XEROGRAPHY: A STUDY IN INNOVATION AND ECONOMIC COMPETITIVENESS

When Chester Carlson invented a means of copying images using sulfur film and lycopodium powder in 1938, no one could have foreseen the advances in materials science and other developments that would turn his nascent technology into today's burgeoning business.

Joseph Mort

The general consensus is that the US in recent years has progressively lost competitive ground in a number of critical economic areas—this despite the fact that it has been the world's leading scientific and technological power and has spent more on nondefense R&D than any other country. Evidently scientific and technological prowess do not guarantee economic competitiveness.

Current economic problems in the US may have less to do with insufficient expenditures on R&D or deficiencies in scientific and technological creativity than with investment strategies and related assumptions as to how science and technology are transformed into economic value. This is why the linkages between science, technology and economic growth are so hotly debated at the corporate and national levels among political, labor and business leaders, scientists and economists. But the conclusions reached in these debates will be very sensitive to the level of shared understanding of the role that R&D plays in the innovation process.

Economic growth and job creation are fueled by innovations. While the word "innovation" is commonly used outside of an economic context to connote "newness," within that context "innovation" refers to a process in which the objective is the profitable marketing of a product. In this sense, even an innovation based on a technical invention or advance is not a result of science alone; industrial research can create an innovation only in partnership with the marketing and business arms of industrial firms.

What are innovations? How do they happen? What role can and does scientific research play, and how might its impact be improved? The creation and evolution of the copier industry, including its current transition into the document business,[1] sheds light on the answers to these questions. (Figure 1, showing novel photoreceptor materials, illustrates one of the enabling factors in the innovation process so important to a firm's or industry's competitiveness: namely, the ability to assimilate, adapt and evaluate emerging technologies for its business needs.)

The first revolutionary innovation in the document business, the invention of xerography, occurred three decades ago and created an industry. Today the industry is in the midst of a transformation, induced by a second round of radical innovations at the interface with computer and telecommunication technologies.

Product evolution

Figure 2 shows the evolution of the document business in the form of three time lines tracing product evolution within the industry in parallel with scientific and technological developments endogenous and exogenous to the underlying xerographic technology (that is, advances developed specifically for the xerographic industry and advances initially unrelated to xerography).

Although a manual xerographic product was introduced by the Haloid Company (later called the Xerox Corporation) in 1949, it was the marketing of the Xerox 914 copier in 1959 that truly constituted the innovation. An automatic machine, it produced seven copies per minute on plain paper with a reusable photoreceptor. The image, composed of carbon-black-impregnated polymer toner, was ideally suited for archival storage.

The impact of the 914 was phenomenal. Market research had projected sales of 3000 units, but over the product life more than 200 000 were sold. The number of copies created per month climbed from 50 million in September 1961 to 490 million by March 1966, while annual corporate revenues soared from $3 million in 1960 to $428 million by 1966.

Through the 1960s and 1970s, the industry saw new copier product lines with improved quality, reliability, cost and—with the arrival of xerographic duplicators—speed. New xerographic product types using pioneering technologies were also introduced. These included long-distance xerography (a groundbreaking but cumbersome method of facsimile transmission) in 1964 and the first xerographic color copier in 1973. Neither of these was a significant commercial success at the time, that is, an innovation as we have defined it here.

The early 1970s saw the entry into the industry of

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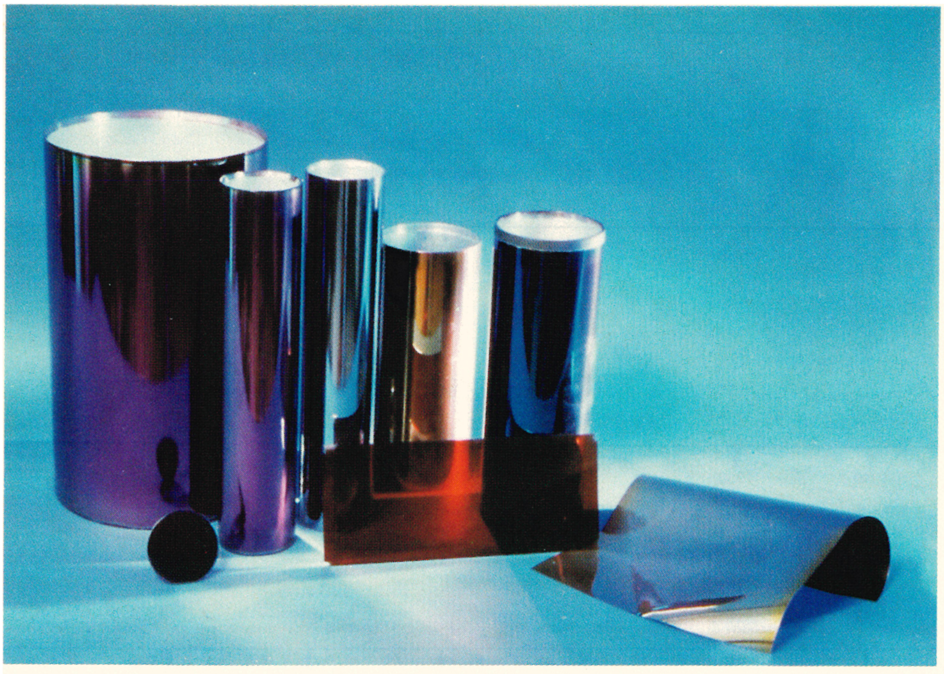


Prototype photoreceptor drums for xerographic copiers and printers coated with plasma-deposited amorphous films 25 microns thick. The different colors arise from passivation-layer coatings of plasma-deposited silicon nitride of variable thickness; a-Si:H films on planar substrates are also shown. These macroelectronic structures illustrate the continuing impact of materials science on the document business. The circular disc (left foreground), a three-inch single-crystal silicon wafer, gives the scale. **Figure 1**

other US and Japanese companies, and over the next decade smaller personal copiers with disposable toner cartridges were marketed to reduce customer dependence on service and improve the perceived reliability.

The most important innovation of the last two decades was the introduction in the mid-1970s of the first laser printers, which used gas lasers to write computer-generated alphanumeric digital data as optical images directly on the photoreceptor. This technique permitted high-speed production of xerographic-quality prints with machines that were significantly quieter and provided sharper resolution than existing impact line printers. This was the birth of digital xerography.

These first xerographic laser printers were centralized, high-speed, high-volume machines serving the dominant computer usage at that time: batch processing and time-sharing on mainframes. All this was destined to change. The development of integrated circuits based on silicon chip technology allowed revolutionary increases in computing power coupled with reductions in size and cost. With parallel advances in computer software and information storage technology, these improvements enabled the diffusion of powerful, affordable computers into the office and into the hands of individual owners.

Office information systems employing personal computers, word processors and workstations in conjunction with desktop xerographic laser printers and digital networks now are used to create, integrate and communicate documents. This transformation of the business is captured in the Xerox Corporation's new trademarked self-description as "The Document Company."

After almost 20 years of laser printing, digital copiers, color copiers and plain-paper fax machines have blossomed as successful innovations, and the worldwide document business for all companies now exceeds $100 billion in annual revenues, with several trillion paper copies and prints being generated each year.

Invention and endogenous R&D

A successful innovation must satisfy a discernible need or create a demand. In the case of xerography, the enormous market potential was far from obvious or recognizable at the outset. Improved ways of copying documents were initially seen as more of a convenience than a necessity.

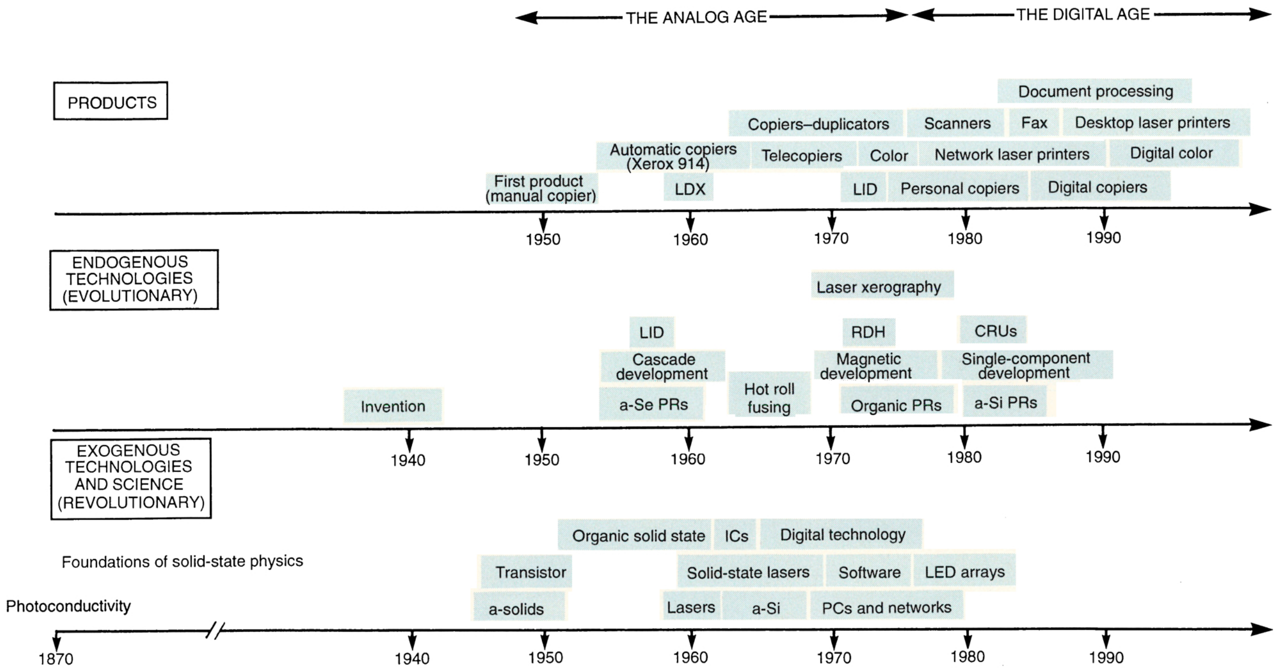
In the early 1930s image production using electrostatically charged insulators to attract triboelectrically (frictionally) charged powders had already been demonstrated. Chester Carlson, the inventor of xerography, recognized that this technique could be exploited together with photoconductivity, and he demonstrated his new method on 22 October 1938.

But this first demonstration of xerography was a long way from being a practical technology. A sulfur film with little sensitivity to visible light was used as the photoreceptor to transform the optical image into a latent electrostatic image; the developing agent was lycopodium powder (club moss spores), which was not very dark and therefore provided poor contrast; and the initial charging involved rubbing the sulfur with a handkerchief.

With only the feasibility of the invention established, Carlson spent the next six years trying to generate industrial support. Finally he convinced Battelle Memorial Research Institute, in Columbus, Ohio, to commit $3000. Beginning in 1947 the Haloid Company, then a small photographic-paper manufacturer in Rochester, New York, agreed to support the Battelle research at an annual level of $25 000—a major risk considering the company's net income was only $138 000.

The new technology was announced in 1948, the tenth anniversary of the first xerographic copy, at the Optical Society of America meeting. The invention of the transistor, which was to have a profound impact on the evolution of xerography, had been disclosed four months earlier. The same year, a major stimulus to future development work came with a grant of $120 000 from the US Army Signal Corps to Haloid to create a dry photographic process.

Though xerography was rooted in the science of photoconductivity, electrostatics and materials, understanding of the materials and processes was limited. As a result its early development proceeded largely by trial and error. Even so, important advances during this early period created the basis for the commercialization of



Evolution of the document business. The three time lines display product evolution, scientific and technological developments specifically related to xerographic technology, and initially unrelated scientific and technological developments. Their indicated times of occurrence, while approximate, provide a visualization of the interconnected flow between knowledge, technology and products. Abbreviations are as follows: a-Se, amorphous selenium; a-Si, amorphous silicon; a-solid amorphous solids; CRUs, cartridge-replaceable units; ICs, integrated circuits; LDX, long-distance xerography; LED, light-emitting diode; LID, liquid image development; PCs, personal computers; PRs, photoreceptors; RDH, recirculating document handler. **Figure 2**

xerography. Required developments (see figure 3) included ion-charging devices, appropriate dry-ink or toner compositions and means of electrostatically transferring and fixing the developed toner image to paper. (For a detailed treatment of these developments, which are not uniquely associated with xerography, see the article by Donald M. Burland and Lawrence B. Schein in PHYSICS TODAY, May 1986, page 46.)

A more systematic and systemic knowledge base was essential for future advancements in the technology, opportunities for further innovations and growth of the business. The commercial viability of Carlson's invention and the future document industry was clearly predicated on the availability of page-size photoreceptor films with the requisite photoelectronic and other properties. Without the constraints of the ordered crystalline state, disordered solids such as glasses were obvious candidates for easily produced, low-cost, large-area thin films. But while such materials typically had the necessary insulating properties, they were not perceived as having useful photoelectronic characteristics.

Amorphous selenium

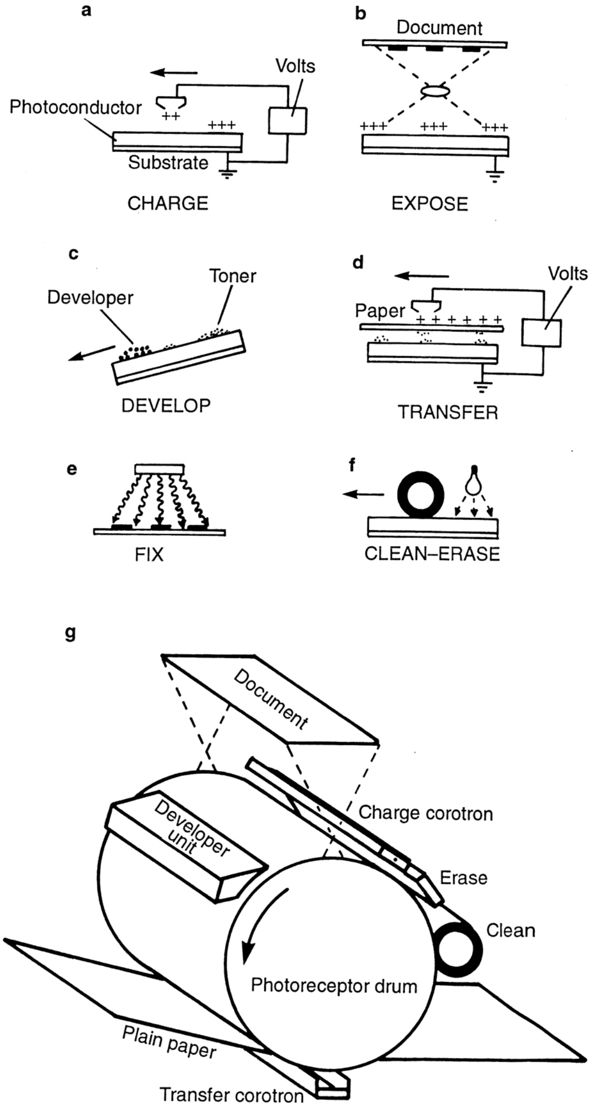
This situation changed with the discovery in the late 1940s of photoconductivity in amorphous selenium—the photoreceptor material used in the Xerox 914. At that time, based on the development of the band theory of solids in the 1930s, with its attendant concept of electron delocalization, solid-state physics was concerned almost exclusively with crystalline solids, since these were viewed as being both scientifically and technologically tractable. This research culminated in the dramatic discovery of the transistor.

But in one of those curious coincidences that recur in the history of science and technology, nascent ideas on the effects of randomness and disorder on the physics of the solid state were being independently generated.[2] In particular, consideration of electron propagation in nonperiodic force fields as a perturbation on band theory led to the recognition of the importance of localization phenomena. The distinctive key characteristics of delocalization and localization in crystalline and noncrystalline solids, respectively, determined the nature of the emergent technologies and innovations with which they became associated—transistors and other solid-state devices on the one hand and conventional and laser xerography on the other.

Despite the innovation of the Xerox 914, questions of both scientific and technological importance remained about the consequences of and limitations on the photoelectronic properties of the necessarily disordered large-area imaging materials. Indeed, despite their critical role, the first unambiguous measurements of the photogeneration and transport of electronic charge in amorphous selenium were not made until the late 1950s, too late to contribute significantly to the initial development of xerography. By the late 1960s, however, concerted efforts were under way by the scientific community to understand more fundamentally the materials and phenomena that provided the foundation for xerography.

This undertaking required not only new theoretical interpretations of the electrical, structural and thermomechanical properties of amorphous inorganic, organic and polymeric solids and of electrostatics and triboelectricity, but also the development of appropriate measurement techniques to systematically characterize those properties. Consequently xerography is one example of a technological innovation that gave impetus to new fields

The six basic steps in xerography. a,b: An optical image of a document is projected onto a page-size insulating but photoconductive layer, the photoreceptor, which is uniformly charged with ions. Selective photodischarges produce a latent surface charge replicating the information content of the document. **c–f:** The image is then developed, transferred and fixed to paper by processes that exploit electrostatic attraction for triboelectrically charged powder, the toner. **g:** Schematic shows how an analog xerographic machine integrates these steps. (A corotron is an ion-charging device.) **Figure 3**



of scientific study.

A major outcome of these studies was the clear understanding that the large-area photoelectronic capabilities of amorphous materials come at a cost: They are dominated by localization phenomena, which curtail electronic mobilities, a measure of the speed with which electronic carriers can move. However, an important step forward in xerographic technology was the recognition that in this regard, the figure of merit for a photoreceptor has more to do with how far charge can move than how fast and that even mobilities one ten-millionth of those in crystalline silicon are not limiting for the highest-speed copiers and printers currently employed in the document business.

Improved photoreceptors

While amorphous selenium was critical for the early commercial success of xerography, it had definite shortcomings. It exhibited a propensity to crystallize, it was mechanically inflexible and it possessed surprisingly little photoconductivity when exposed to red light, even though this was strongly absorbed.

Amorphous selenium's relatively low red sensitivity results from carrier-pair recombination-limited photogeneration processes, which result from the extremely short mean free paths associated with localized charge transport. In such processes, if a photoexcited electron–hole pair thermalizes within its mutually attractive Coulomb radius, there is a high probability that the electron–hole pair will recombine before ever dissociating into free carriers. Since their separation at thermalization decreases with the initial photon excitation energy, the photoresponse in amorphous selenium drops dramatically at longer wavelengths.

From the perspective of engineering and product design, considerable value was ascribed to acquiring a flexible, red-sensitive photoreceptor, for this would make possible the use of a belt rather than a drum as the photoreceptor, as well as full-document flash exposure and higher speeds because of a more panchromatic response. Independently, it also was a business imperative to find cheaper photoreceptors. During the 1960s and 1970s these combined market requirements were major forces driving research to identify alternative photoreceptor materials and devices.

Thus in the 1960s the industry's research laboratories turned their attention to organic solids, including polymers, as potential alternatives to amorphous selenium. Many polymers are flexible, transparent and chemically inert; they have high impact strength; and they can be produced cheaply in large-area coatings. Polymers also generally constitute some of the best electrical insulators. Exploratory studies in the 1950s on the photoelectronic properties of molecular materials gave rise to the hope that coupling an understanding of the organic solid state with creative chemical synthesis might yield the required combination of desirable electronic and mechanical functions. Today that hope is a commercial reality.

The necessary materials design and engineering advances originated in an ever expanding understanding of generic localization-controlled transport and photogeneration processes in disordered systems and, most critically, in the conceptualization and demonstration of their relevance to xerographic technology. In contrast to inorganic amorphous materials, in which localized states derive from covalent-bond distortions or defects, in disordered molecular solids the localization can occur on the molecules themselves. Recognition of this possibility led to the idea of doping otherwise electrically inactive polymer matrices with molecules to realize the required electronic transport. Such charge transport is achieved by virtue of quantum mechanical wavefunction-controlled hopping of electronic carriers between the effectively isolated dopant species.

Because polymers typically do not absorb visible light, the molecularly doped transport layers are combined with a second, thinner, photosensitive layer—the source of the photogenerated charge that, by injection into the transport layer, controls the photoreceptor discharge. Today such sophisticated, molecularly engineered, dual-layer photoreceptors dominate the xerographic industry and constitute the largest industrial use of polymers as thin film electronic devices. (See figure 4.)

More recently, amorphous hydrogenated silicon (a-Si:H), discovered in 1965, has been developed as a commercial photoreceptor. Originally viewed solely in the context of solar photovoltaics, this technology depends on the ability to dope an amorphous solid with extrinsic impurities, which was established by fundamental studies of the origin and control of silicon dangling-bond densities.[3] Though disadvantages of a-Si:H and related materials include high manufacturing costs, nonflexibility and lack of infrared sensitivity, their wear resistance offers prospects for photoreceptors that would last the life of the machine, with obvious advantages for both customer and supplier. From the customer's perspective, the replacement cost of a photoreceptor, measured in terms of cost per copy, decreases linearly with photoreceptor life. The supplier can realize reductions in service costs and changes in product architecture leading to overall product reliability.

Exogenous science and technology fusion

Like products, technologies do not magically materialize in recognizable, ready-made form. They are created and developed within contexts defined by what is known, needed or perceived.

Electrostatic charging and triboelectrically charged powders were used to develop electrostatic images prior to Carlson's invention. Photoconductivity, discovered in 1873, was well studied if imperfectly understood. Carlson's insight was to recognize that linking photoconductivity and electrostatics offered a way to make inexpensive copies on plain paper automatically and quickly.

The current innovations based on xerography, which go far beyond what Carlson originally conceived, were contingent on scientific and technological discoveries that were both unforeseen and whose ultimate relevance was not immediately obvious. For a considerable time after its discovery, the transistor was viewed primarily as a more energy-efficient, more reliable replacement for vacuum tubes. But it unexpectedly presaged the solid-state electronics and integrated circuits that would yield desktop computers and digital information networks. And the laser, in hindsight, was ideally suited for printing digital images. A highly focused, intense spot of light could be scanned across dimensions of a page with modulations in intensity corresponding to the image to be created—truly a pen of light to allow document creation by direct writing on the photoreceptor.

Given the speed at which information spewed out of even the earliest computers, high-speed production of hard copies was necessary, and the noisy mechanical impact printers that were initially used were plainly unsatisfactory. The adaptation of xerography to this market suggested itself in the earliest days of the industry, and laser xerography was demonstrated in the laboratory as early as 1965. Two critical elements for a true innovation were missing, however: the technologies required for commercial exploitation of the idea and, just as important, the need and motivation to exploit it.

The advent of solid-state GaAs lasers, a development initially driven by optical telecommunications needs, brought with it further major new opportunities for the document business. Compared with gas lasers, solid-state lasers have advantageous properties: Among other things, they are smaller and one can control their intensity directly, without recourse to crystal modulators. Because the commercial solid-state GaAs lasers available in the mid-1960s emitted only in the near-infrared region, their application to xerographic laser printers required the discovery and development of infrared-sensitive photoconductor systems. As it happened, organic solid photoreceptors turned out to be the solution to this problem too. Materials such as phthalocyanines are now widely used as photogenerator layers because of their high infrared photosensitivity. In related developments, page-width light-emitting-diode arrays eliminated the need for the rotating polygon-mirror devices required to scan single-beam lasers. Together these advances opened the way for the development of low-cost, desktop laser printers.

Practical, affordable and reliable lasers were one necessity for laser printers, but any significant market for these devices also was predicated on a growth in the use of electronic processing for text and graphics. This would require the infiltration of computer technology into the office and graphic design departments, and the time constant for this process to occur on a large scale was measured more nearly in decades than in years.

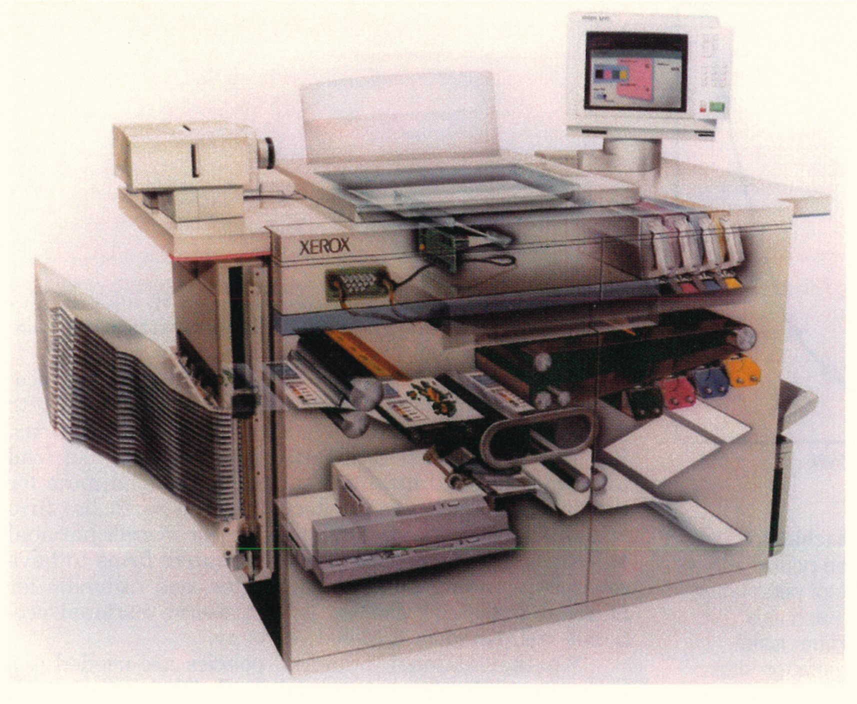
In retrospect, the elements that made the document business possible appear almost to have been preordained. Digital xerography, enabling innovations such as printing, desktop publishing, quality fax and color, required the marriage of xerography with other disparate innovations: the computer, to provide digital electrical signals containing the image information; the laser, whose output intensity could be controlled by computers; and xerography, to convert optical information into marks on plain paper. These technologies were created with different time constants by diverse industries, so that their coalescence to form the newer innovations only became feasible beginning in the 1970s. Their integration continues to this day and is a prime example of what has been termed "technology fusion" and of its importance in the creation of new innovations.[4]

This particular fusion was personified by John Bardeen, coinventor of the transistor. (See the article by George Pake in PHYSICS TODAY, April 1992, page 56.) Bardeen became a consultant to Xerox seven years before the introduction of the Xerox 914, he served as a director of Xerox from 1961 to 1973, and he remained associated with the firm until well into the 1980s. Bardeen maintained his early and active involvement in the development of emerging technologies based on amorphous materials and authored several US patents on materials for photoreceptor technologies. He had a particular interest in the amorphous extrinsic semiconductor a-Si:H both as an important adjunct to the crystalline form of silicon and because of the complementarity of the large-area electronics it enabled to electronics using silicon chip technology.

Indeed, in recent years the need for low-cost optical scanners and page-width solid-state photodetector and thin film transistor arrays for liquid crystal video display terminals for the office has intensified the interest and investment in the commercialization of "macroelectronics" using a-Si:H.[5]

When is a market a market?

A product's introduction to the marketplace is not the end of the innovation process, merely the end of the beginning. In other words, the spread of new products in the marketplace is a requisite of innovation, and one can gain some useful insights by viewing it as a percolation phenomenon involving diffusive flow with connectivity through a granular medium, identifying the market with the medium and its real and potential customers with occupied percolation sites. (See the inset to figure



A digital color copier–printer, the Xerox 5775. In digital xerography, the image is directly written, pixel by pixel, by laser light modulated by digital output from a word processor for printing originals or a scanner for copying. The mechanical flexibility of polymers has led to increasing use of organic-based photoreceptors and allows the production of belt photoreceptors of the type shown mounted above the different-colored development housings in this artist's drawing. The dual-layer organic belt photoreceptor uses a thin photosensitizing layer overcoated with a much thicker, molecularly doped polymeric charge-transport layer. **Figure 4**

5.) If the innovation spread is not to be localized in clusters, sufficient connectivity must be attained to reach the percolation threshold.[5] Thus in addition to the technology and product development phases, a characteristic induction period typically occurs after product introduction.

Consideration of this induction period focuses attention on instances in which innovations prematurely declared failures ultimately become successful. Although xerography is one of the most successful innovations in the history of business, it is itself an example. At any point within the decade bridging the manual product of 1949 and the enormously successful Xerox 914 copier in 1959, there were some who perceived xerography to be a failure as an innovation. The marketing strategy of leasing the expensive automatic machines instead of selling them outright was therefore as revolutionary as the technology itself in ensuring the innovation's ultimate success. It allowed a sufficient number of early users to adopt, with little risk, a fledgling technology of unproven value.

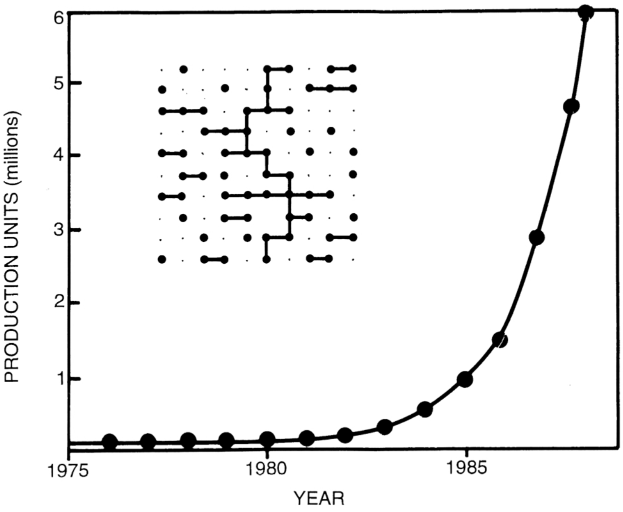
The data in figure 5 showing the growth in the production of facsimile machines from 1975 to 1989 offer yet another example.[6] Despite the marketing by Xerox of an affordable office fax machine, the Telecopier, in 1966, the production volume remained essentially constant before the very abrupt rise in production (reflecting demand) starting about 1983–84. Because it involves the communication of information rather than its creation or reproduction, the fax typifies a special class of innovation: one whose value to a customer is intrinsically linked to the number already sold—the extant connectivity. Other factors, including an initial lack of recognition of the full potential of the technology, insufficiently low prices and the necessity for further improvements in associated technologies, served simply to compound the delay in consummating the innovation.

A final example of the importance of timing for the ultimate success of an innovation is the history of color xerographic products. The first color copier, introduced in 1973, was revolutionary, but it employed analog technology. This placed significant limits on the fidelity and reproducibility of the copy quality. Moreover, the market demand to create color copies was limited by the type and number of color originals available at that time. The successful innovation of color xerography therefore had to await the emergence of digital technology (to allow high-quality color copying) and the ongoing diffusion of the other innovations based on digital electronics (to provide the necessary market demand). (See the December 1992 special issue of PHYSICS TODAY on the physics of digital color.)

Aspects of innovation

The focus here has been on industry-wide innovation, but what of this process within individual firms and the role of national science and technology policies? Innovations come in different varieties: rare, radical innovations that create markets; more common improvement innovations that influence existing markets, often in major ways; and "pseudo-innovations" that introduce barely differentiable changes in products or markets.

The various partners required for innovation, with their diverse cultures, often lack a shared language or metaphor. A helpful analogy for innovation, familiar to the nonscientist and scientist alike, is that of biological evolution.[7] In this paradigm, the long-run purpose of firms as engines of innovation is to survive and prosper through the transformation of knowledge, via technology, into products. Though not the ultimate purpose, profitability is an absolute requirement. Survival depends on three important characteristics of a firm, which respectively determine its choices, its ability to react and the timing of its response in the face of change. First, firms use or acquire knowledge and practices in areas of inquiry relevant to their current and future business objectives; these core competencies form the "genes" of the firm. The second characteristic derives from a firm's very existence, as adaptation requires sufficient time for selection to act on competing varieties; this positive side of a firm's inertia has the negative overtone of undue resistance to change. Third is the effectiveness in terms of content and timing with which a firm mounts its



Japanese production of fax machines, 1975–89, exhibits an induction period and a sharp threshold, characteristic of percolation through a structured medium such as a network (inset). Here the medium is the market, and the occupied percolation sites are real and potential customers. (Adapted from ref. 6; courtesy of Dempa Publications Inc.) **Figure 5**

collective response.

Faced with the same change, firms make different choices, for the choices and responses of all firms are intrinsically constrained by their particular "genetic" makeup and lack of perfect knowledge—their so-called bounded rationality. In Stan Metcalfe's words, "They know different things about a world they share."[8] In fact, these inevitable differentiations between firms are the source of the variety so essential to innovation.

While in the long run, research has proven highly effective in providing the innovations responsible for the spectacular economic growth of the 20th century, the success rate of research at a micro level is much less impressive, giving rise to what Gerhard Mensch has called "the paradox of unexploited technologies."[9] Some causes of this paradox have, I hope, emerged as counterpoints to the major theme of this article, but ultimately the affordability of required resources determines the fraction of technologies that can be transformed into innovations.[10] Such affordability may even be determined by prior investments, so that acceptable, or "system compatible," responses are often constrained by history.

Given this state of affairs, it might reasonably be concluded that there is more investment in research and technology than demand requires. (See the article by John M. Rowell in PHYSICS TODAY, May 1992, page 40.) Left unanswered, however, are the following questions: What are the right investments in terms of both substance and timing, and who should make the choices? Examples abound of wasted resources and lost opportunities that arose from either expecting too much too soon or anticipating too little too late from a technology or marketplace.

Ernest Braun and Stuart MacDonald describe innovation as follows: "A game it certainly is; though whether it be a game of chance involving a lot of skill or a game of skill with a large element of chance is yet to be determined."[11] And so, given that "the price of precision can be error,"[12] as another writer has put it, adaptability rather than certitude should be a guiding strategy in the game of innovation.

At the macro level as well as the micro level, economic competitiveness depends on the relative ability to create or adapt to market changes through innovations. But just as bounded rationality within a firm can lead to an internal optimization that may be nonoptimum for the firm in a market sense, decisions for a particular firm or industry may also be nonoptimum for overall national objectives. Since market survival requires firms to have coherent, winning business strategies, one rationale for national industrial policies is to preserve national economic well-being in a global economy.

Whether national industrial policies are needed is a topic of considerable current debate.[13] The common contention that government departments are unlikely to be very successful at picking winners may be beyond dispute. For the reasons just mentioned, however, it is not obvious that the success rate of firms is inherently better. It must also be pointed out that both solid-state electronics and xerography received funding support from agencies of the US government at critical points in their development. Moreover, for reasons of affordability and selectivity, the private sector may well overlook or neglect critical emerging areas. The debate might therefore be more profitably focused on possible forms for national policies, as those forged out of a common understanding and creative partnership of public and private sectors could be better than those generated by either sector alone.

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The views expressed here are those of the author and not of Xerox Corporation.

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