Electronics: Snapshot of a developing revolution

In their March 18 issue, the editors of SCIENCE have presented what they call a "snapshot" of the electronics revolution. "As the vigor of the industrial revolution fades," says their editorial, "the electronics revolution will provide impetus for the reshaping of society in new directions." The special issue contains 27 articles tracing the development of electronics, assessing its impact and pointing out probable directions for future progress.

Perhaps the crowning achievement of the revolution is the electronic computer, which has just celebrated its 25th anniversary. Ruth M. Davis, the director of the Institute for Computer Sciences and Technology, National Bureau of Standards, predicts that by 1980 complete computers will be incorporated onto small "chips" of integrated circuitry. Everyone, she says, will be potential computer owners or potential customers of computer networks.

The secret of this development is large scale integration (LSI), the process of packing circuit elements ever more densely onto chips of semiconductor material. Robert N. Noyce, chairman of the Intel Corp., Santa Clara, Calif., traces the progress of LSI. The first integrated circuits, built in the late 1950s, had only one component per chip. This year some commercially available chips contain 32,000 components and Noyce predicts that within 15 years the number of elements will increase by a factor of 2,000. Thus, he says, for about the same cost as today's LSI circuits, one will be able to buy single chips capable of storing 1 million "bits" of information or containing 250 "logic" circuits—equivalent to some of today's large computers.

Application of electronics to health care may offer their "most promising opportunity to improve the quality of life in our society," write Robert L. White and James D. Meindl of Stanford University. Already electronics has been used to increase the resolution of X-ray pictures by a factor of 50 and provide other tools for patient examination, including imaging systems using sound and blood flowmeters that do not require insertion into blood vessels. The next series of developments, predict the authors, will likely come in the substitution of electronic devices for damaged nervous tissue. Already 100 electronic pacemakers for the heart are being implanted every day in the United States, and next should come an implantable inner ear for the deaf. Further along may come electronic nerve prostheses for the blind and the crippled, involving signals to the brain's visual cortex or to the muscle of a paralyzed arm.

Application of electronic media to education dates back to the early days of radio, yet so far most attempts have ended in frustation. Stanford professors J.F. Gibbons, W.R. Kincheloe and K.S. Down examine this problem and tell of a recent, successful experiment at their institution. The failure, they conclude, has been the result of devices created too inflexible to be adapted to daily classroom use, compounded by an apparent unwillingness of the educational establishment to "involve itself seriously" in the effort. At Stanford, the use of videotapes for instruction of small groups of students in the presence of a tutor has proven both flexible and successful. Students with lower initial qualifications who used this videotape-tutorial approach outperformed better qualified students who took regular classes. This approach is also cheaper.

Trevor O. Jones, director of the General Motors Proving Grounds, predicts that by 1985, 10 percent of the cost of an automobile will be its electronics. Electronic engine control will be used to improve gas mileage 10 to 20 percent. Electronic displays and diagnostic connections are already being introduced. On-board computers may someday automatically apply the brakes and inflate air bags in case of an imminent collision.

The prospects for electronic mail are reviewed by Robert J. Potter of Xerox Corp. An analysis of mail volume reveals that only about 22 percent is "correspondence," compared to 40 percent "transactions" (bills, payments, etc.), and 26 percent advertising. Handling the transactions electronically would be a normal development in the evolution of what appears to be the coming "cashless society." But other types of mail might also profit from new technology. Facsimile transmission now requires several minutes, but existing technology could reduce this to 12 seconds. If character encoding were used, a page of type could be transmitted in 2.5 seconds.

Several articles address the policy problems that will be encountered as the electronics revolution develops. One problem, which has already emerged in a series of lawsuits and proposed legislation, has to do with who will control computer networks. The telephone company wants to add information processing devices to its communication lines; the computer companies want to establish their own computer networks, even if it means bypassing telephone lines altogether. None of the authors seems very optimistic about an early peaceful resolution of this conflict.

Meanwhile, an external threat to both parties is appearing. John Walsh, a staff member of SCIENCE, reports that Japan is moving to challenge American dominance in the "high technology" area of electronics. Traditionally, the Japanese have relied on license agreements to obtain basic technology, which they then applied with great success. (In the last 18 months, Japanese color television sets have risen from 15 percent to 40 percent of the American market.) Now, however, a major investment in LSI research could place Japan in the forefront of developing technology as well.

Along with the electronics revolution will come an "information revolution," writes Stuart E. Madnick of MIT. This development will help solve several of the problems now pressing on society, including scarcity of resources, low productivity and inadequate decision-making capabilities. The basis of the revolution will be "information utilities," which will make computer networks available to individual subscribers by the mid-1980s. The installed value of computers, worldwide, will double in the next five years, he says, with emphasis on networks with central data bases.

Several new technologies still in the laboratory promise to provide engineers with raw materials for still another generation of spectacular devices. Two new technologies for signal processing—the charge-transfer device (CTD) and the surface acoustic-wave (SAW) device—are discussed by Robert W. Brodersen and Richard M. White of the University of California at Berkeley. By delaying, shaping and filtering signals at higher frequency than previously possible, these devices will have an impact in areas ranging from echo generation for electronic music to separating signals from a radar target from background noise.

Fundamental research in solid-state physics will probably result in even another generation of devices, further along. Some of the products of this research are discussed by J.A. Giordmaine of Bell Labs. The miniaturization of circuit elements will be given another boost by a fabrication technique called molecular beam epitaxy (MBE). Layers on chips are grown by bombarding them with molecular beams. Boundaries can be positioned with a precision of a few atomic layers. Circuits based on superconducting elements, rather than today's semiconductors, may increase computing speeds 10 to 100 times, with even greater savings in energy. Already the cost of storing information by electronics is challenging the cost of storing it in books and the time will soon come when electronic storage will probably be cheaper. □