E Ink

This is a chance for all of us to leave a legacy. Nothing I've seen has shaken my belief that this technology is just fundamentally revolutionary.

—Jim Iuliano, President & CEO of E Ink

The research building of E Ink in Cambridge, Massachusetts, sounded more like a party than a lab for serious, cutting-edge technology. Loud polka music and the laughter of young employees filled the air as they went about their work. Founded just over a year earlier, in 1997, the company aimed to revolutionize print communication through display technology. Black and white photographs, hung throughout the lab, captured scenes of everyday expression that could be affected by E Ink's technology; these photos included everything from subway graffiti to the sign for the tobacco shop in Harvard Square.

Across the parking lot, a different building housed the offices of E Ink's management team, including Jim Iuliano, president and CEO of E Ink, and Russ Wilcox, vice president and general manager. A prototype of E Ink's first product hung outside their offices—a sign prepared for JC Penney. It read, "Reebok High Tops on sale today. Sale ends Friday."

Electronic ink (e-ink) was an ink solution, composed of tiny paint particles and dye, that could be activated by an electric charge. This ink could be painted onto nearly any type of surface— including thin, flexible plastics. Charged particles could display one color, such as white, while the dye displayed another color, such as blue. Charges could be applied through electronic circuitry at the back of the painted surface. Letters or images could be displayed through appropriate combinations of charged particles moving through the dye. Theoretically, the inked surface could be wired to receive radio signals, which would make it possible to update information on any e-ink surface remotely.

The inventors believed that the applications for this technology were limited only by people's imaginations and could potentially affect all levels of communication. In fact, a favorite pastime of the engineers who worked in the E Ink lab was dreaming about all of the possible applications of electronic ink. Ian Morrison, director of Ink Technology, described some possibilities such as, "clothing that changes color and displays information; coffee pots that say, 'I'm empty' when more coffee needs brewing; and electronic maps with an embedded Global Positioning System to tell users

their present location." Despite the many science-fictionlike possibilities they imagined for their products, E Ink's management had decided to focus the company's efforts on large retail store signs for the first application of electronic ink.

Iuliano and his team of managers knew that many people inside and outside of E Ink eagerly awaited their first demo in a retail store. However, putting their first successful demo together was not the only thing on Iuliano's mind. In the next few months, E Ink would almost triple its current workforce of about 35, to approximately 90 employees. Most of these new hires would be involved in scaling up for mass production, which involved taking the ink from the lab bench to the manufacturing floor. As he looked up at their sign for the JC Penney sneaker department, Iuliano wondered how the current environment in the lab would fare given such dramatic pressure and growth.

Company History

The initial idea for electronic ink had come from Joe Jacobson, who was currently a member of the E Ink board of directors, a major shareholder, and a key consultant to the company. Jacobson, an assistant professor at the Massachusetts Institute of Technology (MIT), had always been interested in novel ways to communicate information to people. He had worked on several types of displays as a student at MIT and as a post-doctoral fellow at Stanford, including a three-dimensional CAT scan display. While at Stanford, he had begun thinking about the possibility of creating an electronic book. Jacobson said:

> When I came back to MIT to become a professor, I was interested in inventing a completely new way to make displays. The kind of thing I wanted to enable was the ability to make electronic books. I envisioned a hardcover book that had hundreds of paper-thin pages in it. You could take it off the shelf, open it, and read King Lear, for instance. You could close it, press a button, open it up again, and you'd be reading quantum physics.

Jacobson's ideas for an electronic book were not unique. The idea had surfaced in the mid-1970s at large companies, such as Xerox, that were interested in display technology. Two types of displays had emerged: electrophoretic displays and liquid crystal displays (LCDs). Electrophoretic displays consisted of a dye solution containing particles sandwiched between a glass plate and an electrode (the backplane). An electric charge, sent through the backplane, either attracted or repelled the particles, which brought either the particles or the dye to the surface.

Although electrophoretic displays seemed promising, they also presented some problems to which scientists could not find a solution. One problem was that the placement of the particles was not stable over time; they tended to "settle." That is, particles initially suspended in the display slowly drifted toward the bottom. Since this problem remained unsolved, the idea of electrophoretic displays was abandoned, and LCDs became the ubiquitous display technology for portable electronics.

Jacobson's breakthrough was discovering a way to keep the particles from drifting, a process called microencapsulation. Instead of floating freely between the glass and the backplane, the particles were packaged into microscopic bubbles, or microcapsules. Particles might settle within a capsule, but they could not move outside of the capsule. The microcapsules, applied to almost any surface attached to an electrode, functioned as an electrophoretic display.

Electronic ink displays had several advantages. The display itself was easier to see than LCDs because of its high contrast ratio and wide viewing angle (meaning that the user could easily see the information from almost any angle). Moreover, the displays required very little power; once the particles were in place, no energy was required to keep them there. These advantages, along with

other advances in technology such as flexible backplanes, smaller batteries, and broad bandwidth wireless communication, gave E Ink's displays the potential to be much cheaper and more useful than LCD technology.

Jacobson returned to MIT in 1995 and started to look for help with his ideas for an electronic book. In 1996, another professor introduced him to Barrett Comiskey, an undergraduate who worked on networks in the MIT Media Lab. Comiskey began working on an undergraduate research project with Jacobson because, as Comiskey said, "Joe was a new professor, and since he came in August, he couldn't get any graduate students working for him until the next academic year." Comiskey read patents to learn the chemistry behind electrophoretic displays and microencapsulation, and worked on the project about 30 hours per week during his junior year.

About one year after Comiskey began work on the project, J.D. Albert, another senior in Jacobson's lab, was recruited to help. Albert, describing himself as the prototypical mechanical engineer, said, "I like making stuff. What's really exciting to me is implementing new technology." Albert had a keen interest in machinery and industrial design; enthusiastically describing a trip he took with the Media Lab to the LEGO factory in Denmark, he said, "I love factories!"

During their senior year, Comiskey and Albert essentially re-invented the electrophoretic display. They spent between 40 and 60 hours per week working on it (in addition to taking a full course load). Albert said, "This work was totally outside our areas of training; we just kind of did it by the seat of our pants." The pair dedicated all of their time during January 1997—MIT's Independent Activities Period—to building a working prototype. Finally, at 2:00 AM one cold night in January, the two succeeded in making the prototype work.

Comiskey and Albert considered their lack of experience to be an advantage. Although Comiskey majored in general math, he spent a considerable amount of time dabbling in other areas such as optics, engineering, and cryptography. He said, "I think the problem required someone who could sew together chemistry, physics, and electronics into something useful."

The environment at the Media Lab encouraged the kind of cross-pollination of scientific disciplines that the project needed. Albert described the Media Lab as:

> . . . a really wacky place. You see a lot of cool things, but not many polished things. You see great things that make you think, and see hundreds of people doing really creative things. Being there frees your mind. The Media Lab teaches you that crazy ideas can work. You're not afraid to have something crazy come out of your mouth.

Russ Wilcox joined the team in March 1997, two years after graduating from Harvard Business School (HBS). He wanted to get involved in something exciting after his group was shut down by his previous venture-backed employer, PureSpeech. Wilcox believed that PureSpeech's initial efforts failed because the company tried to develop two unrelated products simultaneously. Having heard about E Ink through HBS connections, Wilcox met Jacobson, Comiskey, and Albert. During the spring he worked with Jacobson and Jerry Rubin on a business plan, benefiting from Rubin's career experience as founder of Lexis-Nexis Corporation and as chairman of a Times-Mirror division. By July, Comiskey and Albert had graduated; in August, the company opened its first office. For several weeks, Wilcox watched closely while Comiskey and Albert worked together to replicate the prototype, as Comiskey put it, "breathing each other's air." (This was literally true; they worked out of one cramped fume hood in a rented space.) Commenting on Wilcox's current role in the company, Comiskey said, "I'm happy that Russ does Business Development for us now because he knows the technology so well." In addition to monitoring the technical effort, Wilcox spent this time recruiting initial staff members, developing corporate relationships, and negotiating a $1.7 million seed investment.

Although the early team was quite small, they generated considerable notice in the press and secured an appreciable level of funding from corporate sponsors, many of who were already involved in sponsorships with other projects at the Media Lab. E Ink was named one of *Fortune* magazine's "Cool Companies" of 1998. From *Fortune*'s description of E Ink, it was clear that this distinction recognized the "cool" technology as well as the eccentric scientists building it:

> Barrett Comiskey and J.D. Albert look like slightly malicious brothers who dyed their hair yellow to tick off Dad. The elders they're trying to annoy are traditional manufacturers of screens and displays, the companies like Sharp, Toshiba, and Sanyo that made up the bulk of the attendees at last month's conference on display technology in Anaheim, Calif.[1]

Prior to their graduation from MIT, Comiskey and Albert were commissioned by Swatch, the Swiss watch company known for its unusual designs, to make an electronic ink watchband. The pair traveled to Switzerland and were given a week to build a prototype of a watchband that could display information and change designs. Comiskey departed with some trepidation about graduation: "I wasn't sure if I was going to graduate. I pretty much blew off my senior year classes to work on this project." Since Swatch's lab closed at 11:00 PM, the pair set up a lab in their hotel room and took shifts making and repairing the circuit boards that drove the demo. They continued to work around the clock all week; on the way to the presentation to Swatch management, they used a laptop to put the finishing touches on the code and successfully completed the prototypes. In retrospect, Comiskey felt that this work exemplified the "make it work attitude" of the Media Lab. He described the experience as the "pinnacle of my MIT career."

The group incorporated in spring 1997, but began operations after Comiskey and Albert graduated. Recalling that starting a company seemed like a good fit for both himself and Comiskey, Albert said, "I knew I wanted to do something weird or a startup; I can't imagine myself working at a big company."

Company Goals

According to Albert, the ultimate goal of electronic ink was to "kill paper." That is, electronic ink would replace all forms of paper-based communication. Director of Display Technology Paul Drzaic was a bit less definitive on the long-term applications of e-ink. He said, "Nobody really knows, because there isn't anything like it. But people *will* find interesting things to do with it." They both agreed that the final goal for E Ink was something called "radio paper." Radio paper would be a high-resolution display that looked like an ordinary piece of paper but behaved like an electronic display. It would have a thin, flexible backplane, and the inked surface would be 100% printable. In addition, radio paper could receive radio signals, making it possible to update the information on the screen remotely. With radio paper, the readers using Jacobson's electronic book could simply download a new book as soon as they finished an old one. Wilcox described some immediate applications for radio paper as "electronic newspapers, wearable displays, and all sorts of 'expressive surfaces.' Ubiquitous information in the future will require our ubiquitous displays."

To achieve the final goal of radio paper, E Ink set for itself a technical path that included two intermediate steps (see **Exhibit 1**). As Comiskey put it, "We've come up with some interim markets before jumping to the magic book." These interim markets allowed the company to generate revenue while taking necessary steps toward the ultimate goal of radio paper, such as making higher resolution, higher quality ink, and exploring flexible backplanes.

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[1] Carol Vinzant, "E Ink," *Fortune*, July 6, 1998, p. 76.

The first step on the technical path was retail signage. It had been Wilcox's task to explore all opportunities for new business development and to identify the first market on which the company would focus. He had received three criteria from Iuliano: (1) the market focus must keep the company on its technical path toward radio paper, (2) it must bring revenue in 1999, and (3) the company must be able to grow that business to $20 million in 3 years.

After exploring several possibilities, Wilcox decided on retail signage. His team focused on the field compliance problem faced by major retailers: only about 20% of signage in retail stores complied with the parent companies' requests. With E Ink signs, the company could control its signage remotely, update information instantly store by store, adapt to specific marketing goals, or respond instantly to competition. With E Ink signs, compliance would be "broader, faster, smarter." Wilcox's team believed that this would make the signs very attractive to large retailers.

There were cost advantages to customers as well. E Ink's instantly changeable signs eliminated the cost of constantly making new ones. The components of electronic ink—paint chips, oil, and plastic—were inexpensive and the displays required very little power to update. Since the cost of traditional signs increased dramatically with size, E Ink's plastic signs had a cost advantage in the large area signage market.

Finally, the signage market was an appealing starting point for technical reasons. Because they did not require the fine degree of resolution of smaller area displays, large area signs were technically easier to produce. Moreover, because small defects were relatively unnoticeable at a distance, the technical specifications were less rigorous than in other markets. And with unit prices over one thousand dollars, E Ink could achieve meaningful revenues while still ramping up the manufacturing process at a reasonable pace.

Wilcox presented these ideas to the company, and the decision was made in July 1998 to pursue retail signage as a first market. Everyone at E Ink realized that signage was a modest start. Iuliano said, "This is not at all sexy, and not what people really envisioned themselves achieving." Albert agreed:

> We have this technology that gets incredible press and a huge amount of excitement. But then you need to get realistic and focused, and ask yourself what's really feasible. It's a very painful thing to do. People get all excited when I say I work on electronic paper, but they're not so excited about the signs for JC Penney. It's definitely less glamorous, but, on the other hand, it helps to see that we can make *something* that works."

Despite the mundane qualities of signage, everyone agreed that it was a necessary first step. Comiskey said, "It is a good exercise to figure out where all the problems are that may not have been anticipated."

Culture

Perhaps the most pervasive—and most visible—aspect of E Ink's culture was its youth. According to Albert, "The young people, the ones just out of school, are definitely the dominant culture group here . . . or at least the loudest one." Although Comiskey and Albert seemed to blend into the sea of young faces in the lab, they were a distinct part of the culture. "Barrett and J.D. are the funk of E Ink," said Wilcox. Iuliano described the pair as

> . . . the eyes and ears of the company. They're smart, inquisitive, and they never say, "It can't be done." They are the keepers of the culture; they embody the culture. We're pulling together a bunch of different technologies to create a new industry.

J.D. and Barrett understand this and see how all the pieces fit together. I want them to remain the master chefs and the keepers of the culture.

Wilcox said that the youthful E Ink culture was marked by "competency, good will, and intelligence. We all take this for granted in each other, so it's easy to get along. Everyone is very fresh. For many people, this is their first job." Many remarked that the sense of good will and collaboration made the lab feel more like a large family. According to Comiskey, "There's a lot of affection and fun in the lab. People are always hugging, laughing, and listening to loud music." Iuliano said, "There is a natural optimism in the culture. There is a belief that there isn't a technical challenge that can't be conquered."

Although fun was a distinct part of the culture, so was hard work. Noting that their long hours and dedication were comparable to those of their counterparts in the Media Lab, Comiskey said that he felt like he "lived the graduate student lifestyle." In many ways, the culture at E Ink was similar to that of the MIT Media Lab, which had earned a reputation for its brilliant scientists taking multi-disciplinary approaches to problem solving, off-the-wall applications, and high-profile corporate sponsors.

Another prominent feature of E Ink was the informal, flat organizational structure. According to Albert, there were only "3.5 levels" in the company. Iuliano was at the top level, followed by the management team (which included Wilcox; Drzaic; Morrison; Vice President of Operations Javed Chaudhary; and Iuliano's other direct reports), and then the engineers and scientists. The technicians who helped the engineers and scientists comprised the "half level"; Albert did not feel that this was truly a lower level.

The informality and flexibility of E Ink was evidenced in employees' email addresses. According to Comiskey, there had been a debate as to how the company should structure email usernames. Some employees wanted to use their first name, a more informal structure, for their email addresses (e.g., barrett@eink.com), but others wanted to use their first initial and last name (e.g., rwilcox@eink.com). Rather than choosing a standard format, they decided to let people choose whichever style they preferred.

Every E Ink employee, regardless of position, made a commitment to learn and understand the technology. There were all-company lunches every Thursday to discuss technical issues. Iuliano said, "E Ink has an environment of constant learning. Everyone has opinions, but nobody's figured it out."

Recruiting

Initially, the founders of E Ink hired generalists, like themselves, searching for people who had a variety of experiences and could adapt to an environment that was bound to change quickly. But, although it took generalists to bring together the many disciplines involved in electronic ink, the top team realized that hiring experts, with years of experience in a specific field, would expedite the technical development process and, later, the manufacturing process. Clearly, they needed experts in the two major components of electronic ink: display technology and ink. Their first two experienced technical hires were Paul Drzaic and Ian Morrison.

Drzaic joined E Ink as the director of Display Technology in early January 1998. His role was to flesh out and develop the company's technological road map toward a flexible backplane. After earning his Ph.D. from Stanford, Drzaic had spent several years at RayChem, where he became involved in novel display areas. He first saw the E Ink prototype at a display conference in 1997. He recalled thinking that, even though it was a primitive prototype, "If I'm so smart, why didn't I think of that?" The technology seemed feasible, and it fit emerging trends in display technology. It was an elegant solution to the old electrophoretic display problem.

Morrison joined E Ink as the director of Ink Technology soon after Drzaic. During a 21-year career at Xerox, he had honed his expertise in colloidal chemistry, the science of surfaces and small particles. Morrison had come across an article about E Ink when looking through a technology journal. Thinking they were a competitor to his department at Xerox, he emailed them to learn more about the technology. Although E Ink did not turn out to be a competitor, the information piqued Morrison's interest. "You always want to work on something that comes to fruition; this project is challenging but doable. I knew the chemistry, and had some experience with product development. I didn't think it would take a long time." He visited the lab during a trip to Boston and, a month later, he agreed to join.

Although their areas of expertise were different, Drzaic and Morrison expressed many similar motivations for joining E Ink. Both had been part of large, well-established organizations. A project in either of their former companies took years, possibly decades, to develop. Once developed, there was no guarantee that it would be commercialized. At E Ink, they could see a product to market in a short period of time.

Along with their high level of enthusiasm for the work, Drzaic and Morrison brought a combined total of over 30 years of experience to E Ink. Iuliano said, "It's good to have people who want to storm every hill, but it's also good to have people who know the best hill to storm."

Iuliano (HBS 1986) joined E Ink in February 1998, after having resigned from Molecular Devices to spend more time with his family. Iuliano had started at Molecular Devices in 1990 as the CFO; after a rift developed between the founder and the CEO, Iuliano was asked to become the new CEO. At the time, the company was 10 years old and losing $2 million per year. It had been known to have a strong technical group, but weak business groups. Under Iuliano's direction, the company experienced 20 quarters of growth, going public in 1995.

E Ink came to Iuliano's attention through the venture capital community. He was impressed with E Ink's technology, commercial potential, and brilliant people. The team at E Ink was equally impressed with him. According to Wilcox, "A lot of experienced candidates came in the door promising results, but Jim was the only one who brought it back to the culture we needed to build. He had managed scientists and Ph.D.'s before and was able to connect with everybody."

The most recent addition to the management team, in January 1999, was Javed Chaudhary, vice president of Operations. Chaudhary had extensive experience with manufacturing, mostly in high-tech start-up organizations. Most recently, he had served as a vice president at Seagate Technology, where he was responsible for manufacturing operations in the United States and Far East. Chaudhary said he was attracted to E Ink because "the whole concept can be revolutionary if we can meet the final objective of radio paper."

In general, recruiting efforts revealed that attractive candidates were interested in E Ink for a few specific reasons: the high potential of the company and its products, the revolutionary technology, the interdisciplinary nature of the work, and the small-company mentality. Comiskey noted that people were interested in E Ink "because they want to change the world. It's not a tough sell." Morrison believed that E Ink had more success in recruiting talent than typical start-ups, saying that, after his initial two-minute explanation to job candidates, they understood the basic concepts and recognized E Ink's potential immediately. According to Morrison, it was easy to get new recruits excited about the technology: "Anyone can sell this stuff!"

Taking electronic ink from its nascent stage to an actual product was also a motivating factor for many new recruits. According to Morrison, "People are really excited about accomplishing something this year." Comiskey added, "At the end of the day, with a display material you have immediate feedback. It's easy for people to get excited." "New hires have an opportunity to make an immediate impact," Morrison said. "If you come here, you'll be an important person." Since there

were so few employees, new hires could see the impact they had within a couple of weeks of coming on board.

Drzaic did not foresee any problems with employee retention, "unless the Boston area becomes more like Silicon Valley, where people have little company loyalty and are willing to move for individual gain." Morrison agreed: "We are not facing any challenges with retention yet. Right now, the main complaint voiced is feeling overwhelmed—there are so many problems to solve, so many possibilities to explore. This is the time to teach people how to pace themselves."

Growth and Change

Growth brought new challenges to E Ink. Paul Drzaic commented, "In the early days, we just gave interviews to the media and showed a little demo that makes a cute picture. Now we have to show that we have something that's stable and reliable. We can't get by any longer by just looking cool."

Many believed that the market was right for an electronic ink display. The recent trend in display technology had been toward flexible, reflective, low-power displays. E Ink clearly had the potential to develop this type of technology; now it had to focus and deliver a product. Chaudhary said, "We have to catch the window of opportunity in the next 18 months to 2 years. There are no real competitors now, and we are protecting ourselves with patents, but someone could still come along. We also need to give the investors a return." Drzaic agreed: "We need to execute before the winds shift."

E-Ink hoped to go into production by the end of 1999. The immediate challenge was in taking ink manufacturing, which was done by hand, to a mechanical process. The two main goals for manufacturing were stability (i.e., ensuring at least a 98% chance that an E Ink sign would last three years) and reliability (i.e., solving the problem that the microcapsules occasionally burst). Moreover, as it scaled up to manufacturing, E Ink had to manage expectations and relationships with sponsors, collaborators, and potential customers, as well as decide on which pieces of the work could be outsourced. Drzaic remained optimistic: "The technology development is still challenging, but we have multiple bets and multiple opportunities, so there is a fair degree of confidence that we'll get some stuff to work."

In order to zero in on the technical challenges, the E Ink lab had recently moved from the exploratory Edisonian approach of the Media Lab to a more methodical scientific process. The Edisonian approach had involved changing several variables at once; in Iuliano's opinion, it would have been impossible to develop electronic ink any other way. Now, however, lab personnel were to change just one variable at a time and follow it through the entire process. Initially, this procedural shift was not well received; eventually, however, the lab group came to see the value of being more precise and systematic.

According to Comiskey, the company was no longer in its "shiniest, happiest moment." In order to meet the demands of manufacturing and technical development, the company had been growing rapidly. By December 1999, E Ink's staff was expected to increase to nearly 90—three times as many people as the company had one year earlier. As the company grew, many noticed growing pains in the culture. Albert said:

> Keeping the fun is really hard as you grow. The excitement gets diluted with more and different types of people and more mundane jobs. When you're zeroing in on specific problems and grinding away and trying to solve them, it's a lot harder to maintain the fun. It's hard to get the culture to conduct quickly when you've got a lot of new people coming in.

Comiskey agreed:

> We've grown a lot, organically. We now realize that we need more infrastructure, like for communication between people and across projects. We need to address these issues, but we also have to balance change. We need to introduce some structure, but maintain the level of autonomy, which allowed us to innovate so quickly. As we grow, it's harder for everybody to see the whole system and understand the details of everything going on. It's important for everyone to have a broad perspective, but the whole thing is getting more complicated and we need some people to architect and coordinate the technology and the business.

For the past few months, the three major groups at E Ink (management, manufacturing, and the engineers and scientists in the lab) had been located in three different buildings. However, this was slated to change in August 1999, when all three groups were scheduled to move to one new building. Wilcox worried, "The functional differences between the groups may be getting more entrenched due to physical separation."

Maintaining the E Ink Culture

As he thought about E Ink's rapid growth, Iuliano reflected on his first job in the financial department at IBM:

> I was fresh out of college, and I thought I could really make a difference. At a gathering of the entire finance group, I realized that I was just 1 out of 300 people. There was a particular manager I admired, who happened to be 6'6". When I spoke to him, he had to stoop to see my nametag. It will be a sad day for me when people wear badges around here. I want to know every person on a first name basis for as long as possible.
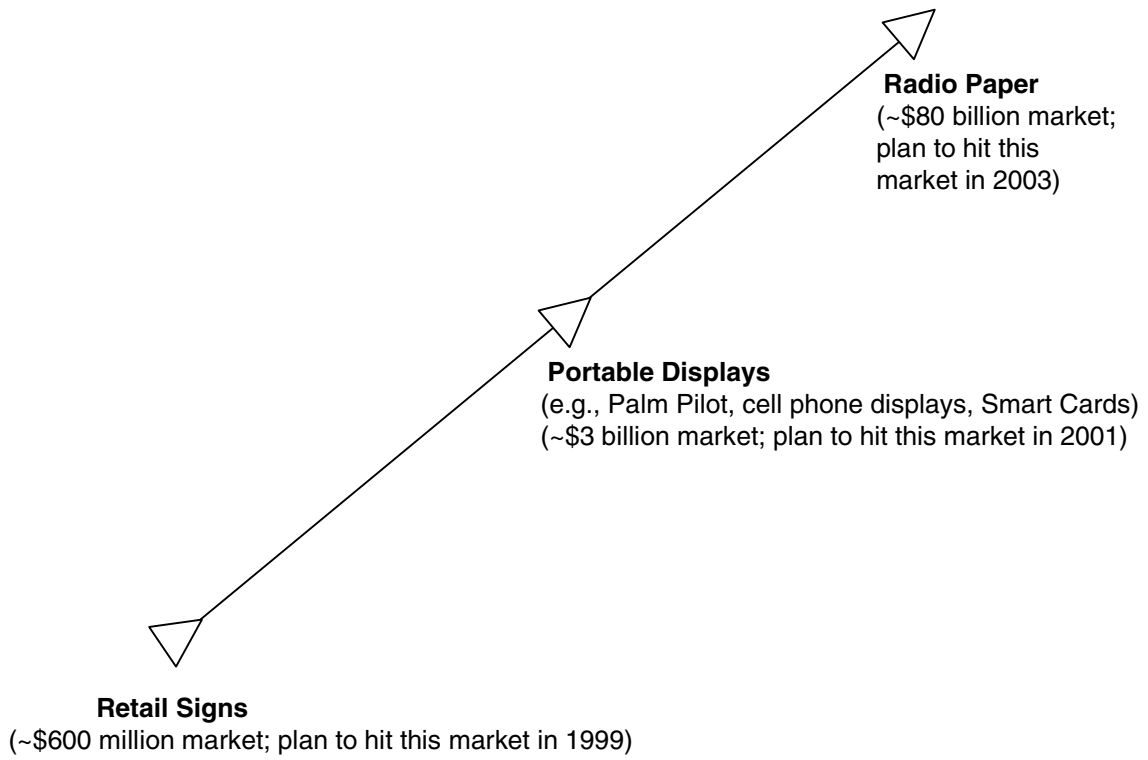
Growth and change also occupied Comiskey's thoughts:

> Culture is very important to me. I want everyone to believe in the technology and each other. I want to keep E Ink an interesting, fun, exciting company where great people want to work. No matter what we do, we need to make the technology as good as possible. I can't imagine anything other than the technology driving us in the lab. As scientists and engineers, I don't want us to get distracted with politics and lose sight of making the ink as good as possible.

It seemed that losing certain aspects of E Ink's culture was inevitable. Wilcox said: "Now, everyone is very excited; there is a lot of tension, mostly self-imposed. Everyone thinks this is a once-in-a-lifetime opportunity, so let's not mess it up. As the company grows, we'll have more policies, and more of a big-company feel."

Iuliano seemed confident that, in the next few months, the company could solve the remaining technical challenges and scale up its manufacturing. However, he wondered if the E Ink culture would scale up quite as well.

Exhibit 1   The Technical Path to Radio Paper

Radio Paper
(~$80 billion market;
plan to hit this
market in 2003)

Portable Displays
(e.g., Palm Pilot, cell phone displays, Smart Cards)
(~$3 billion market; plan to hit this market in 2001)

Retail Signs
(~$600 million market; plan to hit this market in 1999)

Source: E Ink interviews