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CAPABILITIES, COGNITION, AND INERTIA: EVIDENCE FROM DIGITAL IMAGING

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There is empirical evidence that established firms often have difficulty adapting to radical technological change. Although prior work in the evolutionary tradition emphasizes the inertial forces associated with the local nature of learning processes, little theoretical attention has been devoted in this tradition to understanding how managerial cognition affects the adaptive intelligence of organizations. Through an in-depth case study of the response of the Polaroid Corporation to the ongoing shift from analog to digital imaging, we expand upon this work by examining the relationship between managers' understanding of the world and the accumulation of organizational capabilities. The Polaroid story clearly illustrates the importance of managerial cognitive representations in directing search processes in a new learning environment, the evolutionary trajectory of organizational capabilities, and ultimately processes of organizational adaptation. Copyright © 2000 John Wiley & Sons, Ltd.

INTRODUCTION

Organizational change is difficult. Even when established firms recognize the need to change in response to shifts in their external environment, they are often unable to respond effectively. Technological change has proven particularly deadly for established firms, with numerous examples of established firm failure in the face of radical technological change (Cooper and Schendel, 1976; Majumdar, 1982; Tushman and Anderson, 1986; Henderson and Clark, 1990; Utterback, 1994; Tushman and O'Reilly, 1996; Christensen, 1997). Existing explanations for failure to adapt to radically new technology have focused on the nature of a firm's capabilities.[1] In this paper we expand upon this work by examining how managerial cognition influences the evolution of capabilities and thus contributes to organizational inertia.

In the tradition of evolutionary economics, much research has focused on how existing technological capabilities, codified in the routines, procedures, and information processing capabilities of the firm, limit its adaptive intelligence (Arrow, 1974; Nelson and Winter, 1982; Teece, Pisano and Shuen, 1997). A firm's prior history constrains its future behavior in that learning tends to be premised on local processes of search (March and Simon, 1958; Levitt and March, 1988; Teece, 1988). When learning needs to be distant, and radically new capabilities need to be developed, firms often fall into competency traps, as core competencies become 'core rigidities' (Leonard-Barton, 1992). A firm's nontechnological assets also influence the direction of its technological trajectory (Dosi, 1982). Firms are more likely to develop technologies that can utilize existing complementary assets—assets essential for the commercialization of the technology

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[1] Since we are focusing on the distinction between capabilities and cognition, we use the term 'capabilities' broadly to represent a number of noncognitive factors including capabilities, competencies, assets, and resources.

(Teece, 1986; Helfat, 1997). For instance, a firm's existing marketing capability, particularly its knowledge of customers, makes it more likely to develop technologies that appeal to existing customers as opposed to a new set of customers (Christensen, 1997).

Empirical evidence supports the importance of capabilities in explaining incumbent inertia and subsequent failure. When a new technology is 'competence destroying' in that it requires mastery of an entirely new scientific discipline, established firms are more likely to fail (Tushman and Anderson, 1986). More subtly, when a new technology destroys the 'architectural knowledge' of the firm—knowledge about interfaces among product components—established firms also suffer (Henderson and Clark, 1990). Finally, when technological change destroys the value of a firm's existing complementary assets, the firm is more likely to fail (Mitchell, 1989; Tripsas, 1997).

While most innovation scholars have emphasized the role of capabilities, others have focused on the role of cognition in explaining organizational inertia (Garud and Rappa, 1994). Since managers are boundedly rational, they must rely on simplified representations of the world in order to process information (Simon, 1955). These imperfect representations form the basis for the development of the mental models and strategic beliefs that drive managerial decisions. They influence the manner in which managers frame problems and thus how they search for solutions.

Cognitive representations are typically based on historical experience as opposed to current knowledge of the environment (Kiesler and Sproull, 1982). For instance, as senior managers work together over time they often develop a set of beliefs, or 'dominant logic' for the firm based on their shared history (Prahalad and Bettis, 1986). These beliefs include a shared sense of who the relevant competitors are (Reger and Huff, 1993; Porac *et al.*, 1995; Peteraf and Shanley, 1997). Firm founders also play a significant role in establishing beliefs, leaving their imprint on the organization long after their departure (Baron, Hannan, and Burton, 1999). Given the influence of the historical environment on the development of beliefs, in rapidly changing environments top managers often have difficulty adapting their mental models, resulting in poor organizational performance (Barr, Stimpert, and Huff, 1992; Brown and Eisenhardt, 1998).

Our goal in this paper is to explore how the combination of capabilities and cognition helps to explain organizational inertia in the face of radical technological change. We focus on cognition at the level of the senior management team given the critical influence of top management teams on strategic decision making (Mintzberg, 1979; Hambrick and Mason, 1984). We examine how managerial cognitive representations may play a central role in terms of constraining organizational behavior, and ultimately, the development of a firm's capabilities (Zyglidopoulos, 1999; Gavetti and Levinthal, 2000). In order to explore the relationship between capabilities, cognition, and inertia, we perform an in-depth historical case study of a firm undergoing a radical transition. We analyze how the Polaroid Corporation has responded to the ongoing shift from analog to digital imaging.[2] The firm provides a particularly compelling example in that, despite early investments and leading-edge technical capability in areas related to digital imaging, the firm has so far not performed well in the digital imaging market. We explore why Polaroid has had difficulty, with an emphasis on understanding the role of both capabilities and cognition in explaining organizational inertia.

We find that by restricting and directing search activities related to technology development, managerial cognition influences the development of new capability. For instance, given Polaroid senior management's belief in pursuing large-scale 'impossible' technological advances, the firm made significant investments in developing technical capability related to digital imaging. At the same time, their belief in a razor/blade busi-

[2] Digital imaging is the capture, manipulation, storage, transmission, and output of an image using digital technology. Digital imaging is competence destroying for analog photography firms in that it requires the mastery of new scientific domains such as semiconductors/electronics as well as the development of different distribution channels and new customer relationships. (For more detail on the technologies involved in digital imaging see Rosenbloom, 1997.)
There is also a great deal of uncertainty about the digital imaging competitive landscape with firms from the photography, consumer electronics, computer and graphic arts industries all converging on the industry. While the first digital cameras arrived on the market in the late 1980s, only recently has consumer demand for digital imaging skyrocketed. As of the end of 1998 there were over 70 firms that had entered the digital camera market with over 250 models available. The industry is growing rapidly, and the worldwide digital camera market is expected to reach $10 billion by the year 2000 (*Future Image Report*, 1997).

ness model delayed commercialization of a standalone digital camera product. Understanding processes of organizational change thus requires examining not only the central inertial forces associated with developing new capabilities, but also the impact that cognition has on such processes.

METHODS AND DATA

This research is based on an in-depth, inductive case study of the Polaroid Corporation's historical involvement in digital imaging. Given the open-ended nature of our questions regarding the relationship among capabilities, cognition, and inertia, we felt that this approach would be most useful for theory building (Glaser and Strauss, 1967; Miles and Huberman, 1994; Yin, 1984). In addition, by taking a long-term historical perspective we gain insight into the evolutionary nature of both capabilities and cognition. A combination of public data, company archives, and interview data were collected on the evolution of Polaroid's activities related to both digital imaging and the traditional instant photography business.

Publicly available data included a complete set of historical annual reports, financial analyst reports, prior studies of Polaroid's history, and business press articles on both Polaroid and the digital imaging industry. We were greatly aided by extensive prior historical work on Edwin Land and Polaroid's position in instant photography (McElheny, 1998). Company archives supplemented publicly available data. Historical strategic plans, organization charts, internal memos, and technical papers helped to document the evolution of the organization.

Finally, we interviewed a sample of current and ex-Polaroid employees. Our sample varied along three dimensions. First, it included individuals from multiple levels of the organizational hierarchy. We interviewed ex-CEOs, other senior managers, mid-level project managers, and first-line research scientists and marketing specialists. Second, we included individuals from multiple functional areas. Research and development, marketing, and manufacturing were all represented in our sample. Third, we included individuals present at different points in Polaroid's history in order to understand how the organization had evolved. In many cases this process involved interviewing retired employees as well as employees who had moved to other companies. We interviewed individuals present during the 'Land era' (before 1980) as well as outsiders brought in at various points in time in order to facilitate digital imaging efforts. Every key manager involved in Polaroid's digital imaging efforts was contacted and interviewed. Some individuals were contacted multiple times as we worked through the iterative process of data collection and theory development. In total, we conducted 20 interviews with 15 individuals. We stopped interviewing/collecting material when a level of saturation was reached (Glaser and Strauss, 1967).

Interviews were open ended, but based on a common set of questions. Interviewees were first asked to discuss their specific role in the company, and how it changed over time. We then asked them to broadly discuss the evolution of digital imaging activities *vis-à-vis* the evolution of activities in the traditional instant imaging business. A third set of questions specifically dealt with the emergence of strategic beliefs in the digital competitive arena, and the factors that constrained or inhibited this process. Interviews lasted from 1 hour to all day.

Data collection, data analysis, and conceptualization have been iterative (Glaser and Strauss, 1967). Analysis began with a cluster methodology (Aldenderfer and Blashfield, 1984) where each researcher identified common words and topics for clustering. Cluster labels included both firm capabilities and managerial beliefs/mental models. Researchers then met, compared differences, and repeated the clustering, resulting in a final set of groupings related to both capabilities and cognition.

POLAROID IN DIGITAL IMAGING

Polaroid's foundations: 1937–80

Polaroid was founded in 1937 by Edwin Land, based on his invention of light-polarizing filters. It was Land's work in instant photography, however, that made Polaroid a household word. Polaroid introduced the first instant camera, a 5-pound device that produced low-quality brown and white pictures, in 1948. From that point forward, Polaroid focused on making improvements to the instant camera. Through ongoing research, Polaroid was able to significantly improve the picture

quality, decrease the development time required, introduce color, and enable one-step development (see Table 1 for a list of major instant photography developments). Firm performance was exceptional, with average annual compounded sales growth of 23 percent, profit growth of 17 percent, and share price growth of 17 percent between 1948 and 1978.

This period of strong performance culminated in a clear set of firm capabilities and managerial beliefs resulting from both Land's imprint on the firm and years of innovation related to instant photography. We next review what these capabilities and beliefs were and how they influenced subsequent search activities related to digital imaging (see Figure 1).

Capabilities: 1980

As one would expect, Polaroid's capabilities centered around its dominant position in instant photography. The firm's knowledge of the technologies relevant to instant photography technology was unsurpassed in the industry. Land himself held over 500 patents. The firm's patent position was so strong that when Kodak entered the instant photography market in 1976 Polaroid successfully sued them for patent infringement and was able to exclude Kodak from the U.S. market.[3] Polaroid's knowledge included not only a strong understanding of silver halide chemistry, but also a foundation in optics and electronics. For instance, Polaroid spent over $2 million on the development of the eyepiece for the SX-70 camera in the mid-1970s. The firm also used sonar technology to add an autofocus feature to some of its cameras.

Table 1. Polaroid's major instant photography developments, 1948–80

Year	Advance
1948	First instant camera: sepia (brown and white) film
1950	First black and white film
1963	First instant color print film
1964	Colorpack camera
1965	Polaroid Swinger, first low-priced camera (under $20)
1972	SX-70 (one-step developing with no waste)
1978	Sonar automatic focusing

[3] After a lengthy court battle, in 1991 Polaroid was awarded $924.5 million in damages from Kodak.

Manufacturing was another of Polaroid's strengths. While manufacturing of both cameras and film was originally subcontracted, at the end of the 1960s Land decided to bring manufacturing in-house. For this purpose, both a camera manufacturing plant and a color negative plant were built. The evolution of these plants over time resulted in two distinct manufacturing capabilities: one in precision camera assembly and another in thin film coating.

Finally, the firm had strong distribution through mass market retailers such as K-Mart and Wal-Mart. This innovative use of channels contributed to Polaroid's success. By avoiding direct competition with traditional cameras, which were sold primarily through specialized camera stores, Polaroid was able to establish a strong presence without inciting a competitive response.

Beliefs: 1980

Land was a strong character, notorious for his autocratic manner and strong control of Polaroid as well as his absolute commitment to both science and instant photography (McElheny, 1998). His imprint can be codified in a number of beliefs that dominated the senior management team at the end of this period.

Polaroid was clearly a technology-driven, not market-driven company. Land considered science to be an instrument for the development of products that satisfy deep human needs—needs that could not be understood through market research. He therefore did not believe in performing market research as an input to product development; Polaroid's technology and products would create a market.

Consistent with this philosophy, Polaroid management firmly believed that success came through long-term, large-scale research projects. This philosophy was summarized by Land in the 1980 Annual Report's Letter to Shareholders, where he wrote, 'Do not undertake the program unless the goal is manifestly important and its achievement nearly impossible. Do not do anything that anyone else can do readily.' A member of senior management during that time commented in an interview, 'What we were good at

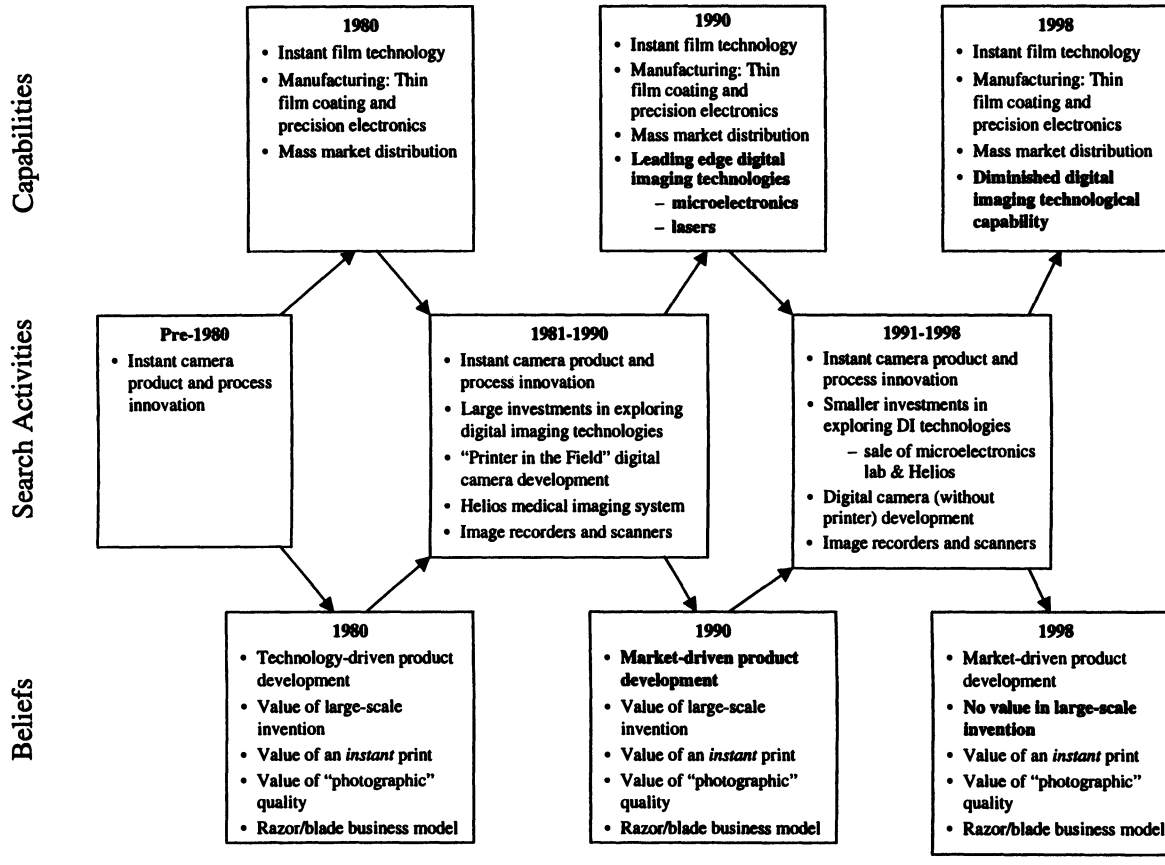

Figure 1. The evolution of capabilities and beliefs at Polaroid

was major inventions. Large-scale, lengthy projects that other firms would hesitate to tackle.' Several projects during this period were exemplary of this belief. For instance, in 1972, the firm announced the SX-70 instant camera after spending half a billion dollars on its development over an 8-year period. The camera was revolutionary in that it was waste free: after exposing the film, it ejected a picture that developed as the customer watched. The one-step SX-70 camera was a huge commercial success and served to reinforce the firm's belief in funding major inventions.

Another firmly held belief of management was that customers valued a physical instant print. For this reason, products such as video camcorders were not considered competition. As Land wrote to shareholders in 1981, 'None of the electronic devices which prepare tapes or magnetic records to be viewed in television satisfied the conditions imposed by that early dream [of an instant print].' The success of the Polaroid instant camera was taken as prima facie evidence of this need.

Throughout this period there was also an obsession with matching the quality of traditional 35 mm prints, driven by a belief that customers required 'photographic' quality. As the 1982 Annual Report's Letter to Shareholders stated, 'Our research and engineering efforts continue to be challenged to bring our amateur systems to a level of performance consistent with the best in photography.'

Finally, there was a strong belief in the razor/blade business model. While Polaroid had initially made money on both camera hardware and film in 1965 with the introduction of the 'Swinger' model, a decision was made to adopt a razor/blade pricing strategy. The firm dropped prices on cameras in order to stimulate adoption and subsequent demand for film. Film prices and thus margins were then increased. This strategy was extremely successful, and over time a fundamental, commonly held belief developed: Polaroid

could not make money on hardware, only software (i.e., film). In one of our interviews, an ex-CEO began his comments with the following:

> One of the things that's terribly important, and I think most people understand it but maybe not as fully as they should, is that in the photographic business all the money is in the software, none of it's in the hardware ... We were good at making hardware but we never made money on it ... So the fundamental objective in these things was to find ways to advance products but that would be useful for improving the software sales.

BEYOND INSTANT PHOTOGRAPHY—DIGITAL IMAGING SEARCH: 1981–89

The capabilities and beliefs articulated above had a profound influence on Polaroid's approach to digital imaging. These digital imaging search efforts were led by a new CEO, Bill McCune, who took over for Land in mid-1980. McCune, a Polaroid employee since 1939, had taken over the presidency in 1975 and was a long-time research colleague of Land's.

McCune began by committing substantial investment dollars to digital imaging technologies. An electronic imaging group was formed in 1981, and as part of this effort work began on a microelectronics laboratory. The microelectronics laboratory opened up in 1986 after a capital investment of about $30 million, and with an operating budget of about $10 million/year. By 1989, 42 percent of R&D dollars were devoted to exploring a broad range of digital imaging technologies. A 1981 strategic planning document identifies the following technological areas for exploration: microelectronics, IC design, advanced optical design, image processing, software design, PC board design, surface mount assembly, CAD/CAM/FEA design, and fiber optics.

While peripherally related to prior technical capabilities (e.g., to knowledge of electronics for instant cameras), these technologies primarily covered new scientific ground for Polaroid. For instance, about 90 percent of the employees in the microelectronics lab were newly hired. Developing radically new technical capability, however, was quite consistent with Polaroid's belief in the primacy of technology. As ex-CEO McCune stated in one of our interviews, 'If you have good technical people you shouldn't be afraid of going into whole new technical areas.' Similarly, one of the individuals involved in electronic imaging development commented, 'We compared ourselves to Bell Labs. Our orientation was 'technical challenge—we can do it.''

The Electronic Imaging group's exploratory efforts were guided by a desire to eventually develop an instant digital camera/printer product termed 'PIF' for Printer In the Field. This product concept combined electronic semiconductor (CCD) sensors for image capture, software for image enhancement, and instant film for image output. As the 1984 Annual Report's Letter to shareholders stated, 'We believe that there is considerable potential in developing new hybrid imaging systems that combine instant photography and electronics.' This work culminated in a 1990 patent (U.S. #4,937,676) for an 'electronic camera system with detachable printer.'

The PIF concept built on both Polaroid's prior capabilities and beliefs. Since the output was to be on instant film, it leveraged the firm's strong film-manufacturing capabilities. It was also, however, consistent with the firmly held belief in a razor/blade model. Since the digital camera was bundled with instant film output, there was a clear consumable/software piece of the product. In addition, the product was consistent with the belief that consumers valued an instant physical print. Rather than provide customers with the capability to view images on something like an LED screen, they were provided with an immediate print.

The second major area of digital imaging investment during this period was in a medical system called Helios. Helios used a high-energy laser to expose a dry film material. It was targeted at radiologists as a higher-resolution substitute for X-rays. Like the PIF concept, the development of Helios was influenced by both prior capabilities and beliefs. Although the media was not instant film, its development still leveraged Polaroid's chemical knowledge base. In addition, manufacturing of the Helios media was quite consistent with the thin film coating capabilities utilized in the manufacture of instant film.

The Helios business model was also consistent with the belief in the razor/blade model used in instant imaging. The majority of the profit stream was to come from the sale of high-margin media following the sale of the hardware. In commenting on the broad support for Helios, one manager in the electronic imaging area told us, '[Helios] was

not, in their [senior management] minds ... an electronic imaging thing. It had an electronic front end, but it's a film product and you make the money on the film. So it fell into the conventional wisdom. This is why it was always well funded and well taken care of.' A member of senior management at the time confirmed this perspective commenting, 'I haven't found many people that can make a buck outside of the consumable area ... and so I think that Helios was part of that same business model. It fit comfortably into it.' Helios also fit the belief in large-scale invention. In reflecting on the large investments made in Helios, a senior manager said, 'The technology ... was too costly. It took us too long ... but it did miracles ... We were three years late, and we never got the hardware costs in line. But by God, we tried to bite off the whole world ... new media, new lasers, new this, new that. And that goes back to doing the impossible.'

In addition to working on PIF and Helios, a small number of electronic imaging products were developed and shipped during this period. A series of image recorders was sold, starting in 1983. These machines were used to print images from computer or video input onto instant film, slides or transparencies. Targeted at specialized vertical markets such as graphic arts, these machines were never sold in large quantities. These products were once again building on existing knowledge of chemistry for the output media, although the electronic front-end was clearly based on newly acquired knowledge. The potential for an ongoing stream of media sales also made these products consistent with the razor/blade business model.

While the beliefs of senior management clearly influenced search activities that did take place, they also had a direct influence on activities that did not take place. In particular, there were three important areas of capability that Polaroid did not invest in: low-cost electronics manufacturing capability, rapid product development capability, and new marketing and sales capability.

In order to compete successfully in the hardware arena using a business model different from the traditional razor/blade approach, Polaroid would have to have developed low-cost electronics manufacturing capability and rapid product development capability—two areas in which Polaroid was particularly weak. Strong, low-cost electronics manufacturing capability would have been fundamental to increasing the typically smaller margins in the hardware business. At the same time, fast product development capability would have been necessary to permit the timely introduction of innovative products in a market where product life cycles were measured in months, as opposed to the years Polaroid was accustomed to for its instant imaging products. Polaroid's weakness in product development was characterized by one digital imaging manager as follows: 'Polaroid didn't have a sense of the distinction between research and product development. It was all mixed up. Many people were totally oblivious to what it means to get a product really developed and make it ready for the market place.' Although it is unclear whether Polaroid could have been successful at developing either of these capabilities, senior management's belief in the razor/blade business model and their resistance to supporting activities that were not fully consistent with this view precluded any investment in them.

Senior management beliefs also influenced the evolution of marketing capability. Consistent with the belief that technology was dominant, Polaroid's top management viewed the transition to digital imaging through a technology-focused filter. Digital imaging was therefore viewed primarily as a technological, not a market shift, with the majority of digital imaging investment directed towards the development of new technical capabilities. As a consequence, the firm never invested in developing any sales or marketing capability specific to digital imaging. For instance, rather than establish new distribution channels, the existing sales force was chartered with selling electronic imaging products. This approach was taken despite the protests of those directly involved in digital imaging product development who were aware of the profound market differences between instant and digital imaging. As one member of the electronic imaging group in the mid-1980's told us, 'We were not really happy about it, but there was not much else we could do.'

Resulting capabilities and beliefs: 1990

The actions taken from 1980 to 1989 were influenced by prior capabilities and beliefs, but also resulted in a gradual shift in those same capabilities and beliefs. By the end of 1989 Polaroid had

not only continued to evolve its expertise in technologies related to traditional instant photography, but also the firm had developed leading-edge technical capability in a number of areas related to digital imaging. Whereas the percentage of the firm's patents related to electronics between 1976 and 1980 was only 6 percent, between 1986 and 1990 that had increased to 28 percent.

Polaroid's image sensor technology was particularly strong with a number of clear advantages over competing sensors. By producing a higher-quality raw input file, Polaroid's sensors were able to generate a resolution of 1.9 million pixels when the majority of the competition had sensors that generated only 480,000 pixels. Polaroid also held a patent on the ability to use rectangular rather than square pixels. This technology improved color recovery. Finally, whereas most compression algorithms resulted in loss of information and thus a decrease in image quality, Polaroid had developed proprietary lossless compression algorithms. Polaroid was therefore well positioned by 1989 to develop a leading-edge digital camera.

During this time period the composition of the senior management team remained relatively unchanged. In 1986 McCune stepped down as president and CEO (although he remained chairman) but his successor, MacAllister Booth, had been with Polaroid since 1958 and was a long-time member of senior management. In addition, seven of the nine officers on the Management Executive Committee in 1989 had been members in 1980. It is not surprising, therefore, that the overall beliefs of senior management remained relatively static during this period.

In particular, the belief in the razor/blade business model remained firmly ensconced. Clearly, this business model was still appropriate for the traditional instant photography business. It was also continuing to be applied to digital imaging. An employee who joined the firm's electronic imaging group in 1989 commented on what he found: 'What's the business model? It's the razor/blade ... so we make money with the film. They [senior management] wanted to duplicate that in the electronic domain. This idea was pervasive. It was an idea they could easily relate to because it was continuing the instant photography business model. Right?'

There was also still a strong sense that customers wanted instant prints. The 1985 Letter to Shareholders states, 'As electronic imaging becomes more prevalent, there remains a basic human need for a permanent visual record.' Similarly, an employee who joined the firm's electronic imaging area in 1990 commented, 'another truth [I encountered] was that people really value an instant print. This was also an ontological truth.'

Finally, there was still a strong emphasis on matching the quality of 35 mm cameras, in both the instant and digital imaging domains. A number of new films for instant cameras were announced in the 1980s, including new high-contrast and high-speed films. The electronic imaging group was also working on developing a mega-pixel sensor that would enable a photographic-quality image to be produced from a digital camera. As one employee in the electronic imaging area commented, 'Polaroid was always stung by the assessment that instant photography was really cool, too bad the quality stunk ... the entire motivation as near as I could detect for the investments that they put into sensor technology and so on was to counteract the 35 mm quality deficit.'

The most significant change in senior management's beliefs was a shift away from being a purely technology-driven company. Polaroid faced stagnant growth for the first time in the 1980s with waning demand in the traditional instant photography market. After having achieved double digit annual sales growth for 30 years, total sales actually decreased between 1980 and 1985. Faced with this situation, management placed an increased emphasis on marketing, and a formal market research function was established. Market input also became an official part of the product development process. In the 1989 Letter to Shareholders Booth stated, 'We have studied the needs of our customers in each market segment and those needs are driving the development of our new products.' This statement is in direct contrast to the philosophy articulated by Land.

REFOCUSING ON DIGITAL IMAGING—SEARCH ACTIVITIES: 1990–98

In 1990, electronic imaging moved up in the corporate hierarchy as part of a major reorganization. Three market-focused divisions—Consumer, Business, and Scientific/Technical Imag-

ing—were formed in addition to a fourth: Electronic Imaging Division. The Electronic Imaging Division was intended to feed products to each of the three market-focused divisions. At the same time, the exploratory investments of the 1980s were curtailed in 1990 when research into fiber optics, solar cells, and disk drives was cut. This decision was made in order to focus research efforts on those technologies directly related to products under development. In addition, in 1993 the Microelectronics Lab was sold to MIT, ending the majority of Polaroid's more basic research in microelectronics.

The composition of the electronic imaging group also changed dramatically after 1990. While a long-time Polaroid employee was initially in charge of the group, the majority of members were new hires with experience in digital imaging and other high-technology industries. Consistent with the new belief in being more market driven, an electronic imaging marketing group, comprised entirely of new hires, was established. This group was given the charter to develop a digital camera product concept. Once this concept was defined, a new hire was put in charge of the overall development project. And in 1994 another outsider was brought in to head up the entire group. This individual brought in yet more outsiders, assigning them to key strategic positions within the electronic imaging group.

Clearly, these new individuals, with no prior Polaroid experience, had a different perspective from that of senior management. The digital camera product concept developed by the group was therefore quite different from the prior PIF concept. While this digital camera could eventually be bundled with a Polaroid instant film printer, the initial concept included just a high-resolution camera, targeted at professionals in industries such as real estate that had a need for 'instant verification,' not necessarily an instant print. Given Polaroid's leading position in sensor technology development, the marketing group felt that Polaroid could offer a significant price/performance advantage over the competition. By 1992, there was a working prototype of the camera.

One can best characterize the period from 1990 to 1996 as one of cognitive dissonance between senior management and the newly hired members of the Electronic Imaging Division. This clash was driven by fundamentally different beliefs. First, there was disagreement about the appropriate business model for digital imaging. One of the newly hired individuals described to us the ongoing dialogue with senior management as follows:

> The catch [to our product concept] was that you had to be in the hardware business to make money. 'How could you say that? Where's the film? There's no film?' So what we had was a constant fight with the senior executive management in Polaroid for five years ... We constantly challenged the notion of the current business model, the core business, as being old, antiquated and unable to go forward ... What was fascinating to me was that these guys used to turn their noses up at 38 percent margins ... But that was their big argument, 'Why 38 percent? I can get 70 percent on film. Why do I want to do this?'

Senior management, on the other hand, felt that the electronic imaging group did not understand the limitations of Polaroid's manufacturing and product development capabilities. As discussed earlier, given the strong belief in the razor/blade model, Polaroid had not invested in developing the manufacturing capability necessary to make money on 'razors.' In addition, the belief in large-scale projects with lengthy development cycles, had precluded investment in fast product development capability. Management did not, therefore, feel comfortable competing with firms that possessed these capabilities. As one senior manager noted, 'We're not just going to be up against Kodak, Fuji, etc. We're going to be up against 30 consumer electronic companies—the Sonys, Toshibas, Hitachis, the Intels, etc. We need to have a unique idea that corresponds to our core capabilities and the way we relate to the marketplace.' There was also concern about Polaroid's ability to simultaneously manage very different businesses as voiced by another senior manager: 'Can we be a down and dirty manufacturer at the same time we're an innovator over here? Can you have two different philosophies running simultaneously in the company?'

As a result of this ongoing clash between senior management and the Electronic Imaging Division, there were continuous delays in development related to the digital camera, an inability to commit to relationships with potential strategic partners, and ultimately a lengthy delay in the commercialization of a digital camera product.

Despite having a prototype in 1992, Polaroid did not announce its PDC-2000 mega-pixel camera until 1996. By that point in time there were over 40 other firms on the market selling digital cameras. The PDC-2000 received a number of awards for its technical achievement (the *Netguide Magazine* State-of-the-Art Award, *Publish* magazine's Impact Award, and the European Technical Image Press Association's Best Digital Product of 1996), but it did not do well in the market. Although Polaroid was more 'market driven' in the sense of using customer needs as an input to development, senior management still did not perceive the need for different sales channels. The Electronic Imaging Division requested separate sales support for the PDC-2000, but was told that they had to use the instant photography sales force. As one frustrated individual commented, 'We had products in the $1000 range and these people were used to going to K-Mart and WalMart.' In 1997 a follow-on PDC-3000 was announced, after which development activity ceased. By this point in time, the majority of the individuals hired to staff the Electronic Imaging Division in the early 1990s had left Polaroid.

Other activities of the Electronic Imaging Division also encountered senior management resistance throughout the early 1990s. Given the belief in a razor/blade model, one obvious avenue for Polaroid to explore was the development of alternative hardcopy technologies, such as ink jet or thermal dye sublimation. The belief that consumers needed 'photographic quality,' however, kept senior management from committing to these alternatives. As one member of the Electronic Imaging Division commented, 'We had the capability ... but there was disbelief that ink jet could be near photographic quality. Mathematical models and demos couldn't convince people.' A member of senior management explained their reluctance to accept a lower-quality ink-jet output as follows: 'I spent an awful lot of my life, [Sr. Manager X] spent almost all of his life—a lot of us ... [Sr. Manager Y] spent an awful lot of his life focusing on improving the quality of the instant image ... So that was an every day, all day part of our lives ... so that can't help but have been indelible in the DNA or something.'

The one digital imaging product that received consistent, ongoing support throughout this period was the Helios medical imaging system. In fact, Helios was such a large project, with an annual investment of about $120 million in development (compared to $30–$40 million for the Electronic Imaging Division), that it was not organized as part of the Electronic Imaging Division, but was a separate group. As discussed earlier, Helios continued to receive such strong support because it was consistent with both Polaroid's capabilities and the beliefs of senior management. In addition a spin-off of the Helios technology, dry-output film for the graphic arts, also received support for the same reasons. Helios finally reached the market in 1993 after almost 10 years of development effort. Unfortunately, despite its technical achievement, Helios was not successful in the market. This failure was attributed to a number of factors including the lack of strength in distribution as well as misreading of the film size required by radiologists. Digital imaging losses of $180 million in 1994 and $190 million in 1995 were primarily attributed to Helios. In 1996 the Helios division was sold to Sterling Diagnostic, although Polaroid still provides the film and lasers.

The sale of the Helios group was just part of an overall decrease in commitment to internal development of digital imaging technologies. In 1996 a new CEO, Gary DiCamillo, succeeded MacAllister Booth. DiCamillo was the first outsider to hold this position, and he brought with him a new top management team. Of 25 directors listed in the 1998 Annual Report, 15 had joined Polaroid after DiCamillo's arrival. With a background in consumer marketing, DiCamillo decreased the focus on technology even more. Soon after arriving at Polaroid he commented, 'We're not in the business to get the most patents. We're not in the business to write the most research papers. And we're not in the business to see how many inventions we can come up with' (Convey, 1996). Consistent with this approach, research and development expenses were cut from $165.5 million in 1995 to $116.3 million in 1996. Not surprisingly, development of Polaroid's next-generation digital camera, the PDC-300 announced in 1997, was totally outsourced.

In conjunction with the decreased emphasis on technology, DiCamillo and his team placed renewed emphasis on marketing in both the instant photography and digital imaging domains. While the amount of money allocated to R&D decreased, the amount spent on advertising

increased slightly from $124.1 million in 1995 to $134.6 million in 1996. Polaroid's marketing department created a new category called 'photoplay,' with products such as the Barbie instant camera introduced in 1998.

Resulting capabilities and beliefs: 1998

The series of digital imaging disappointments combined with a new top management team resulted in the evolution of capabilities and beliefs. By 1998 Polaroid's earlier strength in digital imaging technologies had significantly diminished. The firm had about 50 internal employees devoted to digital imaging research as opposed to a high of about 300 in 1992. Consistent with this decrease, the belief in the value of large-scale invention had disappeared. Instead Polaroid was focused on rapid incremental product development. 'We have announced our intention of becoming a new products company ... to bring 20 to 40 new products to market each year,' DiCamillo stated in the 1998 Annual Report. The transition from a technology-driven to a market-driven company also seemed complete with the 'photoplay' category taking on increased strategic importance.

Some parts of the senior management belief system, however, were surprisingly similar. DiCamillo supported the razor/blade business model, stating in a 1997 interview, 'In the digital world we believe that hard copy is required ... Unless there is a consumable component, the business model falls apart. So we have to focus on what's consumable and what value-added we can provide that's unique' (Rosenbloom, 1997: 16) His commitment to photographic quality and therefore conventional film was also quite strong. 'What are we? What are we good at? We're pretty good at creating images instantly. Not very many companies can do that ... there's both a time and a skill required to take conventional film and make it look good. Substitute technology such as ink jet or thermal technologies are interesting, but they're not here yet' (Rosenbloom, 1997: 13).

Clearly the digital imaging market is still evolving, and it is uncertain what Polaroid's ultimate position will be. We believe it is fair to say, however, that having invested in and developed such strong technical capability in digital imaging in the 1980s it is disappointing that Polaroid was unable to capitalize on its technical position in the marketplace. In addition, despite its early technological lead, Polaroid is ultimately left with quite limited technical strength in this emerging market.

DISCUSSION AND CONCLUSIONS

Our goal in this paper was to explore the relationship among capabilities, cognition, and inertia. While prior work in the evolutionary tradition has shown that failures to adapt to radical technological discontinuities often stem from the local nature of learning processes and, consequently, from the relative rigidity of organizational routines (Teece *et al.*, 1994), little emphasis has been devoted, at least in this tradition, to understanding the role of managerial cognition in driving the dynamics of capabilities. Through the Polaroid story, we clearly demonstrate that search processes in a new learning environment are deeply interconnected to the way managers model the new problem space and develop strategic prescriptions premised on this view of the world.

From a strictly evolutionary point of view, one would expect Polaroid to have had difficulty developing new, unrelated digital imaging technologies. Instead, we find that the firm had little problem overcoming the path dependencies normally associated with knowledge evolution. Indeed, thanks to the early investments in electronic technologies, Polaroid was able to develop leading-edge capabilities in a broad array of technological areas related to digital imaging. For instance, by the time the market for digital cameras started to take off in the early 1990s Polaroid had a working prototype of a high-resolution, mega-pixel digital camera that was a step function improvement in price/performance relative to other products in the market. Similarly, Helios, a medical imaging system aimed at replacing X-ray technologies, although a commercial failure, was a major technological achievement. Despite these capabilities, Polaroid failed to adapt to the radical changes that had occurred in the imaging competitive landscape. Understanding this paradoxical behavior requires us to go beyond explanations focusing on the localness of learning processes and on the inertia of a firm's competencies.

We argue that only by considering the role of cognition and its implication in terms of the learning dynamics of the organization can one

gain insights into this apparent inconsistency. As previously documented, a number of strong beliefs were deeply diffused in the top management of the company, and remained substantially unaltered during its entire history. During the Land era, the company was characterized by a solid belief in the primacy of technology, according to which commercial success could only come through major research projects. There is little doubt that Polaroid's early exploration of the electronic domain, the basis for its state-of-the-art technological competencies in digital imaging, was legitimated by this view of the world. Despite the absence of a market for digital imaging applications, during the 1980s the company kept allocating considerable resources to this technological trajectory. For at least a decade, resource allocation in digital imaging was totally disjointed from any notion of performance. To put it simply, Polaroid did not experience major difficulties searching in a radically new technological trajectory and developing new technological competencies, largely due to the consistency of this purely exploratory behavior with the belief in the primacy of technology.

A second commonly held belief was that Polaroid could not make money on the hardware, but only on consumables, i.e., the razor/blade model. This business model, successfully developed and adopted in the instant imaging business, was applied to the company's activities in digital imaging, and we believe was a main source of Polaroid's inertia. At the beginning of the 1990s, when a market for digital imaging applications slowly started to emerge, senior managers strongly discouraged search and development efforts that were not consistent with the traditional business model, despite ongoing efforts from newly hired members of the Electronic Imaging Division to convince them otherwise. Digital camera development efforts, for instance, were stalled given the inconsistency with a razor/blade business model. Similarly, Polaroid never attempted to develop the manufacturing and product development capabilities that would have been key had Polaroid decided to compete in digital imaging with a nonrazor/blade business model. (e.g., as a low-cost/high-quantity hardware producer.) In contrast, products such as Helios that were consistent with this view of the world received unconditional support on the part of senior managers.

In short, if on the one hand Polaroid's beliefs allowed the company to develop the necessary technological knowledge for competing in digital imaging, they became a powerful source of inertia when decisions were taken on how to further develop such knowledge in specific products and activities. This evidence points to the deep interrelationships between a manager's understanding of the world and the accumulation of organizational competencies. Although much current theorizing on the dynamics of capabilities emphasizes the inertial effects of the path dependencies associated with learning processes, we believe that understanding how capabilities evolve cannot neglect the role of managerial cognitive representations, especially in constraining and directing learning efforts. Importantly, emphasizing cognitive elements in the explanation of the genesis and evolution of capabilities raises both positive and normative issues that traditional explanations in the evolutionary realm largely overlook.

A particularly important issue is the question of how beliefs evolve within organizations. Can the top management team, for instance, simultaneously manage businesses with different dominant logics (Prahalad and Bettis, 1986)? In the Polaroid case, we find that senior management was able to develop new beliefs for digital imaging only as long as those beliefs were consistent with the instant photography business. For instance, they recognized the importance of being more market driven in both the instant photography and digital imaging domains. In contrast, they found it difficult to endorse a nonrazor/blade business model for digital imaging given that it was still the prevalent model for the instant photography business. In such situations Tushman and O'Reilly (1996) have found that successful organizations are 'ambidextrous,' simultaneously embracing multiple contradictory elements through an organizational architecture that combines a mix of autonomy and central control.

Turnover in the top management team is also an important driver of change. In particular, changes in both the CEO and executive team have been found to initiate discontinuous organizational change (Tushman and Rosenkopf, 1996). At Polaroid, the arrival of an outsider CEO, DiCamillo, combined with a new top management team, significantly changed elements of the belief system. The shift from lengthy, large-scale, technology-driven invention to rapid, incremental,

market-driven product development is epitomized by Polaroid's new focus on products for the 'photoplay' market. In rapidly changing environments, however, ongoing turnover of top management teams is likely to be impractical. In these situations, the development of 'deframing' skills, the ability to question current strategic beliefs in an ongoing way, becomes increasingly important (Dunbar, Garud, and Raghuram, 1996).

These arguments suggest that a crucial challenge for organizations facing radical technological discontinuities is the ability to distinguish changes that require only the development of new technological capabilities from changes that also require the adoption of different strategic beliefs. For Polaroid, digital imaging represented an instance of the latter type of change: success in this new competitive landscape required fundamentally different strategic beliefs as articulated at the time by individuals in the digital imaging group. However, radical technological discontinuities do not always provoke mutations in the bases of competition. In fact, in some cases enduring belief systems can be a source of competitive strength (Collins and Porras, 1994; Porac and Rosa, 1996). In this situation, cognitive change can be highly dysfunctional for the organization, since strategic reorientations are costly and associated with high mortality rates (Tushman and Romanelli, 1985; Amburgey, Kelly, and Barnett, 1993; Sastry, 1997). In particular, changes in the basic strategic beliefs of a firm typically have short-term disruptive effects on organizational practices and routines (Gavetti and Levinthal, 2000). When environmental change does not render current strategic beliefs obsolete, the net effect of their modification is hardly positive for the organization.

A second issue that clearly emerges in this research is the role of hierarchy in cognition. Polaroid's difficulties in adapting to digital imaging were mainly determined by the cognitive inertia of its corporate executives. As we have documented, managers directly involved with digital imaging developed a highly adaptive representation of the emerging competitive landscape. They abandoned Polaroid's 'software-oriented' view and adopted a 'hardware-oriented' model that they were not free to put into practice. We speculate that the cognitive dissonance between senior management and digital imaging managers may have been exacerbated by the difference in signals that the two groups were receiving about the market. This evidence is suggestive not only of the presence of profound cognitive differences across hierarchical level, but also that there might be structural reasons underlying differences in cognitive adaptability across hierarchical levels (Gavetti, 1999).

Finally, this work raises important questions regarding the origins of both capability and cognition. The vast majority of research in each of these areas has focused on the capabilities and cognition of established firms, with limited understanding of their historical development. In the case of Polaroid it appears that Edwin Land, the founder, had a profound and lasting influence on the development of both capabilities and cognition. However, given that that not all founders are as memorable as Land, one might ask what other initial factors are important. Work on organizational imprinting has demonstrated that a broad range of environmental conditions at organizational founding (e.g., the social, economic, and competitive environments) have a lasting influence on organizational structure and culture (e.g., Stinchcombe, 1965; Kimberly, 1975; Boeker, 1988). How do these same environmental factors affect capabilities and cognition? By focusing future research efforts on start-up firms, in addition to established firms, we believe we can start to address these questions and significantly enrich our knowledge of both the origins and the evolution of firm capabilities and cognition.

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