Apple Computer Chairman John Sculley to help manage and market the division, and in 1996 hired Dr. Willy Shih, most recently of Silicon Graphics, to run it (Eastman Kodak 1997, p. 24). Computer-industry veterans filled out the staff. The effort diminished the momentum of the conventional system within Kodak, prodding the stuffy research structure to zero in on digital problems. For example, Gustin initiated a printer project that took a languishing prototype and engineered another with only one-eighth the parts, one-tenth the cost, and better performance—in one month (Maremont 1995, p. 67); from conception to launch (1988-92), the original Photo CD project took over three years.

George Fisher came to Eastman Kodak as a ballyhooed outsider, and he may well have felt like a Martian. Economic, cultural, administrative, and environmental stresses buffeted the firm as its managers first tried to preserve the conventional system intact and then sought reconciliation with the digital system. He divined the need for new corporate

values—a new mindset, to use the terminology employed in this thesis—that were common throughought a changed world, a world previous managers failed to understand.

THREE: CONCLUSION

The systems approach makes visible the interconnectedness of photography's technical, administrative, economic, and scientific components. In the conventional system, camera designs and films were highly inter-dependent, as were film manufacturers and processors. For much of the twentieth century, Eastman Kodak controlled all of those. Managers quickly discovered that conservative innovations like factory-loaded cartridges and color film provided features that consumers liked, boosting sales. Furthermore, they gave the company a technical, patent-guaranteed advantage. Institutionalizing the discovery process in a research and development staff, and identifying critical problems for them to solve, managers made innovation a predictable ongoing activity. Eventually Kodak unilaterally introduced new formats like the Instamatic, Pocket Instamatic 110, and Disc. These ever-simpler and -smaller designs appealed to more and more consumers, and the conventional system acquired tremendous momentum.

While Kodak concentrated on simplicity, others chose to upgrade the system with sophisticated new features. Camera makers automated the operation of their products, as did processing equipment manufacturers. In both cases, powerful new features were added that also made the devices easier to use, increasing their appeal. Kodak engineers produced another conservative innovation, "T-grain" emulsions, with superior characteristics. The new emulsions, in turn, made practical complex optical components like zoom lenses. Manufacturers who had continued incorporating electronics into their cameras soon integrated the new glassworks as well, producing what became known as "point-and-shoot" devices. Quite literally, a user with only incidental photographic familiarity could pick one up and shoot—and shoot—and shoot.

The basic components of a digital system had emerged at about the same time. Sony fired first with its video camcorders and, more directly, with its Mavica video still camera demonstration. In response, Kodak executives like Walter Fallon and Colby Chandler publicly rededicated their corporation to the conventional system. A vast computer system gained momentum outside Kodak's sphere of influence, changing consumers' perceptions and infiltrating homes and offices by the millions. Along with the development of accessory components (scanners, printers, flash memory), the evolution and spread of desktop computers prepared the way for the "digital darkroom" and "digital publishing." Because of rigid conceptions of what comprised a photographic system, as well as financial and professional stakes in traditional photography, Kodak managers failed to anticipate any of these radical inventions. They found themselves dispossessed of their technical and production preeminence as the emergent system—or, perhaps more accurately, the amalgam of emergent quasi-systems—coalesced beyond Kodak's control.

The story can be summarized as the transition from a consolidated, bureaucratic industrial system (figure 1), as described by Alfred Chandler (and Reese Jenkins), to an open, fast-paced, collaborative system (figures 3 and 4), as set forth by Richard Rosenbloom and William Spencer. In the first era, Eastman's roll-film system generated the volume that made professional management of the photographic supply business profitable (see Chandler 1977, pp. 6-8). His successors maintained economies of scale and barriers-to-entry by constantly pushing the system harder, both in technology and manufacturing. Their strategies emphasized stability and predictability, which in turn ensured their own power and control (see pp. 8-10). Until the 1980s Eastman Kodak was the big fish in the small pond.

By the end of the period under consideration, bigger was not necessarily better. Firms and products not yet invented in 1980 were surpassing, or at least purporting to circumvent, Kodak's offerings. Alliances and complementary product lines among firms

provided the best chances for profitability. Yet they needed top-notch research staffs with mastery of system-critical knowledge (see Rosenbloom and Spencer 1996, passim). Kodak's officers were learning the hard way that the earlier age had passed; they could not foist Photo CD onto the market as they had the 110 film format a couple of decades earlier. Despite swimming in a much bigger pond, Eastman Kodak was now a big but shrinking fish, with vicious sharks and clever shrimps clouding the waters. Only a considered, informed approach to the digital system could purchase success.

The Kodak story may turn out to be a fable about technological corporations (and systems) turned sour in the 1990s, especially those that computers have touched. The company's executives personify stages in the company's strategy. Walter Fallon (CEO, 1972-83) exemplifies the single-minded linearity of the bureaucratic research corporation; Colby Chandler (CEO, 1983-89), the cautious custodial mentality of the besieged years; Kay Whitmore (CEO, 1989-1993), the befuddled, checkmated interregnum; Phillip Samper (executive vice president, resigned 1989) and Christopher Steffen (CFO, 1993), the frustrated reformation; and George Fisher (CEO, 1993-present), a catalytic new era of industrial development. The plot—aggressive competition triumphs over a staid American icon—is so commonplace as to seem clichéd, but that should only highlight the urgency of the moral. John Staudenmaier (1985) has described the demise of a system as the "senility stage" of a technology:

> Precisely because the larger world is not systemic, because it is continually changing under the influence of a host of exogenous variables that resist inclusion in any humanly constructed system, that larger world will not retain its "fit" with any successful technology forever. When new ambient forces . . . meet in such a way that they render a [technological system] unacceptable, that technology has reached a stage of senility. (1985, p. 197)

By the time Kodak's managers realized their plight and tried to incorporate the digital genie into a hybrid technology with the Photo CD product line, a competing digital system had

gained momentum, rendering their efforts moot. The “senility” of their system in the 1980s and 1990s is anything but unusual.

Robert Reich gives a broad account of the fluctuations in global competition that have blunted the effectiveness of American industrial corporations. In *The Work of Nations* (1991), he recognizes the economic issues facing companies like Eastman Kodak—cheap foreign goods undercutting the Americans’ pricing power, conglomeration strategies gone awry, declining profits, irate investors (pp. 69-77)—that first caused it to stumble. He goes on to postulate the emergence of a “global web” of business operations whereby parts of a problem are solved by not one but many organizations, which may be spread around the world (pp. 110-15). This was the changed world Kodak managers faced, the digital system which had sprung up almost without notice. The momentum of the conventional system led them to try to preserve their traditional business, film and paper, and later to proceed unilaterally with development of the Still Video System, Photo CD, and supporting technologies. Yet the digital system had different momentum and other values, rewarding not so much pioneering research as creative, desirable recombination of technologies to work as single components within a larger system. Beholden to conventional personnel and managers, Kodak administrators failed to acquire the “symbolic analysts” (see pp. 225-240) who excelled in the new environment with their abilities for “abstraction, system thinking, experimentation, and collaboration” (p. 229). Further, using subtle organizational mechanisms as well as outright rejection, managers successfully suppressed internal efforts to encourage or hire decision-makers with these capabilities.

These insights, combined with those drawn from Rosenbloom and Spencer (1996), beg a discussion about the “dynamics of science and research” as have Michael Gibbons et al. (1994) initiated. The co-authors take as a starting point a traditional “mode of knowledge production” (i.e. research), characterized as “disciplinary, primarily cognitive”

(p. 1) and presumably “fundamental” in the lay connotation of the term. They hypothesize that this mode gave way to one identified by problem solving in the context of application, cross-functional teams, flexible and diverse skills, and quality control (pp. 3-8). This description works hand in hand with Reich’s symbolic analysis. In analyzing these modes, the authors posit the evolution of “network firms” that collaborate rather than trying to control their systems (pp. 118-120). The case of Kodak and the digital system bears out their conclusion that network firms compete not so much on price (and cost) as by “making judgments about the knowledge and skills which will be most important to their long-term performance” (p. 121). At the opening of the digital era, Kodak managers made fateful judgments by ignoring the price threat posed by conventional competitors like Fuji and simultaneously concentrating on high-end, proprietary digital products. Even when they made better decisions, such as investing in Sun Microsystems and developing Photo CD technology, they misperceived their strategic use and potential market, and the achievements languished. Again, the momentum of the conventional system led the managers to apply its logic to changed circumstances.

So Kodak’s managers lagged in recognizing radical system change on two counts. First, within the conventional system, Fuji’s competitive strength came as an almost total surprise, one that some managers couldn’t accept a full decade after the Fuji blimp sailed over the Los Angeles Olympics in 1984. Left with little choice, Kodak executives resorted to proven pricing and marketing tactics, recovering some sales but sacrificing some operating profits. One should not assume that the ideal system (figure 1) could have been retained in perpetuity. Certainly Fuji or another foreign film-maker, like Agfa, would have made inroads into America eventually, barring intervention by the federal government. The question of foreign competition is not at issue. What is crucial is the extent to which Kodak’s system managers were unprepared for consumers’ acceptance of the “inferior” imports. The chemists had so much faith in their system that they mistakenly assumed that

it was impenetrable. One can validly compare their behavior to that of the managers at Ford and GM who likewise believed that their systems and markets were static.

Second, senior executives dismissed non-chemical photographic technologies as too problematic. Based on the digital technologies available in the early 1980s, they were not entirely incorrect. But these same technologies improved at breakneck speed, and within ten years they were becoming acceptable for many functions. Additional innovations, such as popular image-manipulation software, even made electronic photography the preferred system in industries like advertising that depended on speedy, flexible photographic images. Kodak marketed its own electronic products, especially cameras. But with the exception of its expensive professional models, they were more or less comparable to those already available. In a given product category, Kodak was often the last to enter, was more expensive, and was less recognizable as a maker of quality electronics. The playing field was universally leveled.

At this point the careful reader should be wondering whether these changes, which I have labeled radical, were really so much so. After all, Eastman Kodak is still in business. It is still a very large company with enormous revenues. And it still controls much of the market for photographic supplies. Each of these statements is true. But one must also consider that Kodak is an enterprise with nagging financial troubles. Despite tens of billions of dollars in revenues, it posted a net loss of $1.5 billion as recently as 1993 (Eastman Kodak 1995, 1996), and the company continues to fall short of investors' expectations on a regular basis. And while Kodak is still the biggest of the big names in photography, it is not as big as it once was. Worldwide, Kodak and Fuji are neck and neck in market share, with Agfa not terribly far behind. More telling, Kodak has not been successful in stemming the erosion of its share of the U.S. film market. And a growing number of images are produced and distributed electronically with nary a hint of a Kodak product in the process (see figure 4a). The company's ultimate fate is far from decided, but

the giants do not always fall overnight.

Systems, and the modern businesses that invent and support them, are not simply superseded. The new system does not arise in a vacuum, although retrospective accounts can easily leave the impression that it does. The technological momentum of the system masks the human factors which underpin its very existence. As time elapses consumers and managers take the technology for granted. Charismatic leaders disappear and organizational structures harden in established companies, generally making them more averse to taking risks. Markets become more ambiguous. System managers always have options open to them. In the introduction I cited the conclusion of Christensen and Rosenbloom (1995) that the strength of "established" and "entrant" firms in conservative and radical innovations, respectively, is attributable not to "technological or organizational capabilities" but rather to "their positions in the industry's different value networks" (p. 242). I noted that this statement parallels the approach used by Hughes (and myself). While theirs is often an appropriate *a priori* assumption, I should point out that it does not follow that all established firms will be poor radical innovators. The real world is frequently less deterministic than a strict business analysis will admit. Motorola let loose many shockwaves in telecommunications, for instance. Corporate managers and executives, and system managers more generally, need not let their "value networks" or "technological systems" dictate their course of action; yet they usually do. Thus, although this thesis builds to a conclusion similar to Christensen and Rosenbloom's, it places ultimate emphasis on the human, indeterminate components of the system. *Systems* do not lose out to other systems; system *managers* lose control of an established system, while an alternative's proponents triumph.

Loss of system control need not originate in a large scale change. Relatively small changes in the system, or seemingly unconnected changes in an "adjoining" one (e.g. video

cameras on chemical photography), can initiate disproportionately large changes throughout the entire system.[11] Two of Hughes's examples of large-scale catastrophes, the Three-Mile Island accident and the Challenger explosion (1989, pp. 463-466), resulted from actions or omissions which, in isolation, seem insignificant.[12] The nearly contemporaneous appearance of Fuji film, the camcorder, and the Sony Mavica undid much of Kodak's hard-won market dominance. Kodak managers initially dismissed each one: as inferior and un-competitive, potentially cannibalistic, or literally fantastic.

A key element of the loss of system control is the narrow definition and consequent selection of problems. In the 1970s and 1980s Eastman Kodak focused on film characteristics, especially resolution quality. Fuji beat Kodak to market with a high-speed, 400 ASA color film; Kodak eventually introduced the heralded T-grain films which matched the speed without sacrificing resolution. Yet company managers were late to appreciate the importance of price, just as they underestimated the attractiveness of computer-aided photography. Since its beginnings, Kodak was a company based on "photography." Only in the 1990s did it become an "imaging" company, finally recognizing Sony, Canon, and other electronics manufacturers as true competitors.

A few generalizations for interested business parties are in order. "What should I take away from this work?" asks the executive at a dominant, research-oriented corporation. First, system managers should understand that the future of any system is indeterminate. For almost one hundred years Kodak "could do as it pleased," as Peter Ueberroth put it. Then, without much warning, the company was forced to begin looking at itself as one piece of the puzzle. They also failed to act on pre-development research

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[11] Bert Moyer has suggested the resemblence to chaos theory, but this topic is best left to a full explanation in another forum.

[12] These examples should not be taken as a misrepresentation of Hughes's argument, namely that these particular disasters were "normal accidents" that are inherent in a tightly bound technological system.

projects, beginning with xerography and extending to camcorders, still video cameras, and other nuggets of the digital system. These all seemed like small matters to someone at Kodak once upon a time, but they eventually upset the very technology the company had relied upon for decades.

Second and very importantly, the technological corporation benefits by viewing its competition very broadly. Research and development functions typically, indeed almost by definition, zero in on a few established problems. With the abandonment of the corporate university model popularized by DuPont, IBM, and others, the danger exists that a company will overlook a valuable technology—one that some other company will eventually uncover themselves. That company will then be a direct competitor, even if it is not at present. On the other hand, visionary system mangers may discern the threat posed by a superficially unrelated company or technology and react because, as stated above, technology is not deterministic. Managers and consumers alike play a large role in shaping any system.

Finally, contemporary system managers must question how much control they really have. Quite probably they have far less authority over the technological system than any that preceded them, in the sense that most systems are now techno-corporate “webs” or “networks.” There are few independent “technology czars” anymore. In their wake have arisen committees, commissions, and corporate alliances. Even Bill Gates has relied extensively on Andy Grove, Michael Dell, and others to build system infrastructure. Human decision-makers still ultimately determine the direction of a system, but in a more collaborative fashion than their prdecessors of eighty or one hundred years ago.

In the twentieth century, technology and research became big business, and vice versa. As American economic predilections spread around the globe in the latter half of the century, business itself changed in ways that few had anticipated. But such abstractions tend to mask the underlying reality. Research and development is a human endeavor, as is

commerce, and consumption. Technological systems are built, not discovered. Individuals, teams, and organizations make the decisions, and they ultimately decide the course of any technology.