Optoelectronics 2000: The Impact of Society

By Howard Rausch

At the turn of the century, the technology professional will operate in a world utterly different from the environment that prevailed only a decade earlier.

The changes are already underway. They appear in new relationships between technology-based companies, their customers, competitors, and governments. This is particularly true in optics and photonics. As technologies, these disciplines find applications across national and industrial boundaries.

Organizations in optics and photonics increasingly seek skills that extend beyond a single function. They place a premium on the technology professional who understands not only research, but also engineering, applications, manufacturing, marketing, and even finance. If a prospective staff member also exhibits understanding of competitive, governmental, and societal trends, so much the better.

Here are eight trends that seem irreversible in the coming decade. The tides should be a lot easier to ride than to buck.

Washington's role in commercial technology will continue to expand.

The Clinton Administration looks on technology as the key to lifting America out of economic shock and into a new era of prosperity. The last time such awe of technology was expressed in high Washington circles was Lyndon Johnson's reaction to the Soviet *Sputnik* in 1957. Johnson, then the Senate Majority Leader, drawled darkly: "The Roman Empire controlled the world because it could build roads. Later the British Empire was dominant because it had ships. Now the Communists have established a foothold in outer space."

Washington's attempts to encourage technology and industry will not end with the Clinton Administration. Nor did they begin when Bill Clinton came to town. Some of the best-known technology programs began under this President's two Republican predecessors. One is Sematech, a consortium that is widely given credit for the U.S. semiconductor industry's turnaround since 1990. The Department of Defense is an important member, providing half of the consortium's $200 million annual budget. An affiliate, Semi/Sematech, consists of most domestic suppliers of manufacturing equipment and materials.

The present administration has expanded many technology policies it inherited, including CRADAs (cooperative research and development agreements) in several government departments, and the Advanced Technology Program in the Department of Commerce.

The concept of technology policy in the U.S. originated serendipitously back in 1798, when Congress authorized an extraordinary purchase from a young manufacturer named Eli Whitney. The order, for 10,000 muskets within 28 months, was 10 times the capacity of Whitney's firearms factory in New Haven, Conn. Devising methods similar to modern mass production, Whitney produced muskets that were the first to have standardized, interchangeable parts. Congress had obtained not only first-quality weapons, but also a volume-production industry for the U.S.

Fast-forward to the 20th century. With various threats to the nation's security, especially since 1940, the U.S. military has sought technological and industrial advantages over rivals. Through economic power, it has exercised a *de facto* technology policy, financing much of the nation's research, development, and advanced manufacture, notably in lasers and optoelectronics. During wars both hot and cold, the government focused on military needs, leaving civilian industries largely on their own.

With the collapse of the Soviet Union, military security now seems within reach. In its search for economic security, the U.S. faces new kinds of perils: Trade and fiscal deficits, intense foreign competition abroad and at home, and increasing dependence on foreign capital and products. In response, Washington is trimming military budgets and increasing its support of commercial competitiveness.

Government encouragement of commercial technology, manufacture, and marketing appears to be succeeding for the most part. It enjoys strong support in Congress as well as in the White House. It receives increasing participation from hundreds of industry coalitions, trade associations, and individual companies.

In addition to encouraging domestic industry, governments support research for another, more directly beneficial reason. They recall that when Michael Faraday was asked by the British Prime Minister of his day what good was his research into electricity, Faraday replied: "Sir, one day you will tax it."

An enhanced role for government has become a permanent force in American industry. Technologists who fail to understand the opportunities and pitfalls inherent in that trend will concede a big advantage to their competitors.

Economic security is supplanting military security as the leading claimant to technological support.

Until recently, Washington was able to leverage its military superpower status to advance U.S. economic and political interests. But the roles are reversing. The military now relies increasingly on commercial technologies, where advances are spurred by global competition.

A corollary trend is that commercial spin-offs from military R&D are slowing down while "spin-ons," technology movement in the opposite direction, are picking up speed. The Pentagon has observed that commercial companies frequently develop better technologies, faster. Hence the Department of Defense's (DoD) eagerness to develop dual-use technologies with civilian partners.

Federal R&D follows the same pattern. The military share of the federal R&D portfolio is expected to decline from 60% a few years ago to 54% in 1995. The goal is 50% by 1997.

Administrations of both political parties have long sought ways to encourage selected industries. The latest effort

"Until one is committed, there is hesitancy, the chance to draw back, always ineffectiveness. Concerning all acts of initiative (and creation), there is one elementary truth, the ignorance of which kills countless ideas and splendid plans: That the moment one definitely commits oneself, then providence moves too.

"All sorts of things occur to help one that would never have otherwise occurred. A whole stream of events issues from the decision, raising in one's favour all manner of unforeseen incidents and meetings and material assistance, which no man could have dreamed would have come his way.

"Whatever you can do or dream you can, begin it. Boldness has genius, power and magic in it.

"Begin it now."

—Goethe
(suggested by William G. Clark, CEO, Clark-MXR)

is a Pentagon-led attempt to jump-start domestic production of flat-panel displays, at a public cost of more than $500 million and a private sector cost nearly as large.

The Washington technology establishment—especially the military—is eager to tap the creativity of small companies. Many small firms refuse to do business with DoD because of the department's "often esoteric, sometimes outdated military specifications and standards, and an extremely cumbersome procurement system," reports Lionel S. Johns, associate director of the White House's Office of Science and Technology Policy. Fielding a complex technology for the government typically requires 840 bureaucratic steps over 16 years.

While it remains difficult for small or even medium-size companies in optics or photonics to sell products directly to the military, rich opportunities are emerging for R&D partnerships with various military agencies. The best prospects appear when the optics company bids as part of a coalition of organizations.

❋ Direct federal funding of basic research may be peaking out, but joint "applied" projects with industry should expand.

While federal funding for all research remains fairly constant, corporations and government are less willing to support cutting-edge research, to the alarm of technology-policy specialists. "Could America afford the transistor today?" *Business Week* asked in the title of an article on this subject in March.

Congress is pressuring scientists to link research to national needs. The Senate Appropriations Committee, for example, has urged that 60% of the National Science Foundation's (NSF) research activities be "strategic." Fortunately, the committee left it to NSF to decide which research fell into the "strategic" column.

Corporate research also tends to favor "strategic" efforts. If this trend continues, basic exploration could be left largely to universities. Bell Communications Research Inc. (Bellcore), for example, has stopped most long-term research in physics. It concentrates instead on immediate needs of its owners, the Bell telephone companies. One of many displaced Bellcore scientists, now at the California Institute of Technology, complains: "It took years for Bellcore to build one of the best corporate research labs, but only a few months for it to be smashed."

Science policy is coming under intense scrutiny. Specialists ask such sweeping questions as: Is basic research as important when economic and environmental concerns displace the military needs? Rep. George E. Brown (D–Calif.), chairman of the House Committee on Science, Space, and Technology, answers this question with an emphatic "yes." Brown, who is science's most effective ally on Capitol Hill, points to unanticipated benefits from scientific discovery. "Invention is the mother of necessity," he says.

Other friends of science like to quote Napoleon: "What, sir, you mean to tell me that by lighting a bonfire under the deck of a ship you can make it sail against the wind and the current? I pray you excuse me. I have no time for such nonsense." He then showed Robert Fulton out of his office.

An increasing number of fast-growing programs for industry seem the most likely to offer federal R&D opportunities. These include CRADAs, the Advanced Technology Program (ATP), and the Technology Reinvestment Program (TRP), which seeks dual-use advances that promise both military and commercial benefits. Although few winners have been entirely optical or photonic, these technologies are involved in about one-third of all ATP awards, and the proportion is believed to be similar in CRADAs and TRP contracts.

One example: Environmental research is the goal of a TRP in which the Air Force—with civilian partners including Unisys, other companies, and academics—is developing an optical screening tool to rapidly characterize surface sites. The technique, based on laser fluorescence, would assess distribution of specific contaminants.

More than 70% of DoD research has dual-use applications, according to the Pentagon, and a majority of TRP winners involve at least one small business. The department already invests more than $2 billion a year in dual-use technology, not counting funding of basic science. It spends $100 million a year specifically on optoelectronics R&D, in addition to supporting education in optoelectronics.

Another possible change is in the scope of the peer-review process. The process works well *within* disciplines. But as competition for funds intensifies, there's increasing support for peer review *between* disciplines. One criterion in multi-disciplinary review would be a proposal's prospects for advancing the economy toward national goals.

The technology professional should become familiar with trends and priorities among these funding agencies.

❋ Information in every form is becoming the leading growth industry.

Whether it becomes a highway or a railroad, a freeway or a tollway, information transport is becoming less expensive and more widely accessible. Voice, data, and pictures will travel over a mosaic of media, but fiber optics seems likely to be the backbone. Fiber optics specialists will have to understand the technology's relation to competing, as well as to

complementary, media. To stay ahead, fiber specialists must also have a clear perception of where the business is moving.

Government's role in the information infrastructure will be not as the builder, but as the traffic cop. In rules of this road, repeal will be as important as adoption, especially for the next few years, as restrictive regulations are stripped away. Removal of regulations can be especially beneficial to fiber optics, a technology whose deployment is held back by, among other things, an archaic system of depletion allowances. This system discourages replacement of one technology, *i.e.*, metal wire, as soon as a better one, *i.e.*, fiber, is ready.

Regulation is clearly on the way out. Open competition is emerging throughout the communications system, even in the subscriber loop, the last stretch of service to the home. The only questions are how fast it will come, and what architectural forms it will take.

It's tempting to applaud this trend unreservedly, but deregulation brings its own problems. Remember other recent deregulations: Airlines, savings and loan organizations, the telephone industry.

Remnants of regulation will remain. One remnant will be necessary to monitor expansion of telephone companies' dual role: as competitors with service providers, and as monopolistic providers of a core infrastructure for their own use as well as their competitors'.

Another regulatory remnant will be universal access. A division of the public into telecommunication "haves" and "have nots" is politically unacceptable. The administration is committed to a broad concept of universal service, offering to all Americans "easy, affordable access to advanced communications and information services, regardless of income, disability, or location," according to the Executive Branch's task force on information infrastructure. Congress appears to agree.

That implies, for example, that people who live in the desert, far from the nearest telephone exchange, should have a multimedia line, even at a prevailing cost as high as $30,000. But who will pay for that extension of service? Should the phone company? The government? Taxpayers won't lightly accept information subsidies at a time when polls show that many are reluctant to pay for universal healthcare.

This raises questions about who will be in charge: Conduit (*i.e.*, phone or cable TV) companies or content (*i.e.*, program) companies? And let's not ignore the influence of program providers. Domestic telecommunications is "only" a $224 billion industry; the media or program economy is half-again as large, at $372 billion.

The answer to the question of broadcast TV versus cable TV is clear. The day of over-the-air, advertising-supported TV is coming to an end, even though the present infrastructure is predominantly broadcasting. Because it serves only a few channels, the value of time on broadcast TV is too high to justify airing anything but programs and commercials of very broad interest. The emerging information infrastructure will be the opposite of this. Just as affinity groups such as trout fishermen have their own bulletin-board "clubs" on the Internet, they could have their own video programs on cable TV.

The technology professional will have access to more information in the future, and to more opportunities to design systems. Selection of the best opportunities will require keeping track of trends in services and in their delivery mechanisms.

❁ International competition will continue to intensify as capabilities become more widely distributed among nations.

Multinational enterprises are increasingly global in their origins, sourcing, communications, production, and outlook. Foreign affiliates control as much as one-quarter of all economic activity in host countries, according to the congressional Office of Technology Assessment (OTA). The congressional research arm adds that goods and services exchanged between parent companies and their own foreign affiliates account for more than 40% of U.S. imports and 35% of U.S. exports.

Many companies in optics and photonics already derive about half their revenues abroad. That's not very surprising for a highly specialized manufacturing concern. But when a broad service company such as AT&T says it expects to generate 50% of its revenues overseas by 2000, that tells something about globalization.

As Europe moves toward integrating into a single continental market, American companies will certainly expand their beachheads abroad while foreign players continue to seek customers in North America.

Export prospects in Asia are just as promising. Trade and other transnational challenges have prompted the creation of national strategic alliances, among multinational companies and also among nations. Because money and knowledge know no nationality, trade requirements are inspiring new types of integration that largely ignore national boundaries. Such alliances cause profound changes in the tactics required for U.S. industry to strengthen its long-term competitiveness.

To be most valuable to an employer, the technology professional should be familiar with these expanding international opportunities and challenges.

❁ Universities will be increasingly attractive sources of technology.

The U.S. spends more on R&D than any other country; in fact, its research expenditures equal the combined research of Japan, Germany, Britain, and France, according to John T. Preston, director of technology development at the Massachusetts Institute of Technology. Like their industrial counterparts, university laboratories are finding mechanisms to commercialize their technology beyond publishing research results and transferring trained people. They have become excellent sources of technology itself.

From 1985 through 1992, MIT's licensing income grew to $16.2 million from $1.8 million, Preston reports. The figures include equity that the institute frequently takes instead of royalties. This practice encourages companies to accept the up-front risk necessary to commercialize MIT-developed technology. In that same period, Stanford University's licensing income climbed to $25.5 million from $3.9 million, and the University of California's soared to $31.4 million from $5.4 million.

About half of MIT's licensing agreements are with small companies with fewer than 100 employees; 10% are with new companies, created around the technology.

❁ Many jobs lost in the past few years won't come back—at least not in their earlier form.

In contrast to previous recessions, downsizing in the most recent one appears to be a permanent condition, not a temporary aberration. The Bureau of Labor Statistics calculates that the value of manufactured goods will rise 41% in the next 15 years, but the number of production workers will decline by 3%.

Conventional wisdom holds that job displacement in manufacturing industries will be compensated in service industries. But service industries, which turned in a $52 billion trade surplus last year, may not long remain the engine of job growth. White-collar unemployment reached parity with blue-collar unemployment last year for the first time, according to Morgan Stanley Bank. The disturbing prospect is that creation of new industries may not provide jobs fast enough to replace those lost as a result of increasing productivity.

Another permanent new condition is reorganization of companies and industries. Many of the technology jobs created in the coming decade will be different from those lost in the past decade. Unplanned interruptions in employment will always be painful, of course. But the technologist retains the means of production—knowledge—that is increasingly necessary in the modern economy. Those who can also adapt to innovation and to the tides of change will have the best chances of finding attractive, rewarding roles to play.

While the balance between the disappearance of "old" jobs and the emergence of new ones may be precarious in the short term, the new work in technology pays better. That's because the benefits of the productivity boom are beginning to increase technologists' value to their employers. After several years of stagnation, salaries are rising

again. Skilled workers in high-tech companies earn significantly more than their counterparts in less innovative organizations, according to economist Steven G. Allen at North Carolina State University.

Corporate superstars of the future will have different qualities from those of the past.

To cope with rapid change in technology and in markets, companies are decentralizing. Technology professionals must be knowledgeable about opportunities for innovation not only in technology, but also in markets, in finance, and in society.

This means, for one thing, that technologists must accept responsibilities outside their realm of expertise. For another, technologists of the future are very likely to be women, as this group claims its deserved share of professional jobs.

Another form of discrimination is also on the way out. The modern corporation suffers when technology professionals think of their business colleagues as "bean counters" and the front-office considers technologists as "nerds."

This semester, Carnegie Mellon University was to begin a master's program involving four of its colleges: engineering, business, computer science, and public policy. This is just one—but perhaps the most sweeping—joint program that combines engineering and business education. In each case the goal is to help overcome the divisions between specialties, which impede American manufacturers' competitiveness.

The ever-closer relationships among departmental functions place a premium on technologists who are willing to work across organizational boundaries and have a good appreciation for trends in corporate functions other than their own. Those who know how to tap external sources for advice, funds, and business will have even greater value to an employer or business partner.

Howard Rausch *is president of Capitol Gains, a business intelligence and consulting service based in Washington, D.C. with clients in both industry and government. He is national correspondent for* Photonics Spectra *and former director of technical activities for OSA.*

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