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the cover

The United States' second domestic communications satellite, Westar II, rides atop a Delta launch vehicle as it rises from its pad at Cape Canaveral (see p. 36 and p. 83).

spectrum

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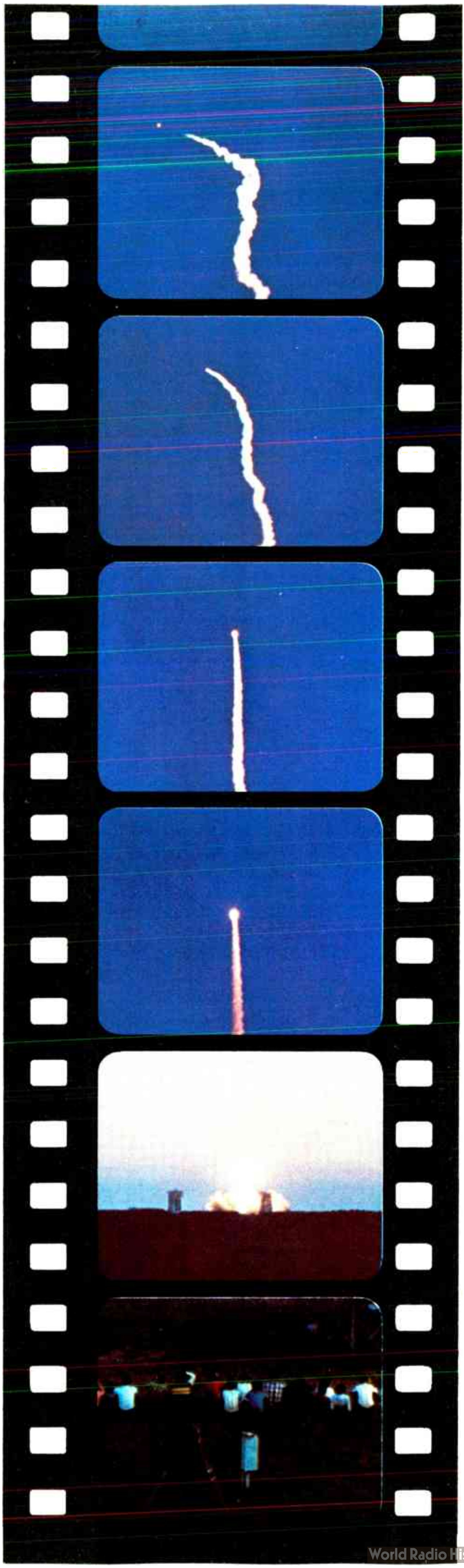


Photographic sequence of Westar II by the author, October 10, 1974, at Cape Canaveral.

Special report

Technology '75

Looking ahead with the experts to predict hardware/software trends in the near-term future. Solid-state and computer technologies continue to dominate.

Scarcely a year goes by without worries that "overriding events" will hinder worthy new applications of technology. The year 1974 was no exception, nor, evidently, will be 1975, with rising concerns over the world economy, inflation, unemployment, fuel shortages, etc. Nevertheless, developments proceed, if not always at the pace their advocates desire. This special issue is a distillation of evaluations by hundreds of industry experts, including members of IEEE Groups and Societies, covering ten technical areas, and including a section on technology and society. By and large the reports avoid blue-sky projections, concentrating instead on near-future hardware and software.

If any single item stands above others in this review of technology, it is the microprocessor. It provides a perfect example of the marriage of solid-state and computer technologies in a way that substantiates their key role in the electrical/electronics arts.

The microprocessor is finding its way into point-

Donald Christiansen Editor

spectral lines

Hawthorne revisited

Dealing with people is a lot different from dealing with things. We know this, of course, but often forget it in our daily battles with the project, the equipment, our colleagues, and the boss, tending to see them all as equally intractable. Accustomed to unprecedented progress in the application of technology, we are often dismayed at the seemingly glacial pace of progress in the organizations to which we belong. This was underscored recently when industrial managers, behavioral scientists, and a smattering of engineers met to probe "Man and Work in Society."

At the invitation of Western Electric, the participants converged, appropriately, on the company's Hawthorne (Ill.) Works, where, 50 years ago, landmark studies of factors relating to productivity and worker satisfaction were begun. There, in 1924, the now-famous "illumination experiments" were undertaken in cooperation with the National Academy of Sciences. Enlightened industrial managers around the world are conversant with the Hawthorne experiments, and so are many engineers, particularly those in the electrical/electronics industries.

Nevertheless, the writer, prior to joining the Hawthorne conferees, thought it appropriate to test the recollection of colleagues concerning the conduct and conclusions of the experiments. Some recalled that the studies measured the effects of changes in lighting on the output of assembly workers (partly right), while one thought they related to the effects of different color schemes in the work area (wrong). Regarding what the studies proved, several believed that no matter what changes were made in the work environment, output improved (partly, but only sometimes, correct). Many believed the studies began and ended with the lighting experiments. But in fact when the National Academy of Sciences ended its participation in 1927, Harvard stepped in to cooperate in studies of other test groups in (1) relay assembly, (2) mica splitting, and (3) wiring, soldering, and testing central office equipment. These studies continued until 1932. The principal investigators, William J. Dickson of Western Electric and Fritz J. Roethlisberger of Harvard, concluded, among other things, that industrial organizations are social systems having a structure quite apart from that which any organizational chart might suggest.

It was with the spirit of high anticipation that I joined the Hawthorne convocation, fully hoping to come away with a well-defined "Hawthorne model," and to have been shown by the variety of experts (both scientists and practitioners) present how new and novel contemporary industrial organizations fit the Hawthorne model. But such was not to be. Instead, 50 years later, there is considerable disagreement concerning what the studies proved. The theorists themselves draw a variety of conclusions—not all of them in harmony. One panelist, asked to define the "Hawthorne Effect," replied, "I'm sorry you asked!"

Harvard's Prof. Jay Lorsch seemed to put the finger on the problem when he noted, in summing up the conference, that a multiplicity of models (perhaps spawned by Hawthorne?) exist in organizational behavior theory today. This, he believes, is consistent with the state of social science in general, but notes that even physical scientists are hard pressed to develop and enhance models that advance the state of knowledge. And in social sciences, searching for widely applicable models is complicated by the dynamics of social phenomena, the difficulty in comparing data collected at different sites or at different points in time, and, far from least, the social values to which each individual behavioral scientist subscribes.

In what Prof. Lorsch described as "a modest proposal," he suggested that progress in the study of organizational behavior would be aided if behavioral scientists were to become fully aware of (1) the biases of their predecessors and colleagues and (2) their own biases, which, if expressed, would, in turn, aid their coworkers and successors. Specifically, Prof. Lorsch believes that researchers should be more explicit in their writings about "where they come from" (their intellectual heritage and values, as well as their assumptions about the nature of people) and about their views of motivation (how and to what extent individuals can alter their own behavior). The difficulty of the task goes without saying. (Perhaps Prof. Lorsch's proposal could be of even greater significance to engineers, who, immersed daily in problems of a "hard" nature, are likely to get uptight when colleagues or others behave "illogically"—the technologist's code word for behavior not in accordance with his own value biases!)

Reflecting upon Hawthorne and the many schools of thinking it helped create, one observes a gap between practitioners—including engineers and managers—who live with time-bounded projects and today's specific problems, and behavioral scientists, who understandably, must think in terms of long-term experiments, statistical validity, and controls. This, along with Prof. Lorsch's observations, may well suggest that the *next* 50 years will be devoted to finding out what Hawthorne *really* meant.

Donald Christiansen, Editor

of-sale terminals, automobile control uses, and even into consumer games. Its use in instruments to compute, convert, compensate, and calibrate has helped propel more manufacturers into the marketplace and boosted 1974 sales to some six million dollars. And this seems to be just the beginning, with more powerful microprocessor-based instruments inevitable.

The drive to speed up integrated circuits has prompted the development of integrated injection logic (I^2L), having bipolar speeds and densities of MOS devices. Liquid crystal and light-emitting-diode (LED) displays have been improved in efficiency and reduced in cost, while charge-coupled devices are being considered for use as serial access memories and image sensors.

Communication cable congestion, as in or near metropolitan areas, may be aided by the use of fiber optics, a technique that has yet to be tested for commercial viability. The U.S. Navy is using fiber optics aboard ship, and more short-run uses are anticipated.

Better quality digital transmission of voice signals over commercial telephone networks may result from using a "predictive encoding" technique. Although a hardwired format is presently advantageous, microprocessors may again come to the rescue with logic residing in software stored in a read-only memory.

Belatedly (as a result of rocket trouble), Western Union got its two Westar communications satellites into orbit during 1974, to provide the first U.S. domestic communications satellite network. In full operation, the Westars, in association with five ground stations, will cover all 50 U.S. states and Puerto Rico. Both Westars have 12 transponders, each with a capacity of 1200 voice channels. NASA also launched the powerful ATS-6, which is equipped with some 20 experiments related to health and educational TV programs, and which will be used for tracking and relaying tasks for the Apollo/Soyuz mission.

Maturation seems the keynote in the industrial controls field, particularly in direct and computerized numerical control. Manufacturers of such equipment are concentrating on operator controls that deemphasize concerns about whether or not the system is computer-based. On the other hand, programmable control techniques are expanding for such applications as conveyor control, plastics production equipment, weighing, and batch mixing.

Many new small programmable controllers use low-cost IC ROMs that can be easily erased for program modification, while larger, more sophisticated controllers can perform arithmetic functions, provide limited process control, and, sometimes, self-checking operations.

In the consumer electronics field, novel calculator developments continue, so that special purpose chips are produced for statistics programs, metric conversion, and surveying. And new digital, as well as quartz-crystal analog watches are under development. Hours and minutes can be displayed sequentially (to save space on petite women's watches) using a 2-digit display and a CMOS module by Hughes.

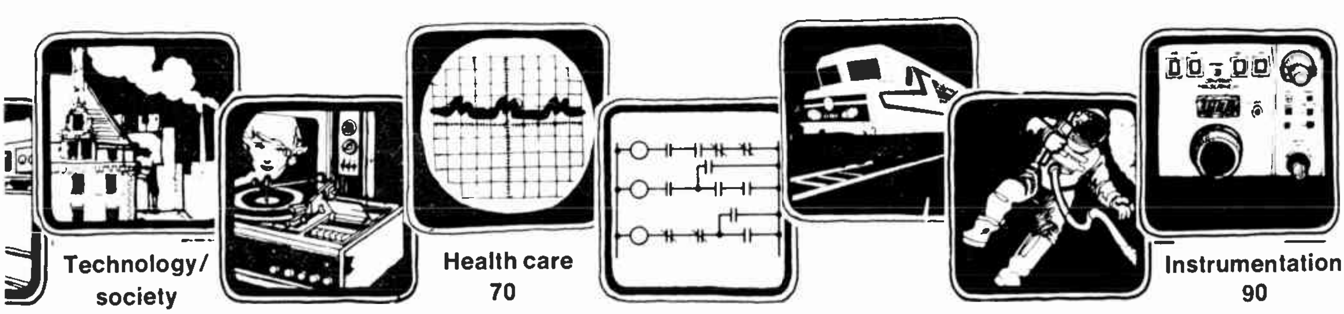
Miles-per-gallon in real time may stem from a General Motors' project based on a fuel-flow transducer, while another program is designed to signal defective steering gear or shock absorber conditions.

Transportation enthusiasts view recent developments in that field as signaling a quantum leap forward. Automatic operation of the complete BART route (120 kilometers) is now in effect; five-hour rail express service between London and Glasgow was inaugurated; the Washington (D.C.) Metro is scheduled for limited revenue service this year; and very-high-speed vehicles have completed thousands of kilometers in test runs on the French National Railroads.

In the economy-wracked power field, against sometimes heavy odds, technical developments are proceeding. Emphasis is on improved efficiencies and the substitution and/or conversion of types of fuel or heat energy. For example, a pilot plant to produce low-thermal-output gas from coal for coupling to a high-efficiency combined cycle unit is under test at a Westinghouse site, and, elsewhere, a fluid-bed gasification of oil demonstration unit is planned.

On still another energy front, the design of the Clinch River liquid-metal fast-breeder reactor is going ahead on schedule; and fusion programs such as the Tokomak study at Princeton University may benefit from an infusion of funding this year.

Noteworthy developments in biomedical engineering range from computer-assisted reading of electrocardiograms to sensory aids for the blind. The ability to transmit ECG data by telephone line accounts for the success of computer-read ECGs, and leads to projections that, by 1980, there may be 1500 such computer-based systems in the U.S. alone, compared to about 50 today. ◆



Computer systems: hardware/software

LSI is filling the gaps between microcomputers, minis, and large machines

Large-scale integrated circuits—in the form of microprocessors, semiconductor memories, and logic arrays—continued, during 1974, to pace the changes in the computer industry.

Single-chip processors

A growing variety of microprocessors were finding their way, as components, into instruments and systems for computation, control, and communication. Semiconductor memories and LSI processors were helping to broaden the scope of minicomputers, so that they now reach up into applications formerly exclusive to medium and large-scale computers. At the same time, they reach down to rival microprocessors for original equipment applications.

Bit-slice computers

Looking at the whole field of computer systems, users saw the formation of an almost continuous spectrum of capabilities, from the tiniest 4-bit, one-chip processor to one-board machines with minicomputer capabilities, to full-fledged minicomputer systems, to medium and large-sized conventional machines, and finally to giant supercomputers.

Software developments continue to lag far behind the pace set by LSI hardware, but there were developments of major importance in structured programming, languages, operating systems, and microcomputer programs.

ROMs PROMs

Developments in computer networks settled down from their formerly hectic pace to the somewhat calmer but essential process of implementing and standardizing established data communications techniques.

More and better microprocessors

Microprocessors poured forth in rapidly growing numbers during 1974 as an additional half-dozen semiconductor manufacturers leaped into the marketplace. The handful of microprocessors available at the beginning of the year had grown to about 20 different types—for development and production—by the end of 1974. Both manufacturers and users became increasingly aware that a central processing unit (CPU) on a chip is of little use without memory, supporting circuitry, and software. In market terms, the six million dollars worth of microprocessors sold in 1974 provided a base for 60 million dollars worth of associated logic and memory circuits. A ten-fold growth in these markets is expected during the next three to four years.

From the designer's viewpoint, every microprocessor is surrounded by dozens of other integrated circuit chips, and system design is a process of properly selecting and interconnecting these large-, medium-, and small-scale integrated elements.

In terms of the microprocessors themselves, current offerings are either of the single-chip CPU type, or bit-slice types, where several chips are used to make up a CPU. Single chip CPUs that made first deliveries for production during 1974 include the Intel 4040 and 8080, the Mostek 5065, Motorola's 6800, and Toshiba's TLCS-12. All were fabricated in either n-channel or p-channel MOS technology. In addition, test samples of two CMOS microprocessors, RCA's COSMAC and the Intersil 6100, became available in 1974.

The bit-slice approach, first used by National Semiconductor in their PMOS microprocessor, became available during 1974 in the form of bipolar chip test samples from Intel (3001) and Monolithic Memories (6701). These bipolar elements have microinstruction times ranging from 150 to 250 ns. They open new opportunities for microcomputers to penetrate major data processing and communications equipment markets. In the near future, we can expect to see large computer systems built from arrays of such elements.

Programmable memories and logic

Strides in semiconductor memory have been complementing the development of new microprocessors. From this viewpoint, a broad selection of various types of read-only memories is probably the key new memory development.

Mask-programmable MOS ROMs are available in 2k- to 12k-bit packages. Access speed for these MOS

With a keyboard full of APL language symbols, this microprocessor-based desk-top computer from ILC Data Device Corp. makes a powerful higher-level language available to individual engineer-users. The cassette tapes act as a virtual-memory extension of the semiconductor main memory.

Howard Falk Senior Associate Editor

ROMs is about 1 μs, and cost is about 0.2 to 0.5 cents per bit. Bipolar mask-programmable ROMs are available in about the same-sized packages as the MOS versions. Bipolar cycle times run from 40 to 300 ns, with costs per bit of approximately 0.3 cents.

Programmable ROMs (PROMs) are derived from bipolar technology. Bit patterns for these memories are written by a voltage or current overstress. Typically offered in 1k- or 2k-bit packages, PROMs have access times of 40 to 60 ns and cost approximately 1 cent per bit. Once an ordinary PROM has a bit-pattern "burned" into it, that pattern is permanent, but there are also reprogrammable types (REPROMs). These are typically offered in 1k- to 2k-bit packages, have access times of about 300 ns, and cost about 1 cent per bit.

For solving complex control problems, the Programmable Logic Array (PLA) is proving to be a flexible and economical tool. Devices now available allow 10 to 12 logic inputs that can be interconnected to 100 to 200 AND gates to drive 8 to 16 output functions through a set of wide OR gates. These arrays are extremely fast (100 to 300 ns) and are marketed at $20 to $40 per package. Compared to other types of ROM, they are considerably more flexible—although still hardwired—and they can be used to generate a broad variety of logic functions at very high speeds.

Microprocessor applications and interfaces

ROM elements are well suited for building dedicated-function machines—that is, machines that perform a preestablished repertoire of tasks.

For example, an impressive step forward toward special-language computers was taken this past year with the introduction of an APL-language desk-top computer built around a modified Intel 8008 microprocessor. Built by ILC Data Device Corp. (Hicksville, N.Y.) this computer—called the MCM/70—provides the user with a keyboard of APL symbols, a one-line plasma display, and cassette tape storage. The MCM/70 computer is specifically designed to use the higher level APL language and only that language, implemented by microprogrammed routines stored in ROM memory. But, the MCM/70 is only one item in a mushrooming variety of microprocessor applications.

Incorporated into instruments as components, microprocessors compensate and calibrate, act as the control center for instrument operation, make logical measurement decisions, compute, and convert measured quantities into convenient and meaningful displays. During 1974 many new, microprocessor-based instruments appeared on the marketplace, and these are just the forerunners in a trend that is expected to dominate the instrument field within the next two to three years.

Other applications have been spreading from intelligent CRT terminals into point-of-sale terminals and computer peripheral controllers; from on-board automobile control to control of automation and continuous processes; from pinball machines into home entertainment and games. And as these applications proliferate, designers have become increasingly aware of the importance of supporting circuitry—particularly of interfaces between the processors and peripheral devices.

Single-chip interfaces

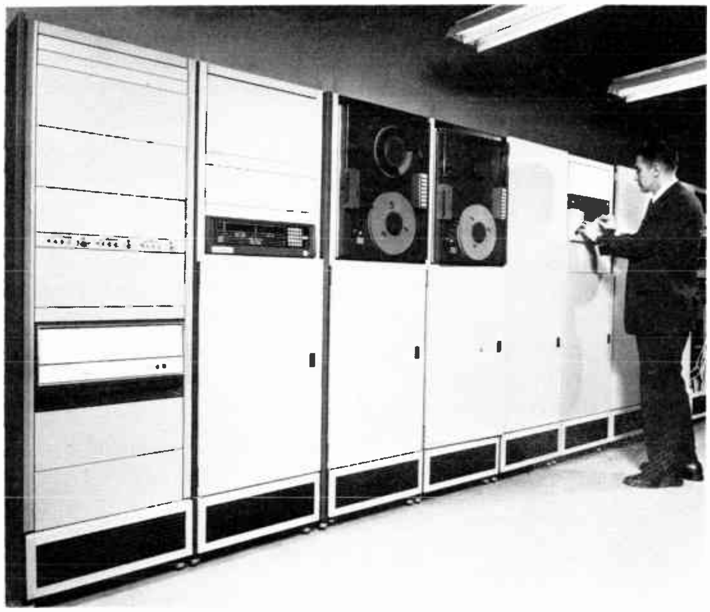
The outstanding recent development in this area has been the single-chip interface. Motorola's Peripheral Interface Adapter (PIA), for example, provides a flexible interface for a wide variety of peripherals on a single chip, complete with control and interrupt lines, and including program-selectable functions. Communication interfaces have been using universal asynchronous receiver-transmitter (UART) chips, for some time. This past year, more complete single-chip communication interfaces, like Motorola's ACIA and Rockwell International's TDI, were introduced.

Minicomputers broaden and spread

Mega mini-computer

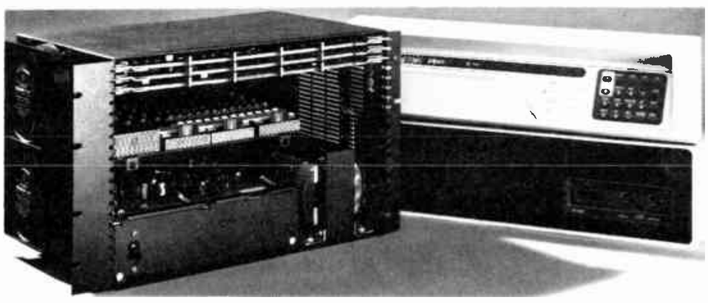
Minicomputers have generally had up to about 64k words of memory, but during 1974, that number was climbing, and the Mega Mini from Interdata (Oceanport, N.J.) allowed access to over a million words of memory. Such increased memory capabilities were only one phase of a broad upward movement of minicomputers into competition with more traditional medium-sized computers—machines with word-lengths of about 24 bits.

An important boost to minicomputer power has come from the 4k-word random access memories (RAMs) derived from MOS technology. Introduced this past year, the 4k-word Motorola 6605 exhibits a



Capable of extension to more than a million bytes of memory, this Interdata Mega Mini is representative of the upward movement of minicomputer systems.

Using large-scale integration techniques, Digital Equipment Corp. has been able to provide a PDP-8A machine selling for $1100.



4-K RAMs

read cycle of 370 ns and a write cycle of 490 ns; the Mostek 4096 has a read access of 350 ns with a cycle time of approximately 500 ns; while the TI 4030 has a read/write cycle of 470 ns with a read access of 300 ns. The expected low cost of these memories when high-volume yields are achieved makes semiconductor memory an attractive alternative to core memory. In the near future, more and more computer memories will be comprised of semiconductor components. The major problem with semiconductor RAMs is the fact that they are volatile. However, in a system environment, there is usually enough nonvolatile storage available so that volatility is not a problem, providing there is sufficient power backup to permit memory dumping when power is lost.

Floppy disks

In the area of low-cost, low-capacity random-access media, the floppy disk has essentially antiquated tape cartridges and cassettes. Now there are numerous vendors offering either single-disk drives or dual-disk drives with corresponding capacities ranging from two million to four million bits. The key implication of these developments is that magnetic recording continues to be an evolving and viable technology. It is particularly well suited to those applications where the cost per bit is an important consideration and the emphasis is on removable, nonvolatile, or large capacity storage. In the foreseeable future, it is reasonable to expect more advances, especially in the areas of rotating magnetic media. Disk memory is particularly attractive due to the allocation flexibility which this media affords and its inherent, low random access speed when compared to serial media such as tape.

Super-computers

High-density storage

For larger systems, there were important developments in memory subsystems and elements. IBM announced the 3340 removable disk with a packing density of 5500 bits per inch at a track density of 300 tracks per inch. These high-density files are available in modules of 35 or 70 megabytes. And several other manufacturers are planning to introduce similar products. In the area of magnetic tape systems, IBM is again the leader. The IBM 3420 stores 6250 characters per inch and has a capability of recording 9000 flux reversals per inch. In the field of gargantuan memories, IBM offered the 3850 Mass Storage System, a mechanized honeycomb of data cartridges each carrying up to 50 million bytes. A full-capacity system can hold the equivalent of 47 200 reels of tape.

Beyond the memory area, minicomputers with programmable instruction storage—like the HP 2100—now allow users to alter instructions and code sequences dynamically during actual execution of programs. There is a definite move by minicomputer manufacturers to an overall system orientation, with the computer mainframe, peripherals, and software working together to meet customer needs.

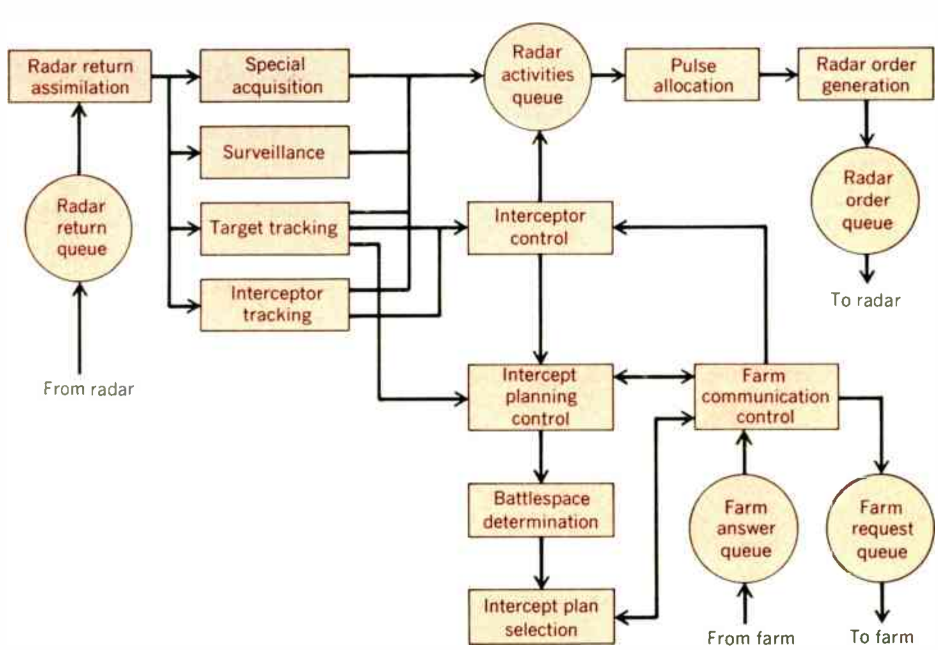
At the same time as they have been moving upward to compete with large computers, minicomputer manufacturers are moving downward to challenge the microcomputer for original equipment manufacturing applications. For example, Digital Equipment Corp. has come out with a large-scale integrated version of the PDP-8 machine at a price that makes it feasible for use as a component.

The supercomputer slump

The news about very large machines—the supercomputers—was not encouraging during 1974. Sales of existing supercomputers were disappointing and no new machines were announced. Apparently, users were tending to upgrade existing machines with more memory and peripherals rather than taking on new, larger machines.

Government agencies—the Departments of Defense and Transportation—were simulating and evaluating the use of large systems to help with ballistic missile defenses and traffic control. At the same time, some of the major design problems that have blocked expected successes with the huge machines were becoming clearer.

The first of these is a *control problem*. Large systems spend a lot of time and resources simply figuring out what they should be doing. Half, or more, of the total computation may go into such efforts. Then there is a *software problem*, since the programs for



These ballistic missile defense calculations are the kind of problems that some supercomputers—like PEPE (Parallel Element Processing Ensemble)—are designed to solve. In the diagram, the data sets or queues are shown by the circles, and the processing functions by the rectangles. Still under development, PEPE is funded by the U.S. Department of Defense, but does not seem to be feasible for commercial use.

the huge machines often do not use hardware capabilities efficiently. For example, sequential software is a misuse of parallel hardware resources. With supercomputers, extensive maintainance is required because there is a severe *reliability problem* due to the large number of devices used and the very large programs. For example, large-scale integrated circuits produce intermittent faults, due to temperature changes. Even though such faults disappear in a few microseconds, they can affect system operation unless the system is designed to cope with them. Finally, there is a *security problem*. A huge complex system may "blow up" at a critical moment due to unintentional or intentional programming bugs.

Distributed architectures

The trend in large-scale computing seems to be away from single-machine supercomputers and toward distributed processing. Here, each computing job is broken up into segments and dedicated, interconnected processors work on each segment. Some of the proposals for the NASA space shuttle project involve this kind of distributed computing. For computer architects, distributed systems are raising new problems of communication between machines, and bus architecture, in particular, seems in need of improvement. The architects are also looking forward to an era when they will configure new machines from off-the-shelf microprocessors, ROMs, RAMs, and input-output controller chips.

What is structured programming?

Structured programming is an effort to apply to large programs the same kind of discipline that is employed in large engineering design efforts. Traditional engineering practices, such as hierarchical organization of design solutions, and precise specifications on subsystems, have direct counterparts in structured programming.

The goal of structured programming is to produce programs that, despite large size, are so well organized that they can be easily understood, analyzed, and modified. The key to such organization is to have the program or specifications designed so they can be partitioned into processes or modules that have functional unity.

In 1969, Edsgar Dijkstra (Technical University of Eindhoven, Netherlands) observed that programs would be much easier to analyze if only three basic types of program control constructs were used. These were: simple linear sequences of program instructions; conditional sets of instructions such as **If** *P* **then** *A* **else** *B;* and simple loop constructs such as **while** *P* **do** *A*. All three of these constructs can be nested (contained within each other) as often as is needed, and programs that are limited to these three types can be cleanly partitioned into functional modules. Specifically excluded from such programs is the unrestricted *go to* type of construction, because it tends to create links between program segments that prevent clean partitioning.

Dijkstra's limitation on program control constructs is one central idea in structured programming, but it is only part of a still-developing and sometimes controversial overall effort to cope with large programs. For example Niklaus Wirth, (Technical Univeristy of Zurich, Switzerland) F. W. Zurcher (IBM, Yorktown Heights, N.Y.), Bryan Randell (University of Newcastle, Newcastle Upon-Tyne, England), and others have described methods for incremental, top-down development of programs. These methods characterize a system's function using multiple levels of abstract description. C. Anthony R. Hoare (Queens University, Belfast, No. Ireland), David Parnas (Technical University of Darmstadt), and others have described ways to specify the functions of a program module so as to permit formal analysis of a system independently of the program code. Harlen Mills, in his "Chief Programmer Team" concept, has integrated a number of these ideas, together with a scheme of tight managerial control of group effort, into a practical and effective software engineering methodology.

Structured programming practice is spreading rapidly, and numerous tools have been developed for appropriately adapting present languages to it. Many tough problems remain, such as the proper organization of data, the building of well-ordered and efficient program hierarchies, the design of powerful specification languages, and the proof of large, hierarchical systems.

Jack Goldberg
Stanford Research Institute
Menlo Park, Calif.

New tools to cut software costs

In 1974, software for computers of all sizes continued to be an area of growing concern, as the key importance of software costs and deficiencies to computer system operation became increasingly evident. Software advances have been strongly outpaced by hardware cost reductions and performance improvements. Huge and ever-growing systems and data bases, with increasing security problems, are also placing severe new demands on software. As a result, there is increased attention paid to improving engineering practices for software.

Structured programming

For example, practical uses of structured programming have been blossoming. To cut their COBOL programming costs, the U.S. Air Force and U.S. Army began a joint effort to use the IBM Chief Programmer Team method, developed by Harlen Mills (IBM, Gaithersburg, Md.). And favorable experiences with Mills' structured programming techniques were reported by many governmental and industrial software groups. In the face of growing enthusiasm, the senior philosopher of structured programming, Edsgar W. Dijkstra, (Technical University of Eindhoven, Netherlands) warned that progress is being oversold, and that "simple souls have been made to believe that we have all of the answers to the problems of the programming profession."

In one of the more significant efforts to establish sound engineering practices for software, Grace Hopper, Captain in the U.S. Navy, and her associates recently set up a working service for validation of COBOL compilers. Together with the National Bureau of Standards, their next target will be Fortran compilers. This work can have a great impact on the correctness of running programs, and on the transportability of programs from one machine to another.

Computational aids

There has been a steady growth in available computational aids and procedures for programmers. These include precompilers, program generators, testing and documentation aids, and performance aids. However, use of more powerful programming support tools is still limited to the research community. For example, Do-What-I-Mean (DWIM)—developed by Warren Teitelman at Xerox, Palo Alto, Calif., and now available only to programmers using the INTERLISP language—automatically corrects many programming spelling errors, and accommodates minor variations in programming syntax.

Recent software achievements

Programming languages

The U.S. Navy and the Air Force have recently described new versions of their general-purpose programming languages (CS-4-Navy and J73-Air Force), designed to provide stable long-term use and to allow the development of powerful supporting aids. A significant development in the art of software system design is the BLISS language developed by William Wulf, at Carnegie-Mellon University. Offered this year by Digital Equipment Corp. (Maynard, Mass.) as a supported product, BLISS is oriented both toward good program structuring and efficient machine utilization. Several languages having great power of expression—for example, QA4, QLISP, PLANNER, and CONNIVER are now in use within the computer research community, and may have a strong influence on the design of future programming languages.

Operating systems

An important recent trend in software is the development of major systems for particular computers by organizations other than the manufacturers. A second important trend is a great concern for system security. Both of these are exemplified by the MULTICS operating system, developed at M.I.T. (based on work done previously by General Electric and Bell Labs), and recently established as a standard Honeywell product. The first trend is further exemplified by KRONOS, for the CDD 6000 series, and TENEX, for the DEC PDP-10.

A growing area for operating system technology is fault tolerance. The goal of high-availability systems, as exemplified by the University of California's PRIME and the Bell System Electronic Switching System, has placed new demands on operating systems. Software for ultrareliable systems remains a research and development effort.

Hardware experts who understand data base problems insist that the major changes in the next computer generation will result from properly addressing the problems of data base processing. Currently, there is much ferment over how data should be organized. Both local and distributed data bases are growing rapidly in size and number. Data-base software developers must solve problems of logical complexity and huge scale and have recently had to add the problems of networking, security, and privacy.

Libraries of programs have been assembled since the earliest days of computing. At one end of the scale of scientific computing, a library exists for a programmable hand-held calculator (the HP-65). At the other end of the scale, the NSF-AEC-sponsored National Activity to Test Software (NATS) project is a very productive, multigroup effort to produce certified, high-quality, robust, and transportable scientific software.

Practical applications of artificial intelligence (AI) research are starting to appear. M.I.T.'s MATHLAB has been used by astronomers and economists to solve problems by direct manipulation of mathematical formulas. Stanford's DENDRAL is being used by chemists to solve problems of molecular structure. These are representative of a class known as knowledge-based systems, which employ, in explicit form, representations of human expert knowledge of some subject domain. There is much laboratory work on a variety of applications, including management systems, speech understanding, automatic programming, and industrial robots. This research makes use of some extremely powerful languages, including QLISP, INTERLISP, and PLANNER.

Microprocessor software

During 1974, microprocessor manufacturers increased the software support for their chips. Cross assemblers were available for at least a dozen different microprocessors, and several machines offered self-assemblers—for stand-alone operation. A wide variety of editing, loading, and debugging programs, as well as a few machine simulation programs were offered. Efficient subroutines for microcomputer arithmetic and elementary functions also began to appear. User's program libraries were launched by Intel and National Semiconductor, and users began trying out Intel's higher-level microcomputer language, PL/M.

Networks: regulation and standardization

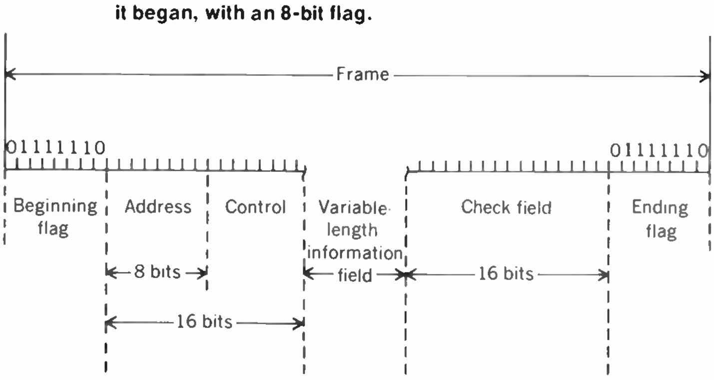
After several years of very rapid new developments, the bloom seemed to be off the rose of computer networking. Concern shifted from technological developments to problems such as regulation and standards.

Packet-switched services

Federal Communications Commission's approval of "value-added" network service offerings began in November 1973 with the approval of the application of Packet Communications, Inc. (P.C.I.) in Waltham, Mass., to establish and operate a packet-switched data communications network. Early in 1974, two additional applications were approved, one by Graphnet (Englewood, N.J.) to establish and operate a facsimile network and one by Telenet, Inc. (Washington, D.C.) to establish a packet-switching network similar to that of P.C.I. These networks are expected to be operational early in 1975.

During 1974, major changes in telephone company tariffs reflected increasing competition from specialized common carriers. After repeated failures to block the specialized common carriers on the regulatory front, it appears that the phone company is prepared to do battle on the price front. Tariff changes for WATS service were in response to the increased use of that service for message-switching applications. The changes somewhat lowered the cost of long-distance calls, but raised the costs for shorter distances,

All active communications regulated by IBM's SDLC procedures have this frame format. Information is preceded by an 8-bit flag, followed by address and control bits. A 16-bit check field follows the information, and the frame ends, as it began, with an 8-bit flag.



while putting a limit on the number of hours of usage provided without overtime charges. And users with large numbers of short-holding-time calls, such as those that occur in polling-type data communication systems, were penalized by these tariff changes.

Even more significant was the introduction of a new "HiLo" pricing scheme, which provides lower-cost service to users in high-density areas—where the specialized common carriers are in competition with the telephone companies—while service costs are increased in low-density areas, which the specialized carriers are avoiding. Such pricing may more closely reflect the phone company's actual cost of providing service, but the major motivation appears to be to compete better with such specialized carriers as MCI (New York City) and DATRAN (Vienna, Va.). These new tariffs are for private-line service, and the same pricing philosophy has apparently been followed in the proposed tariffs for the new phone company digital data service (DDS) which is under construction. The specialized carriers can be expected to retaliate against the tariff changes, so this is an area in which continuing developments can be expected in the future. Several commercial network-design packages have already been modified to reflect the new tariffs, and many users are reconfiguring their networks to realize cost savings, or at least minimize any additional communications expense.

In the standards area, IBM introduced its Synchronous Data Link Control (SDLC), a new bit-oriented protocol that is at variance with protocols being developed by the American National Standards Institute (ANSI) and the International Standards Organization. SDLC was introduced for a variety of special terminal-based applications, such as those in banking and retailing, and was incorporated in the new "Advanced Function for Communications" which IBM announced in September. This system tied the new terminal family and virtual storage operations into a unified teleprocessing structure using SDLC. IBM has proposed SDLC to ANSI as in industry standard, and, while the issues are still being considered, it appears that with IBM's weight behind it, the new proposal will prevail.

SDLC

Internationally, there was increased attention paid to standards issues related to packet switching. Governmental post and telegraph systems, including those in Great Britain, France, Spain, and Japan, are planning to offer packet-switched services. The International Telegraph and Telephone Consultative Committee (CCITT) is currently studying several proposed international service offerings, and an International Federation of Information Processing Societies group is organizing interconnection experiments between several computer networks, including the American ARPANET, the British NPL network, and the French Cyclades network.

Communication tariffs

There is an ever-increasing variety of service offerings, including packet switching, satellite operations (in which IBM is the newest competitor), specialized common carriers, and digital transmission services, and the coming year can be expected to serve as a shakeout period for all of these new services. ◆

Information for this article came from several sources. Major contributors were: Jack E. Shemer (Xerox Corp., El Segundo, Calif.), Jack Goldberg (Stanford Research Institute), C. V. Ramamoorthy (Univ. of Calif., Berkeley), Thomas N. Pyke, Jr., and Ira Cotton (National Bureau of Standards, Washington, D.C.), Don Nelson (Bell Telephone Laboratories, Naperville, Ill.), and Eric Aupperle (Merit Computer Network, Ann Arbor, Mich.).

Communications and microwave

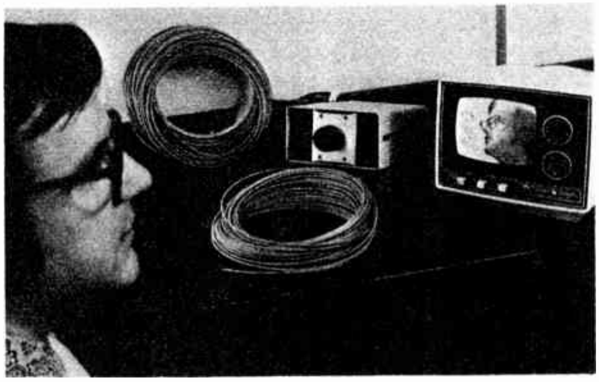
Fiber optics, solid state, and digital techniques boost transmission efficiency

Inspired by growing demand while contained by the limits of bandwidth, physical plant, and esthetics, the telecommunications industry made important progress in 1974 toward providing increased traffic density and improved message-handling capability. Significant advances were made in the promising art of fiber optic communications; improved electronic systems became available for branch exchanges and switching centers; and new hardware and software for digital encoding promise lower-cost, lower-data-rate digital transmission of voice signals.

Don Mennie Associate Editor

Newsworthy developments in the microwave field were relatively scarce in recent months, but improvements in device technology did allow wider use of Gunn diodes as low-noise power amplifiers in repeaters, and digital microwave radios with improved transmission efficiency became available.

Communications continued to look upward, as the ATS-6 satellite was put to work to help fine-tune the propagation characteristics of satellite links. And there were new antenna designs both on the ground



[1] Both audio and video signals from a portable television camera have been successfully modulated, transmitted through as much as 335 meters of optical waveguide, demodulated, and produced on a conventional television set.

and in space to increase the performance of these links. A variety of new printed circuit antennas were developed too, along with an antenna to detect buried pipes.

Conquering congestion

Fiber optics

Where huge volumes of traffic are concerned—such as the proliferation of personal phone conversations circulating within any large city or even between nearby metropolitan areas—existing wire circuits are rapidly running short of capacity. Often, there simply isn't room for more huge bundles of telephone cable.

The answer is a communications system that can carry a considerably greater number of messages within the same or smaller space constraints. Fiber optics, one promising solution, takes light's inherently large capacity for handling information and couples it with special internally reflective fibers, capable of low-loss light transmission (Fig. 1). Important work continues at several laboratories around the world on both improved fibers and longer-lived lasers and light-emitting diodes (LEDs) that serve as transmitters and repeaters.

In Japan, fiber optic communications elements, looking very much like engineering prototypes for commercial systems, have appeared. And this seems to be the moment in time when engineers, rather than research physicists, are moving into the field of fiber optics, to begin practical system component designs. Such efforts should push the fiber optic art closer to its ultimate test of economic viability in competition with twisted-pair wires, coaxial cables, and microwave links.

During the past year, there has been substantial progress in reducing dispersion in optical fibers, thus allowing larger communication capacity in terms of channels per fiber. (Dispersion causes a short pulse of light to become wider and wider as it travels down the fiber. Short, closely spaced pulses may overlap, then the information they carry will be lost. Therefore, dispersion forces the use of longer pulses with wider separations over a given length of fiber, with consequent loss of information-carrying capacity.)

An equally important parameter, attenuation, measures the reduction of light intensity during transmission through a fiber and thus determines the number of repeaters needed to make a system workable. Fibers with losses of only 1 to 4 dB per km have been announced by several researchers in the U.S. and England. These are strands of silica, doped with germanium, boron, or phosphor. Improved fibers have also been fabricated directly from commonly available quartz covered with a plastic cladding.

During 1974, Corning began marketing fiber optic bundles, housed in a plastic jacket, in lengths up to 500 meters ($28.50 per meter quantity price), but the maximum loss of these cables is about 30 dB per km.

Optical communications also awaits further development of lasers and LEDs, the prime light source (transmitter) candidates. Aluminum gallium arsenide injection lasers and diodes have been fabricated, with operating lifetimes in the tens of thousands of hours. Indications are that these lifetimes will soon be extended to hundreds of thousands of hours, making these devices feasible candidates for continuous operation in long-distance communications links. Adequate detector devices have been available for some time.

Fiber optic cables that can be easily handled and spliced are not yet available, although work on such cables is going on in many laboratories in several countries. In the U.S., Corning and Bell Labs are experimenting with optical couplers for waveguide communications systems to minimize losses when signals branch off from main lines at terminals.

Traffic cop

ETS-4 switching system

Efficient, modern communications is rated not only by capacity, but also by its ability to route calls quickly and dependably to their correct destinations. The largest capacity, stored program controlled switching system available thus far from a U.S. manufacturer reached full-scale commercial production in 1974. This is the multiprocessor-controlled ETS-4, a four-wire tandem switching machine, designed and produced by the North Electric Company of Galion, Ohio (Fig. 2).

In its maximum configuration of 72 000 total terminations, the ETS-4 can handle 780 000 hundred-call-seconds (ccs) of traffic and process 390 000 busy-hour attempts with less than 0.2-percent lost calls (number of calls times duration in seconds per hour divided by 100 gives traffic density in ccs). This traffic-handling capacity is achieved with a centralized, common control complex containing seven pairs of redundant processors in a multiprocessor configuration.

In this multiprocessor complex, each redundant processor pair works independently of the other processors when checking its own performance and when executing tasks initiated by the telephone system (and peripheral) equipment connected to its own input/output channel. This system architecture can economically cover a wide range of system sizes, as the control complex of the ETS-4 system can be expanded in a modular fashion to the full seven-pair complement, starting with a single processor pair, in accordance with the required number of trunk terminations and traffic-handling capacity in any particular installation. Each processor pair operates independently during normal call processing, but in the case of control complex failure and recovery situations or during system loading and startup processes, all equipped processors of the multiprocessor configuration behave as a single integrated system.

The ETS-4's multiprocessor control and codebar switching network is based on the architecture of the AKE-13 system, originally developed in Sweden by the L M Ericsson Company. The first AKE-13 was put into commercial service in Rotterdam, Netherlands. Although the ETS-4 follows AKE-13 design concepts and dimensional structure, it has been functionally modified to conform to the North American network operation, with system performance and features substantially enhanced. This has been achieved by modifying the AKE-13 telephony software design and by gaining real-time processing power through the use of higher processing speed, made possible by MSI electronics and peripheral control processors.

The first production model ETS-4 was installed in a new building at Long Beach, Calif., during 1974. Final acceptance tests were completed by the year's end, and the system should be placed in commercial service soon. The Long Beach office is controlled by three processor pairs. It has been engineered to handle a busy-hour attempt rate of 170 000 calls at 29 000 trunk and service circuit terminations. Four more ETS-4 offices are now in various phases of installation and checkout, with others on order.

An even larger switching machine, the No. 4 Electronic Switching System (ESS), developed by Bell Laboratories, was installed by Western Electric during 1974 in a new Chicago toll switching office. Final testing of the system in this commercial environment is now underway with full service expected by January 1976.

[2] Toll test desk for the North Electric Co.'s ETS-4 large-capacity telephone switching system in full operation.

Besides having high terminal capacity (107 000 terminations), No. 4 ESS can handle peak traffic loads of 1 700 000 ccs, surpassing previous toll systems. In terms of actual conversations, the equipment can process up to 350 000 toll calls per hour, three times the volume of Western's older switching installations.

In another break with tradition, the No. 4 ESS switching network design allows many calls to be switched electronically over a single physical path. Central to this capability is the 1A Processor, a stored program complex that controls system operation. The processor achieves a circuit density 30 to 40 times that obtained with conventional electronic switching.

PABX with delta modulation

Field evaluation and public demonstration of a new all-electronic private automatic branch exchange (PABX) system were performed this past year by Digital Telephone Systems Inc., San Rafael, Calif. Designated the D1201, this PABX uses a time-division multiplex switching network controlled by a stored program constructed from preprogrammed read-only memories. The voice-frequency inputs are converted to delta-modulated digital format prior to switching and decoded to voice frequency prior to output to the station. System wiring external to the cabinet is standard, and conventional rotary or push-button dialing telephone sets are used.

An essential element of the D1201's operation is converting each analog signal to a digital format. This is accomplished with large-scale integration (LSI) fashioned from p-channel MOS which provides encoding and decoding in a 56-kb delta modulated format. In addition, this MOS circuit provides digital multiplexing and demultiplexing of associated signaling functions and includes switching of external networks. (Necessary active filters and conventional IC amplifiers are external to the MOS LSI.)

Among the D1201's unconventional features is a 32-port all-digital combining conference unit. This unit permits any number of conferences, each with any number of participants up to the maximum ca-

Justice wrings the Bell

In November, 1974, the U.S. Justice Department formally initiated an antitrust suit against the giant of giants: the American Telephone and Telegraph Co. Key provisions of the Justice Department's action would sever AT&T's manufacturing arm, Western Electric, making it an independent supplier of telephone equipment. Also targeted is AT&T's Long Lines Department which handles most U.S. interstate calls. It, too, might be split from the Bell System to compete with other carriers of long-distance communications. And the status of Bell Laboratories would be reconsidered.

Though resolution of these matters probably lies many years and many court battles into the future, independent equipment manufacturers and common carriers can now at least entertain the possibility that their tenure as a distant and collective "second fiddle" is not indefinite.

Perhaps typical of companies whose fortunes could be affected by the Bell System's bout with the Justice Department is Farinon Electric, San Carlos, Calif. They are heavily involved in the design and manufacture of long-haul common carrier systems such as sophisticated microwave repeaters. Corporate secretary Harry Lewenstein told *Spectrum* that no short-term impact was foreseen due to the expected delays before any decisions are final. But the possibility of Western Electric's arrival on the open market was described as a two-edged sword. True, more small suppliers would have a shot at supplying AT&T's huge annual needs, but Western could also prove a formidable competitor for business *outside* the Bell System.

ly spaced, large-aperture horns. Grating lobes are controlled and high gain and low sidelobes are preserved over many beamwidths of array scan by proper control of odd modes in the horns. Cluster-feeding of reflectors can produce a shaped beam to cover a particular geographic area, or multiple beams to cover specific areas or stations. Excellent unfurlable reflector designs have been developed at Lockheed Aerospace, Sunnyvale, Calif. Very-high-gain (>50-dB), multiple-beam arrays for satellite communications systems are in the planning stage at the National Aeronautical and Space Administration (NASA), Goddard, Md.

Unfurlable antennas

Very-low-sidelobe (>30-dB) and -backlobe (>50-dB) antennas have been developed using corrugated or lossy rims on the reflectors and corrugated walls on the horns. An extremely efficient, low-sidelobe, corrugated-horn antenna for a satellite-borne radiometry system has been developed for NASA Langley, Hampton, Va., by the Ohio State University ElectroScience Laboratory (Fig. 4).

In a more general sense, a new radiating element having characteristics very desirable in an array was introduced during this past year. (See *IEEE Transactions on Antennas and Propagation*, no. 4, pp. 521–526, July 1974.) This element, a slot with parasitic wires, has E- and H-plane radiation patterns that are essentially identical and very nearly proportional to the cosine of the angle from the pattern maximum. An element such as this permits wide-angle scanning of an array antenna with less change in the mutual interaction between elements as a function of scan angle.

Pipe detector

Empirical designs cut costs

Printed antennas with feeding circuits that are potentially capable of mass production using stripline or microstrip techniques have undergone rapid development recently, too. The principal emphasis has been placed upon combining practical methods of mechanical packaging and processing with empirical antenna design data.

Printed antennas

A new class of microstrip antenna elements and arrays has been developed at Ball Brothers Research Corp., Boulder, Colo., where the antenna element or elements and feed networks are photoetched at the same time, on the same side of the board. Hence, no board alignments—a common requirement for conventional stripline fed arrays—are necessary. The microstrip antenna's bandwidth is primarily related to the thickness and dielectric constant of the PC board with up to 10-percent bandwidth, at X-band, measured for antennas mounted on 0.63-cm teflon fiberglass board.

Metal radome

Another interesting class of printed circuit antennas has been developed at RCA, Moorestown, N.J., where the feed circuitry is printed on both sides of a PC board with a reflecting plate placed a quarter wave behind and a radome placed a quarter wave away in the direction of radiation. This antenna, which uses printed dipole elements, has an operating bandwidth of 500 MHz at X-band.

Westinghouse Electric, Baltimore, Md., has reported progress in developing a low-cost, conformal, phased-array design using multilayers to print phase shifters and circuits in a compact unit that will fit conformally on the surface of an aircraft. This S-band device has 28-dB gain and can scan ±70 degrees in azimuth and ±70 degrees in elevation. The antenna elements are printed circuit spirals.

A broadband stripline-fed array element, which can operate satisfactorily over 2 to 1 and even up to 5 to 1 bandwidth with multiple polarizations, has been developed at Raytheon Missile Systems Div., Bedford, Mass. The radiating element consists of a TEM-mode stripline feed with a flared notch etched out of the outer copper sheets. The notched element has been constructed in arrays with good scanning properties over a 2 to 1 bandwidth out to angles of 60 degrees.

One major gap in developing large quantities of antennas at relatively low cost for precision applications exists because very little comprehensive design theory or data is presently available for this class of antennas. This is particularly true of microstrip and stripline models where the feed circuits are in the near field of the radiating element, and thus couple to it.

Finding pipes, fighting the elements

Ohio State University has developed, for the Columbia Gas System Service Corporation, Columbus, Ohio, a new electromagnetic pipe detector with the ability to detect buried plastic or metal pipes. The system uses a periodic video pulse as a source which transmits a very broad spectrum into the ground. Unique antennas couple the source energy to the target. The reflected pulse is observed on a specially constructed sampling oscilloscope using an LED display.

This system has been used to observe 2.54-cm-diameter plastic pipe to a depth of 76 cm, and it has the sensitivity required to observe the same pipe at a depth of about 3 meters. A polarity reversal is noted when observing a metal pipe. Pipe direction is obtained in real time simply from the orientation of the antenna for maximum response. Reliable in the presence of clutter, the system has an azimuth resolution of 15 cm and a depth resolution of 15 cm as observed by nontechnical operators.

A novel metal radome has been designed, constructed, and tested, also at the Ohio State University. This particular radome consists of a 19° cone with a base diameter of about 30 wavelengths. It is approximately 90-percent metal. Energy is transmitted through a very carefully prepared slot array. No discernible pattern distortion in the main beam region is produced when the radome is placed over a pencil beam antenna. Even the lower sidelobes are not altered significantly by the metal radome structure.

Boresite measurements indicate that the metal radome contributes less to boresite error than do conventional dielectric radomes. It remains to develop mechanically hardened structures before such devices can be used to replace dielectric radomes. Potential advantages of the metal radome include reduction of static discharges, lightning damage, and rain erosion, plus increased mechanical strength. ◆

Information for this article came from many sources. Major contributors were: Aaron J. Goldberg, GTE Sylvania, Needham, Mass.; Ferdo Ivanek, Farinon Microwave, Mountain View, Calif.; Adam Lender, Chairman, IEEE Data Communication Systems Committee; C. Gunnar Svala, North Electric Co., Columbus, Ohio; and C. H. Walter, President, IEEE Antennas and Propagation Society.

Circuit/system building blocks

CCDs, I^2L, and magnetic bubble devices get smaller and more powerful

Progress continued unabated during 1974 in device and component technologies. The push to make ICs faster and denser accelerated the development of:

- I^2L (integrated injection logic) devices, with the density of MOS (metal oxide silicon) and the speed of bipolar ICs
- CMOS (complementary MOS) ICs with microwatts of power dissipation needed for consumer electronic products
- Microprocessors that promise to revolutionize the manner in which instruments, systems, and circuits are designed, and to improve information-processing techniques.

At the heart of IC advances are photolithographic and ion-implantation processing schemes. Research into newer schemes, such as electron-beam and ion-beam implantation pattern generation, holds great promise for the future.

Liquid-crystal and LED (light-emitting-diode) digital displays continued to improve in power dissipation, efficiency, and cost. LEDs are now available in a wide choice of colors that include red, green, and yellow. Blue LEDs are being investigated. The newer field-effect liquid crystal displays have improved appearance compared with the older dynamic scattering types.

One of the hottest device technologies is the CCD (charge-coupled device), which is being readied for use in serial-access memories, image sensors, and signal processing applications.

In linear ICs, converters, op amps, multipliers, dividers, multifunction modules, active *RC* filter networks, and hybrid ICs experienced advances.

Upgrading standard logic

While the vast majority of electronic circuits make use of TTL (transistor–transistor logic) ICs for logic functions, improvements in TTL speed and power-consumption characteristics have resulted in such newer families as low-power Schottky TTL for lower power dissipation and somewhat higher speeds.

SOS (silicon-on-sapphire) technology continues to advance. It combines MOS technology with the use of a sapphire substrate. A thin single-crystal silicon film is formed on the substrate by epitaxial growth. Such a technology offers several advantages that include high speeds, low power dissipation, high packing densities, and high reliability, and is potentially cost competitive with bulk-silicon CMOS. Gate delays of a few nanoseconds and microwatts of power dissipation per gate have been possible.

Roger Allan Associate Editor

Many companies are interested in this technology, are doing research in it, and have fabricated devices in the laboratory or on a custom basis. Inselek, for example, is offering a relatively complete line of SOS circuits commercially. The line includes logic gates, flip-flops, memories, counters, and microprocessors in the RCA 4000 CMOS series. RCA's solid-state division will introduce a high-speed 1k- by 1-bit SOS RAM early this year, as well as a series of self-aligned-gate SOS CMOS ICs.

An example of some of the nearly ideal characteristics of SOS can be seen from an experimental device RCA's Advanced Technology Laboratory built under an Air Force contract. The 8- by 8-bit multiplier array with 2112 devices on a 210- by 214-mil chip operates at 10-MHz data throughput rates with power-dissipation levels under 10 mW.

Even though SOS seems to be an almost ideal technology, some problems have yet to be solved. Chief among them are the relatively high-leakage currents at the silicon–sapphire interface, and the high costs of manufacturing, polishing, and cutting the sapphire material.

I^2L—a bipolar revival

The newest of IC technologies is that of I^2L, also known as MTL (merged-transistor logic), developed in late 1972 by IBM, Germany, and Philips, Holland, and now being pursued by a number of IC companies, worldwide. This new approach to bipolar LSI IC design offers high packing densities, low power-delay products, and low fabrication costs. Power-delay products of 0.35 picojoule and gate densities of 100 or more per mm^2 have been reported in I^2L ICs made with conventional bipolar processes.

I^2L

In an I^2L IC (Fig. 1), a pnp transistor acts as a current source and load for an npn inverting transistor operating with multiple-collector outputs. Since the processing required is that of conventional bipolar structures, the low-level I^2L gates may readily be mixed with standard bipolar structures, both digital and linear, on the same chip, to produce interfacing with external circuitry. IC designers are optimistic about the wide number of applications for this IC newcomer. Circuit functions include logic arrays, control logic, microprocessors, read-only memories, frequency counters and dividers, converters, and linear functions of all types.

Low-power Schottky

SOS

Philips of Holland has introduced several I^2L IC products during 1974, some of which were used in the company's line of digital voltmeters. Many other companies are known to be working actively on products in this technology.

One of the promising areas of application is consumer electronics, where low cost and high packing densities become very attractive features. Late in 1974, for example, Texas Instruments teamed up with the Benrus Watch Company to produce a digital wristwatch with an I²L IC. The IC has a packing density that is 25 percent less than that of an equivalent IC using CMOS, the IC technology conventionally used for high packing densities.

E-beam photolithography

The real payoff in I²L is the ability to combine relatively low-speed, low-power devices (for high-density memories or slow logic, for example) with high-speed, high-gain, npn devices (for off-the-chip buffering, driving, and amplification), all on the same chip.

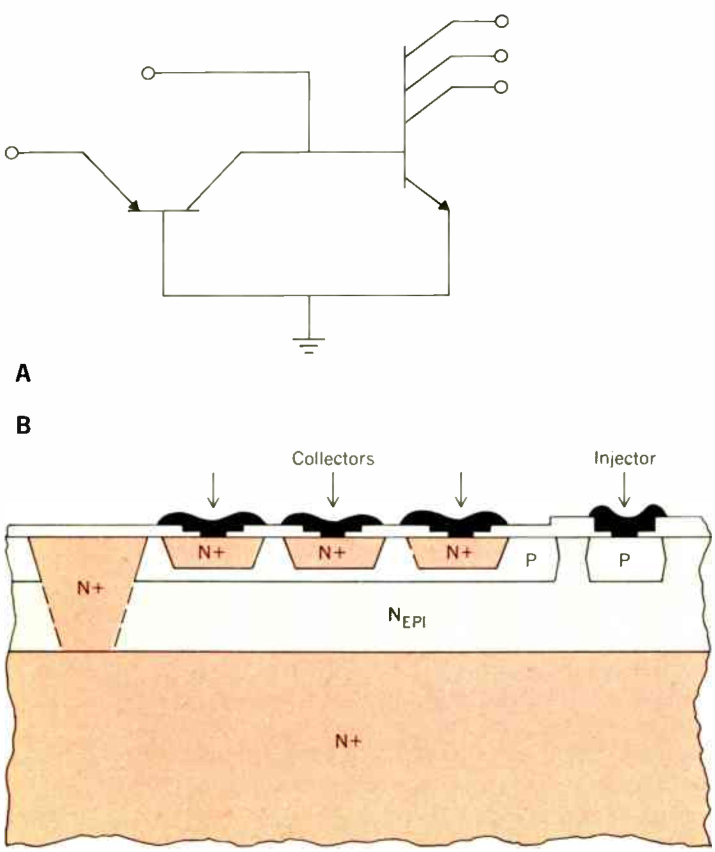
NMOS

N-channel MOS, or NMOS, is the latest MOS evolution from p-channel MOS and is reported to have better operating characteristics than PMOS, including easier interfacing to TTL levels and better speed–power products. Because NMOS ICs require less silicon (for a given operating speed), they cost less than PMOS devices and are consequently finding their way into high-density memories, like 4-kb RAMs (random-access memories), which have now become cost competitive with 1-kb PMOS RAMs.

Processing advances continue

Fundamental to all IC device developments are the various processing technologies used to make them, particularly the pattern delineation steps. Today's photolithograph pattern-generation technologies make

[1] A basic I²L gate consists of a pnp transistor used as a current source and load for an npn inverting transistor, operating with multiple-collector outputs. This configuration is simple to interface to other types of ICs, as the processing is entirely compatible (A). Furthermore, it allows easy layout of compact circuits (B).



use of photographic masks that must be produced with almost incredible precision. A typical photomask, for instance, having an active pattern diameter of 7.5 cm, may have a complex pattern with features as small as 2 μm, may be precise within 1 μm, and may have less than 0.5 defect per square cm. Making such a mask is equivalent to laying out a football field to within 0.8 mm, and guaranteeing that within that area, there are fewer than a dozen defects as large as a grain of sand. Conventional optical processes are hard pressed to meet such requirements.

Electron-beam masking techniques, which are just beginning to emerge from the laboratory, may well provide the key to improved patterning. While most electron-beam pattern-generation equipment has been developed by major IC manufacturers for their own use, a few companies, such as Thomson-CSF in France and Radiant Energy Systems in the U.S. (the latter under Government contract), are developing systems for the general market. This will permit "the little guy" access to the new technology.

Getting better masks is only part of the problem, however, since current contact-printing operations can often fatally damage a mask the very first time it is used on a wafer. Projection printing offers a solution to this problem, but new techniques are necessary if adequate resolution is to be obtained over fields large enough to cover 3-in- (7.62-cm-) diameter or larger diameter wafers. An example of the necessary innovative approaches is Perkin-Elmer's Micraline series printer, in which a portion of photomask is imaged with great fidelity, by purely reflective optics, onto the corresponding portion of the IC wafer, and the entire pattern is transferred by mechanically translating the mask and wafer in a synchronous manner.

Novel electron-beam projection systems are also being developed to overcome the contact-damage problem while providing high resolution.

In an alternative solution to the mass-degradation problem, increasing attention is being given to proximity or "near-contact" printing in which a small, but well-defined gap (typically around 10 μm) is provided between mask and wafer. When used with conventional ultraviolet exposing radiation, diffraction effects associated with the gap inevitably compromise resolution—a problem which can be overcome by exposing the wafer to soft X rays whose short wavelengths make diffraction negligible. The special resists and masks necessary to make this process practical have received a great deal of attention—leading contenders being gold on thin-silicon or gold on thin-plastic films.

Advances in ion implantation, which gives tight control of doping impurities, are having a considerable impact on the development of linear and digital-signal bipolar and MOS circuits. Most new processes include at least one ion-implantation step.

A number of device fabrication techniques involving dielectric isolation (for high operating voltages, faster switching speeds, and greater packing densities) include Isoplanar, OXIM (oxide-insulated-monolithic), and dielectrically isolated-FET schemes.

Improved Isoplanar processes, such as Isoplanar II, developed late in 1973 by Fairchild Semiconductor, are being applied to more and more bipolar and MOS

IC products thereby reducing chip areas by 60 to 70 percent.

The choice is wide with memories

From mainframe to scratch-pad units, semiconductor memories experienced rapid growth rates during 1974. Anticipated advances in CCD memories, and new developments in magnetic-bubble memories, promise to make the designer's choice of memories the widest it has ever been.

During the past year, three major semiconductor manufacturers—Motorola, Mostek, and Texas Instruments—introduced 4-kb MOS RAMs. These n-channel memories, selling presently at anywhere from 0.25 to 6¢ per bit, depending on quantity and performance, are expected to drop down to 0.1¢ per bit by 1976 to become an attractive alternative to core memories, once production levels get high enough.

Siemens Research Laboratories, Germany, built three different, fully decodable, experimental, 4-kb NMOS RAMs with 100-ns access times. These memories were made by Siemens using SOS technology and were incorporated on 16-mm^2 chips.

Research and development efforts in CCDs were expanded in 1974, with nearly every major semiconductor manufacturer taking part, as the CCD promises to become another approach for a low-cost, large-capacity, serial memory. At this moment, many memory experts give CCD the near-term edge over other mass-memory types (Table 1). CCDs also have applications as image sensors and in analog-signal processing.

Experimental arrays of 4 kb, 8 kb, and 16 kb have been reported for CCD memories. The 16-kb serial memories were reported by RCA and Bell Northern Research of Canada. Fairchild has promised commercial availability of a 9-kb (1024 by 9) CCD memory by early this year.

At the moment, it looks like CCDs will have applications as memory elements somewhere between very-large-capacity-but-slow floppy disk and bubble memories, and smaller-capacity but much faster MOS RAMs. Their use as shift registers is also expected to increase.

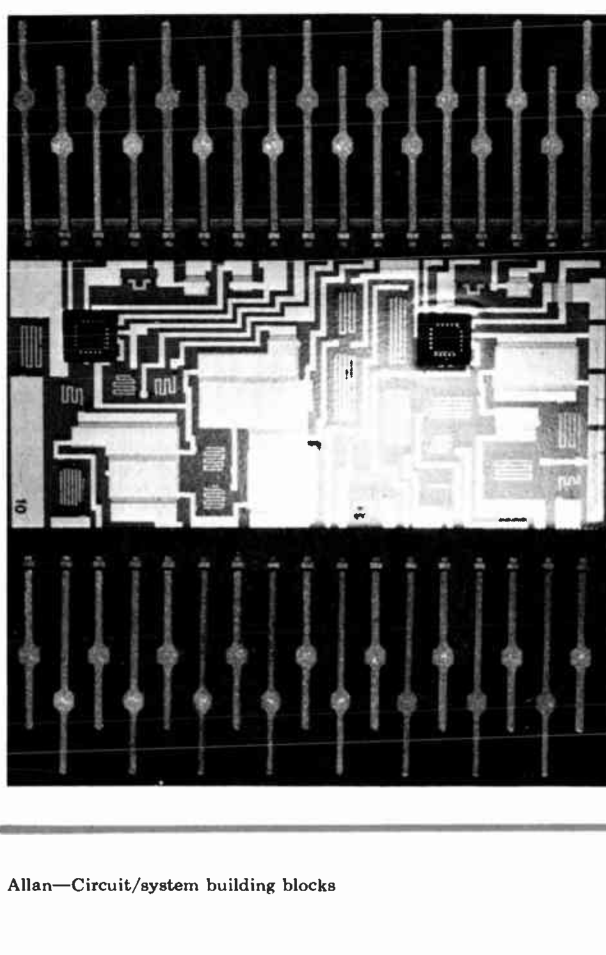
CCDs

CCDs for analog-signal processing have found various military and commercial applications, ranging from electronically variable delay lines to transversal filters with up to 500 stages. And CCDs are being readied for use in TV cameras, where their use will make possible very small and light weight cameras. (In 1974, RCA developed a CCD image sensor that was employed in a miniature TV camera with standard TV-screen resolution of 525 lines.) Fairchild has announced the immediate availability of a 256-element linear imager and the future availability of a 1728-element unit, nearly 2.54 cm long.

Magnetic bubbles

Magnetic-bubble memories are now ready for production. While no commercial bubble memories have been made, Bell Telephone Laboratories announced last year the largest-capacity bubble device ever made in the smallest package—460 544 bits in a package 9.53 by 5.53 by 2.06 cm. The memory has an average access time of 2.7 ms, a data-transfer rate of 700 000 b/s, and a read error rate of less than one error in 630 billion read operations. Bell also delivered a 300-kb prototype bubble memory to Western Electric Company, last year, for product development

Active filters for telecommunication



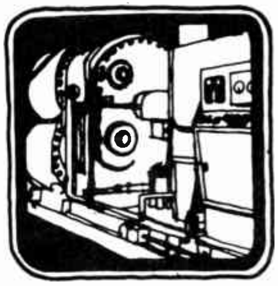
Recent progress in the technology and manufacture of tantalum thin-film resistors and capacitors, fabricated in a planar geometry and on the same substrate during a single batch process, has led to high-volume manufacture of active-RC or hybrid-IC filters for replacing larger, often more-expensive, and less flexible LC channel filters in the FDM (frequency division multiplexing) voice-frequency paths.

Active filters operate by manipulating the frequency response characteristics of networks containing IC op amps, resistors, and capacitors. Passive filters are networks made up of discrete capacitors and inductors, the latter contributing to weight and size drawbacks.

Today, the Bell System's D3 channel banks, the terminal equipment for the Bell T1 PCM (pulse-code-modulation) system, make extensive use of active-RC filter networks in place of older LC filters, at a savings in costs with an improvement in voice-transmission characteristics.

The success of implementing thin-film materials for active filters into resistor-capacitor networks has also increased the demand for such RC networks for use in all types of linear and digital circuitry.

A three-stage RC active filter used on the Bell System's T1 telecommunication lines. The filter is built on a ceramic substrate 20 by 30 mm. The input JFET stage filters the input signal and adds a gentle 8-kHz notch by switching. The second stage sharpens this notch, while the third stage smooths out the passband, and adds a second notch at about 4.5 kHz, sharpening the cutoff at approximately 4 kHz.



Power/energy: a year of struggle

Seeking efficiency gains, the industry pushes both new and "new/old" technologies

Coal gasifier

Combined-cycle power plant

In terms of plant expansion, licensing, and the construction of much-needed facilities to keep pace with the increasing demand for power, 1974 was hardly a banner year for the power industry. Tight money, high interest rates, and fuel costs were primarily responsible for putting the damper on both fuel and nuclear expansion programs. Added to all that, the consumer really decided to conserve on electricity and cut back on his energy consumption by about 5 percent during last winter's fuel crisis/crunch. The effort proved to be a two-edged sword in that it had a reverse cutting edge, reducing revenues for the utilities. Thus, a paradoxical situation occurred: a rise in electricity rates for the *nonuse* of power—much to the chagrin of industry and the consumer. The utilities, however, blamed the increased rates on the exorbitantly high cost of fuel oil since the Mideast war of 1973. As a matter of fact, *Dun's Review* estimates that, on a national basis, the average unit cost of electricity increased by 55 percent in 1974—compared with 12 percent during 1973.

Fluid-bed oil degasification

The highest cost for electric energy in the U.S. was in New York City. By contrast, customers in San Francisco paid about one half the bill of customers in New York. (It should be noted, however, that Pacific Gas & Electric's system is 50 percent hydro generation, whereas Con Edison's system is principally fossil-fuel fired.)

Nevertheless, and despite the problems associated with fuels, costs, and conservation, HVDC long-distance transmission construction proceeded apace (especially overseas), with the initial Cabora Bassa ±533-kV transmission going on the line in mid-1975 (see *IEEE Spectrum*, pp. 51–58, Oct. 1974) and the Inga power complex in Zaire well underway.

Energy conversion

Fusion-energy research

Thermal efficiency of energy conversion processes was particularly stressed in 1974; toward that objective, the power industry made efforts to upgrade the technology of existing power plant design and is developing new power plants from unconventional technology. Thus, the thrust in commercial, industrial, and domestic use of energy shifted noticeably to improved efficiency and to the substitution and/or conversion of types of fuel and/or heat energy. Furthermore, the reuse of heat and combustible material in waste streams was emphasized. Technological advances were made in all these areas last year, despite the fact that no short-term economic payoffs are foreseen.

Westinghouse Electric Corp. is part of a consortium (including the U.S. Office of Coal Research) that is developing a gasifier that produces low-thermal-content gas from coal, for coupling with a high-efficiency combined-cycle (steam and gas turbine) power plant. The gasifier is a two-stage fluid-bed unit that incorporates in-bed dolomitic desulfurization. The gasifier is pressurized to about 10 atmospheres, and the effluent gas at 1150°K is ducted directly to the combustor of a gas turbine for the generation of electric power. The ideal power plant of today is the combined-cycle unit which attains excellent thermal efficiency over the intermediate load range. When the combustion gas leaves a gas turbine, it is passed through a post-fired convective steam boiler from which additional energy is taken from the combustion gas and converted to more electric power by a steam-driven turbogenerator.

Gordon D. Friedlander Senior Staff Writer

A 13.7-tonne/day pilot plant was completed by the consortium last year at the Westinghouse plant site at Waltz Mill, Pa., near Pittsburgh. Following successful testing this year, this plant will be the forerunner of a planned 100-MW combined-cycle power station to be built (with the described coal gasifier) for the Public Service Company of Indiana's electric system.

Fluid-bed gasification of oil, with in-bed desulfurization features, was also investigated to provide an oil combustion system for power plants that can burn high-sulfur oil within the limitations imposed by the Environmental Protection Agency, or state and city ordinances. In 1974, continued laboratory efforts led to the design of a demonstration plant for use on a 30- to 100-MW generating station. Construction of this unit is scheduled during this year.

As reported in *Spectrum's* February 1974 issue (pp. 85–89), the AEC and the utilities are funding a 360-MW demonstration liquid-metal fast-breeder reactor (LMFBR) to be built at the Clinch River site of TVA. In 1974, the reactor design proceeded on schedule and will continue through 1975, with a tentative construction schedule targeting criticality for mid-1982. (However, costs of constructing this LMFBR are wildly escalating. Furthermore, one highly knowledgeable power systems engineer advised this writer that the breeder ratio is poor—30–40 to 1.)

Fusion-energy research has received increased impetus. Large programs were developed in 1974, for imminent Government funding this year. Among these programs are

- The large-scale Tokomak investigation project scheduled for the Princeton University test facility
- Lawrence Livermore Laboratory (University of California)—about $17 million has been funded for the development of a high-energy solid-state neodymium-glass laser facility

• Los Alamos Scientific Laboratory (LASL)—the facility was awarded about $12 million for the development of a large CO_2 laser for use in conjunction with nuclear fusion

At Princeton, a large two-component torus will be constructed; with such a device, there is a possibility that the temperature for nuclear fusion can be reduced from about 100 million to 30 million degrees.

High-voltage substations

Developments in high-voltage substations were influenced by four simultaneously occurring factors:
• The financial crunch on U.S. utilities
• The "space crunch"—the high cost of land, and, in many cases, the inability to obtain adequate space for conventional substations
• The steadily rising cost and decreasing productivity of field labor under typical jobsite conditions
• The growing public pressure to keep substations pleasing in appearance, as small as possible, and preferably hidden from general view

In outdoor substation design, the appearance problem is accelerating the trend toward A-frame and equipment-support structures by the use of structural beams and columns (rectangular or round steel or aluminum tubes) especially in EHV substations (345 to 800 kV).

However, in high-voltage substations the trend toward gas-insulated metal-clad construction was even more noticeable. In the U.S. and Canada, gas-insulated facilities were developed for urban locations at lower voltages. Figure 1 shows a typical 230-kV urban gas-insulated substation. This is a three-breaker ring-bus installation, with three incoming cables. The cable potheads are in a sulfur hexafluoride (SF_6) atmosphere and are located in the cylindrical housings in the picture's foreground. This type of substation occupies 10–15 percent of the space that would be required by a conventional facility.

Unit-breaker module

While in the area of substation equipment, mention should be made of the line of SF_6 elements, introduced by Allis-Chalmers, Westinghouse Electric, GE, and others, for outdoor breaker and compact substation use in the service range of 115 to 800 kV.

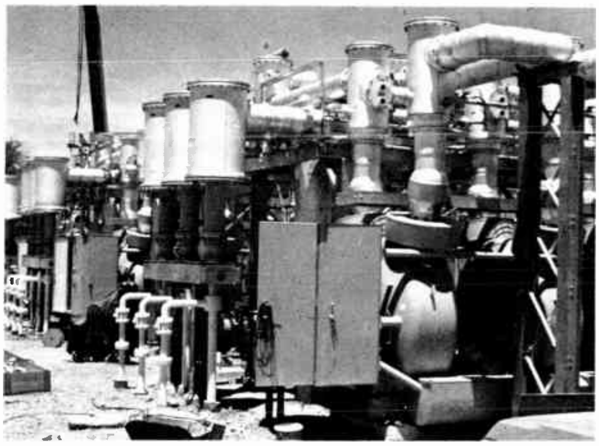
One of the unique items is the unit-breaker module that is shown schematically in Fig. 2. The module comprises the power circuit breaker, with "plug-in" interrupters; disconnect and grounding switches; bypass (if desired); and current transformers. The module is terminated either by means of solid-core bushings, oil-cable potheads, or a SF_6 bus. The unit is usually factory-assembled and package-tested. Other interesting features of the module are that (1) all control and breaker disconnects are mounted on the unit; (2) the SF_6 gas systems for the breaker and disconnect switches are separate, but can be serviced from manifolds in the control cabinets; and (3) with the exception of bushing installation, all field assembly and erection are eliminated.

Recent advances in SF_6 interrupter technology have permitted the design of an interrupter module with a fault-current rating of 63 000 amperes. Just one of the improved modules is required per phase at 362 kV. Two series modules are sufficient for operation at 800 kV. All breakers have two-cycle interrupting times with current ratings from 40 000 to 63 000 amperes. Switching-surge control is provided, when required, by utilizing closing and/or synchronized-closing resistors. A new single, or unit, module 362-kV breaker is also available.

Current-limiting fuses

Current-limiting fuses are hardly new—they have been used for the past 35 years in power distribution systems. Their primary application, however, was in utility substations, industrial systems, or in connection with capacitors. They were generally specified where noiseless operation (without expulsion byproducts) and high-fault-current interruption were among the functional criteria. With the present-day emphasis on increased safety factors on distribution systems, there has been a resurgence in the use of these devices.

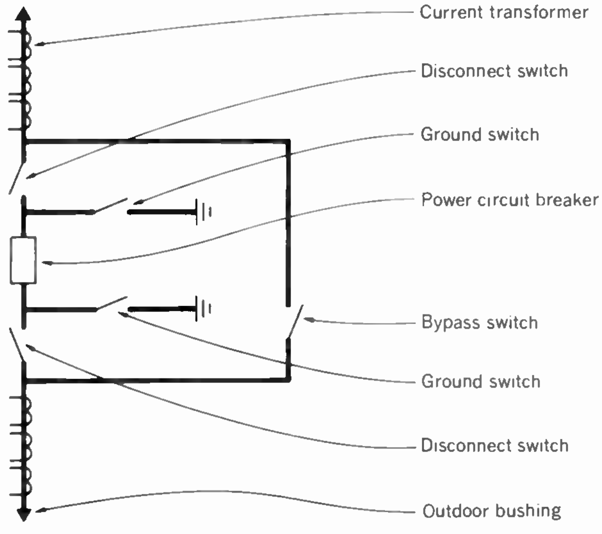
Well-designed current-limiting fuses *are* excellent high-fault-current interrupters and energy limiters. Be-

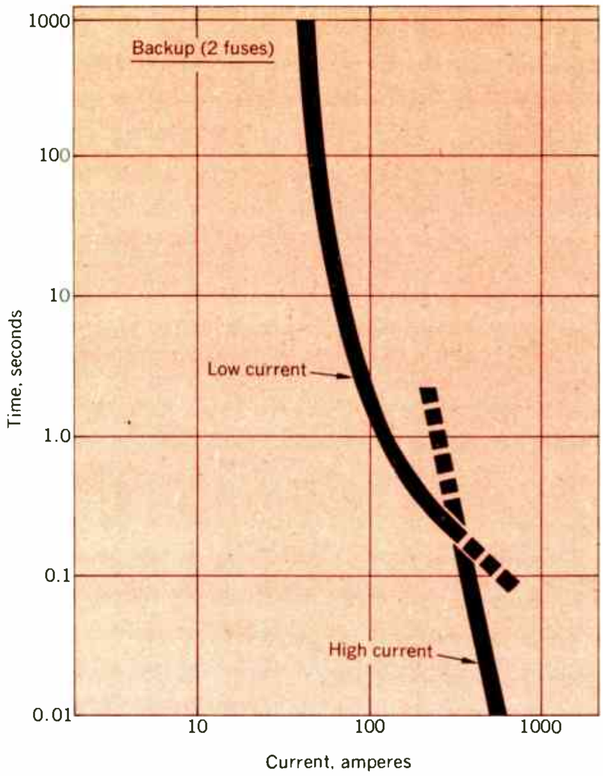


Gas-insulated EHV substations

[1] A 230-kV gas-insulated low-profile substation of a type suitable for urban installation. This is a three-breaker ring bus station, with three incoming cables. The cable potheads are in SF_6 atmosphere and are located in the cylindrical housings in the foreground.

[2] Unit-breaker module consisting of a power circuit breaker, disconnect and grounding switches, bypass (if desired), and current transformer.





[3] Time–current characteristic curves for a typical backup current-limiting fuse.

cause system voltages have greatly increased and higher-MVA-rated substation transformers are now standard equipment, available fault current has increased proportionately. Therefore, the capabilities of conventional "weak-link" oil-expulsion fuses used to protect distribution transformers have been exceeded. But the ability of the current-limiting fuse to interrupt fault currents of 25 000 to 50 000 amperes—or more—makes the device especially attractive.

Current-limiting fuses are available in two types: general purpose, and backup. Both types contain a pure silver core-wound fusible element. The assembly is then enclosed in a filament-wound tube and is subsequently filled with a high-grade silica sand.

Backup current-limiting fuses

In some applications, a weak-link oil-expulsion fuse is used in conjunction with a backup current-limiting fuse to form a two-fuse protective system. In operation, the weak-link device protects the backup fuse at and beyond the former's point of weakness. Since the weak-link has excellent low-current performance capabilities, it is commonly used to clear all low-current internal faults.

Compressed-gas-insulated tube

Perhaps the most persuasive benefit favoring the use of the two-fuse system is that the well-designed weak-link fuse is a *full-range* performer within its interrupting rating. Momentary currents that could open the element would result in positive clearing, since only a modest element burnback would be replaced by the oil reservoir. The pressure caused by the 1- to 2-cycle arc of clearing low currents can be easily relieved by transformer pressure-relief devices. Momentary currents, possibly caused by self-clearing secondary faults, would be expected to be failure-inducing to many general-purpose current-limiting fuses. As indicated in Fig. 3, the total clearing curve would cross the current-limiting backup fuse's minimum melting curve safely beyond its minimum breaking-current level and before the functional need for energy control. (Generally, as shown on the graph, the crossing point is below 1000 amperes.)

Two-fuse systems

Vacuum fuse

Although the vacuum interrupter has been commercially available for more than ten years, it is just now "coming of age" insofar as widespread usage is concerned. As vacuum technology matured—and its acceptance increased—it became apparent that a fuse operating in the manner of a vacuum interrupter would be highly desirable. Thus, a decision was made to merge the technology of the vacuum interrupter and the power fuse to produce a vacuum fuse. (Vacuum-interrupter technology has contributed the materials science necessary to provide the envelope and the techniques for dissipating the plasma formed during an interruption. Power-fuse technology has provided the design techniques for a complete assembly that has the desired dielectric and thermal characteristics for the time-current characteristics of the fusible element, and for the electrical and mechanical requirements of the user.)

During a high-current fault, the fusible element instantly vaporizes over its entire length. This forms an arc-supporting plasma, with a vapor pressure of the order of one to three atmospheres. The difference in pressure here (compared with the surrounding vacuum) outwardly accelerates the metal vapor and the arc. The vapor splatters against a shield that is positioned inside the fuse body for this purpose. The path taken by the arc is controlled by the shape of the arc runners and the magnetic effects produced by them. In this way, the arc is moved and cooled until the first "current zero"—when interruption is completed.

The electrode material effectively keeps the arc stable until the current is at (or very near) current zero. Sustaining the arc between two stationary arc runners allows interruption to occur without current chopping. Several cycles of a low-current fault may be required to burn the element back far enough for arc running to begin. Once it does begin, however, fault interruption occurs in the same manner as described for high-current faults.

Cable transmission

A number of compressed-gas-insulated tube (CGIT) applications were started experimentally several years ago; in 1974, they "came of age" for high-voltage operation. During 1975, about 20 very short transmission lines—carrying up to 800 kV—will be installed and energized. And, very soon thereafter, such transmission lines will range up to the 1200-kV level. To date, a number of CGIT systems have been installed and are operating as buried, open-air suspended, vertical, or open-trench applications.

Several novel applications include vertical takeoffs from SF_6-GIS (gas-insulated systems) miniaturized stations that rise to a height of 41 meters above grade to tap an overhead transmission line. Another example is a high-current 230-kV line to a 550-kV substation (rated at 4000 amperes). This was placed in an open subgrade concrete trench; it is probably the world's first single 1500-MVA cable-type circuit.

Two CGIT cable-like structures are to be considered in the near and distant future. They are: (1) an isolated-phase type, with (2) the eventual goal of combining all three phase conductors into one sheath. The U.S. Department of the Interior and the Electric Power Research Institute (EPRI) are funding a development project on the latter design for 230-kV to 500-kV systems. The new design considerations of CGIT will lead to capacity characteristics that are far superior to those of conventional cables or overhead lines. The ampacity of CGITs can be greater than either standard cable or overhead conductors, and the critical lengths of these new cables is up to 500 km at 500 kV (and even longer at lower voltages).

Higher distribution voltages

Many electric utilities are adopting primary distribution voltages in the 25- or 35-kV levels as their new standard—replacing the currently used 5- or 15-kV distribution. Through careful planning, a utility will design and build new higher-voltage equipment eight to ten years in advance of a changeover. When the new equipment is phased in, the transformer taps are reconnected in order to accommodate the increased voltage.

It is sometimes necessary to supply a new high-voltage feeder or lateral from an existing low-voltage substation or feeder. But as the new voltage takes over, the reverse may occur: it may be desirable to furnish residual low-voltage feeders or laterals from the new high-voltage system until conversion becomes practical.

Ties between the high- and low-voltage portions of the system are normally effected by means of step-up or step-down transformers. Often these units are of "distribution" size (that is, rated 500 kVA and less), but the duty imposed upon them may be much more severe than that experienced by the "normal" distribution transformer.

In recognizing the seriousness of this problem, a new line of step transformers—specifically intended to withstand the rigors of such demanding service—has been developed. By means of strip conductors (whenever practical) and unusual winding configurations, through-fault-withstand capability has been dramatically improved. However, these new winding techniques have required modest increases in transformer size and weight.

On-line dynamic power system equivalents

A number of power system operating centers in the U.S. presently utilize on-line computer and data-collection equipment to calculate automatically the effect of contingencies on their bulk generation–transmission systems. This contingency evaluation plays an important part in maintaining a high degree of security and reliability in present-day power pools and grids. At the present time, these evaluations involve static checks only; that is, only the effects of the loss of transmission lines and generating plants on the resulting steady-state line flows are examined. But, in addition, it is desirable to have the ability to conduct transient and dynamic stability evaluations to supplement these static checks. The now-available implementation of transient and dynamic stability-evaluation software in on-line computing operations represents a real development of major significance in this area.

Transformers: normal and step

The "normal" transformer usually supplies a relatively short, low-voltage secondary system in which faults are infrequent and often self-clearing. By contrast, the "step" transformer generally supplies a relatively long, higher-voltage secondary system in which faults are fairly frequent and may be cleared only after a recloser has cycled through multiple operations to lockout. Furthermore, each time a surge arrester on this secondary line operates, the transformer "sees" it as a fault.

To reduce size, cost, and weight, most step transformers have been built as autotransformers; and, such units have characteristically low impedance and, therefore, little self-limiting action to through-fault currents. Also, the high secondary voltage make it difficult to provide the mechanically rugged coils that are typical of normal transformers. The combination of high through-fault frequency and severity, low self-limiting of faults, and the lack of inherent ruggedness predisposed early-model units to premature failure. In fact, surveys made by the Rural Electrification Administration (REA), and other users, indicated failure rates for step transformers to be several times those for normal units. How this problem was met and solved is described in the text. . . .

Based on field instrumentation, it appears that sufficient information is present in dynamic system measurements, under normal operating conditions, to permit the identification of equivalent parameters.

Off-the-shelf hardware

Concluding this power technology overview are the watthour transducer, the subject of ultrasonic detection, and power-factor-correction capacitors. Solid-state watthour meters have been available for a number of years, but they have not been competitive in price with induction-type meters for commercial use—although some solid-state meters have been used in standardizing work. Now, however, a competitive solid-state watthour-measurement meter is available.

New step transformers

Watthour transducer

Early in 1974, a watt/watthour transducer, in both unidirectional and bidirectional models, was placed on the market. This transducer utilizes the time-division-multiplication principle; and it not only offers an analog output proportional to watts, but also integrates the watt and gives a pulse output proportional to watthours. At unity power factor, both the watt and watthour outputs are rated at approximately 0.1 percent of reading throughout most of the load curve.

The technology of ultrasonic detection is being extended to use on electric equipment. The technique provides detection of corona (at lower levels than has been possible with other methods) in enclosed equipment such as transformers and capacitors. The technique also shows promise for studying the behaviour of dielectric liquids.

Plastic-film capacitors

And finally, regarding power-factor-correction capacitors with film dielectric, development has been completed on capacitors that use a plastic film instead of paper, or the combination of paper and film.

One of the principal advantages of the construction is that the dielectric losses are much lower than those of previous designs. Thus, small units for a given rating can be utilized; also, single units, with a higher rating, can be constructed.

A look down the road—after looking back

The year witnessed developments that can only give the "cold cobbles" to investor-owned utilities. For example, last May, Massena, N.Y. (population 17 000) voted to establish a municipal electric system by purchasing the existing distribution facilities of the Niagara Mohawk Power Corp., the utility that provided power for the town. The action was largely motivated by the reality that residents in surrounding communities, not served by Niagara Mohawk, paid much lower rates for power supplied through municipal systems from the hydroelectric plants of the Power Authority of the State of New York (PASNY).

The high cost of electric power, coupled with the skyrocketing price of fuel, has encouraged similar movements throughout the U.S. toward converting existing private utilities into municipal utilities. To add to this dim prospect for the future (insofar as the investor-owned utilities are concerned), there have been gloomy predictions by prominent consulting engineers that the "days of many large private utilities may be numbered." However, another body of professional opinion contends that there is little chance that any financially viable investor-owned utility will be converted to a public operation. Time will tell. ◆

Information for this article came from many sources. Major contributors were: T. H. Lee, president of the Power Engineering Society, H. C. Anderson of PES, and representatives of the electrical supply and the power industries.

Technology and the public

Interface topics: energy, banking, data banks, public safety, business ethics, and trust-busting

A mixed bag of seeds was emptied across the sociotechnical landscape during 1974.

- In energy, the germs of future financial disaster for the utilities in the United States (as well as for many of the industrialized nations) began to sprout during the year. If left untended, even the U.S. consumer may find himself energy-hungry by 1980.

Further, the controversy about nuclear power does not seem to be abating. Recent evidence indicates that the U.S. Atomic Energy Commission had suppressed significant data in the past. The Commission, which was abolished in October through enforcement of the Energy Reorganization Act, conceded this but said that the public now knows all it needs to know. Does it? Not only the U.S. or European citizen needs the answer to this question. India, for example, recently allocated huge sums out of an already strapped budget for the development of nuclear power.

- In communications, 1974 offered little evidence, beyond the traditional rhetoric, to suggest that the weeds of privacy-invasion-by-technology would soon be rooted out. Positive efforts that have been made in this area will be reported, however, as will be an intriguing experiment—carried out in the state of Nebraska—in electronic funds transfer brought into the local supermarket. So far, the experiment has produced a hybrid yield of both positive and negative implications for what could eventually become a "cashless" society.
- In military avionics, the first prototype of the long-awaited B-1 bomber has now been unveiled and, accompanying that unveiling, comes the increasingly likely prospect of a rerun of the battle over the SST.
- In the area of professional ethics as related to hard technology, an issue has emerged from a series of suits following in the wake of a fatal commercial DC-10 crash near Paris in March—one that set a record by killing 346 people. The issues involved, while not directly involving EEs, are too reminiscent of those underlying the BART case to be ignored.
- And in the area of Government regulation of corporations employing EEs, two cases have recently arisen producing potentially mammoth sociotechnical implications. Both IBM and AT&T have been targeted by the U.S. Department of Justice for antitrust suits.

Ellis Rubinstein Associate Editor

Energy—after embargo, rotting financial fruits

To the electricity consumer, sociotechnology 1974-style presented one issue of overriding importance: as the year progressed, he was paying more and more per kilowatthour. Depending on how well informed he was, he may or may not have been aware as well that inflationary energy costs were driving up more than his utility bills and transportation expenses. During 1974, escalatory energy costs were moving insidiously into every sector of the world economy. They were in large part responsible for the economic woes of nearly all the industrialized nations—the worldwide recession-*cum*-inflation that dominated headlines throughout the year. And they were increasing the possibility of mass starvation in underdeveloped nations forced to divert funds normally earmarked for the international food market to meet escalating chemical fertilizer and fuel costs.

But, in the U.S., perhaps the most ominous consequence of rising energy costs is least known to the average consumer. It involves the financial plight of a less-than-glamorous segment of the U.S. economy—the public utilities.

For a number of years, but intensified since the Arab oil embargo, the U.S. power industry has been plagued by deteriorating profit pictures. Consolidated Edison, the New York giant, was so badly off at one point during 1974 that it was unable, for the first time in its history, to pay out dividends. Doing somewhat better lately, it looked for a while as though Con Ed had barely staved off bankruptcy. And Con Ed is not alone. Many privately owned utilities, especially those that are primarily oil-dependent, have been forced into personnel layoffs and construction cutbacks in recent months.

The consequences of a continuation of poor utility profit pictures could be dire indeed. But to understand the effects, one must consider the causes. Having held stable since the end of World War II, the average price for fuel in the U.S. (see Fig. 1) suddenly jumped in 1969—long before the embargo, but in concert with round one of the current inflationary bout. From 1969 on, fuel prices in the U.S. (as elsewhere) have been leaping upward. Because, according to the utilities, little can be done in the near term to increase fuel-use efficiency (it is likely to hold at about 35 percent through the next decade), the cost of fuel per kilowatthour has been rising steadily for six years. By the time this article goes to print, it is projected by the Edison Electric Institute that fuel cost per kWh in the U.S. will have more than doubled its 1969 level.

Nevertheless, rising fuel costs, though clearly a significant strain on the financial structures of the public utilities, can eventually, and sometimes immediately, be passed on to the consumer. Far more dangerous in the long term are four other factors:

High cost of money

1. The effect of the high cost of money in the U.S. on capacity-expansion funding, be it nuclear or conventional in technology. (Here, it should be noted also that the high cost of money is affecting not only the energy utility but all segments of the U.S. economy, to a greater or lesser degree. Limiting the discussion to energy production, the fossil fuel supplier needs to borrow, just as the utility does, in order to expand production. Further, "expensive" money could prohibit the development of alternative sources [synthetic fuels] and, in combination, these effects set the stage for fuel shortages down the road—a subject that will be returned to later.)

Synthetic fuels

2. Inflation-whipped equipment and labor costs.

Deteriorating utility profit pictures

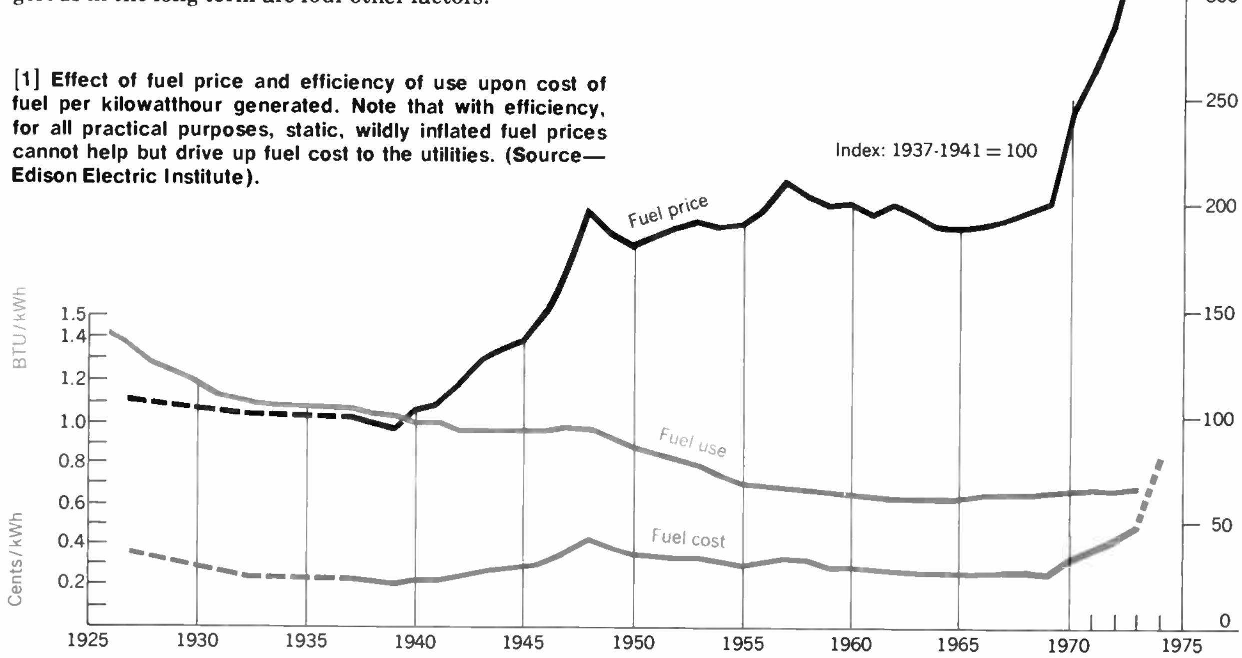
3. The effect of U.S. energy conservation practices on utility revenues.

4. Increasing environmental expenses—the *least* important of the four, *not* according to an environmentalist, but based on the frank opinion of a utility spokesman.

The financially debilitating role of "expensive" money has further ramifications, which will be discussed shortly. Meanwhile, it must be noted that, while operating costs have been skyrocketing, electric rates, though increasing in the U.S. (for commercial and industrial customers, up about 50 percent during the first half of 1974 as compared with 12.3 percent for all of 1973) and though under periodic review by governmental regulatory agencies, cannot match rising expenses—at least according to the utilities.

Rising fuel prices

Why? First, because there is an unavoidable time lag (which in a period of runaway inflation becomes doubly serious) between expense hikes and rate adjustments. (This is more a political than legal problem—regulators tend to be wary of consumer reaction to high-percentage hikes.) Second, what was formerly



[1] **Effect of fuel price and efficiency of use upon cost of fuel per kilowatthour generated. Note that with efficiency, for all practical purposes, static, wildly inflated fuel prices cannot help but drive up fuel cost to the utilities. (Source—Edison Electric Institute).**

a steadily rising energy-demand curve in the U.S. (see Fig. 2), which had permitted volume efficiencies, has now become less predictable.

Shortly after the oil embargo, volume of electric power consumption took a sharp drop as a result of conservation efforts. Since then, a combination of continued conservation, higher rates, and, most recently, the recessionary U.S. economy has prevented volume from exceeding its year-old peak. The dilemma—for both the regulatory agencies and expansion-minded utilities—is to know just how great the rise might be through the next decade.

Declining utility cash flow

Whatever the answer to that question, the net effect on the utilities of rates that cannot seem to match increasing operating expenses is an ominous decline in profits. This, in turn, has become one factor in an even more ominous decline in utility cash flow. Other factors include: (1) weakened investor confidence (itself based on poor profit pictures) in the utility issues; (2) the effects of high interest rates and poor prospects for return on equity, which have made utility borrowing impractical, if not impossible; and (3) the leveling off of demand, which, as has already been mentioned, has further clotted utility cash flow. And again it should be emphasized that these same factors are plaguing all segments of the economy, but the utilities, currently, may be suffering most.

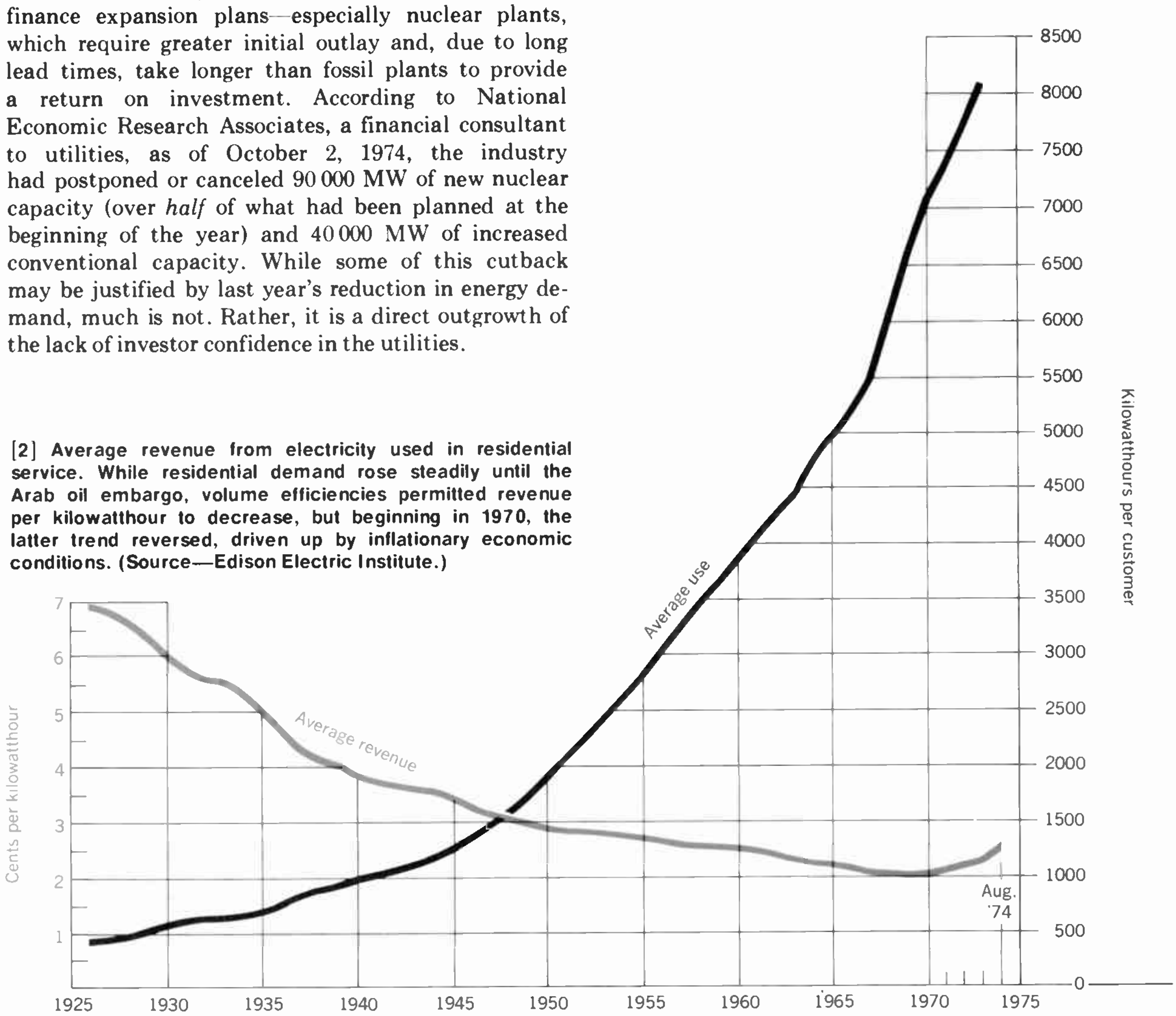
Nuclear expansion cutbacks

What does all of this add up to? It means that the utilities are finding themselves increasingly unable to finance expansion plans—especially nuclear plants, which require greater initial outlay and, due to long lead times, take longer than fossil plants to provide a return on investment. According to National Economic Research Associates, a financial consultant to utilities, as of October 2, 1974, the industry had postponed or canceled 90 000 MW of new nuclear capacity (over *half* of what had been planned at the beginning of the year) and 40 000 MW of increased conventional capacity. While some of this cutback may be justified by last year's reduction in energy demand, much is not. Rather, it is a direct outgrowth of the lack of investor confidence in the utilities.

For the U.S. consumer, this conjures up the possibility of "a decline in services before the end of the decade," as utility spokesmen put it. That phrase, though intentionally vague, applies to anything from localized brown-outs to still more expensive conventionally produced energy (because nuclear plants, in the long term, will often be more economical than conventional ones whose principal advantage lies in short construction lead times and lower initial fund outlays). Compound this with the similar, though so far less exacerbated, plight of the fossil fuel producer and, in the longer term, with the potential economic inability to finance fuel development alternatives, and the U.S. may very well be in for an actual shortage of electric energy!

To govern or not to govern

While the U.S. energy consumer may not suffer actual shortages in fuel resources before 1980, the European is having a somewhat tougher time of it. Except in Norway, where there is jubilation over what promises to be a major oil strike, most Europeans have begun to face up to stringent conservation efforts already beginning to be legislated during 1974. By the end of the year in England, for example, the gas tax had been tripled. Similarly, the French Government worked hard throughout the year to lessen its reliance on Arab oil and, in December, it announced that it



[2] Average revenue from electricity used in residential service. While residential demand rose steadily until the Arab oil embargo, volume efficiencies permitted revenue per kilowatthour to decrease, but beginning in 1970, the latter trend reversed, driven up by inflationary economic conditions. (Source—Edison Electric Institute.)

had worked out an agreement with the Government of Iraq to borrow $1 billion that would be used to purchase Middle Eastern oil.

But in the U.S., shockingly little has been done. The current speculation in Washington is that the removal of John Sawhill as Federal Energy Administrator and the vesting of energy policy authority in Rogers Morton represent an Administration policy decision to minimize the Federal role in energy.

Project Independence

All objective evidence supports this speculation. Ever since Richard Nixon's bold pronouncement at the height of the Arab oil embargo (November 7, 1973) that, by 1980, Project Independence would free the U.S. from its dependence on foreign oil, the Nixon and successor Ford Administrations have been backing off. For instance, it was almost immediately clear to Government energy analysts that 1985 was a more realistic target date and zero importation was an impracticable fantasy. Then, just over a year later (November 12, 1974), Gerald Ford's Administration released the much-heralded Project Independence report, compiled at a cost of more than $5 million. Originally promised to be a detailed blueprint for U.S. energy policy over at least the next decade, the report turned out to do little more than provide an 800-page, 30-volume "backgrounder" for *future* energy policy analysis.

The consequences of Administration nonpolicy (and confusion in policy, like the internal, but widely publicized, bickering over the efficacy of a gasoline tax hike) remain to be seen. It is safe to say, however, that the public utilities claim to be in a quandary. They are afraid, for example, to invest heavily in coal without Federal assurances, much less to flirt with bankruptcy by pursuing new nuclear capability. Further, the individual U.S. citizen must certainly be growing increasingly annoyed by empty speeches calling on him to make personal sacrifices in life style.

Communications—threats to privacy

After energy, the second major sociotechnical concern of 1974 may well have been computer-based communications systems and their effect on the citizen's right of personal privacy. Also implied, of course, in this selection, is the progress (or lack of it) in protecting the citizen against computer invasion.

Data banks

But first, the latest developments: During 1974, there were two attempts in the U.S. to establish data banks of awesome proportions. One involved the Federal Bureau of Investigation, which sought and received tentative approval from the Justice Department to enlarge the capacity of its National Crime Information Center by introducing "limited message switching" capability. The second attempt was conceived by the General Services Administration in combination with the Department of Agriculture. Together, they sought to establish a Government-wide packet switching network, to be called FEDNET, which would provide the potential of interconnecting many Federal data bases.

FEDNET

In the case of FEDNET, Congressional pressure has already resulted in the scrapping of the plan. But despite the deep concern of Senators Sam Ervin (D-N.C.) and Roman Hruska (R-Nebr.), the chairman and ranking minority member, respectively, of the Senate Subcommittee on Constitutional Rights, as well as outright criticism from John M. Eger, acting director of the White House Office of Telecommunications Policy, the Justice Department has yet to withdraw approval of the FBI message-switching plan.

According to Mr. Eger, the danger in the plan is that it could "result in the absorption of state and local criminal data systems into a potentially abusive, centralized, Federally controlled communications and computer information system." Another Federal official noted that "the person who controls communications can control the agencies." And Sen. Ervin observed that "freedom is political power divided into small parts" and that the U.S. "was not based on the idea of efficiency so much [but] on the idea of power diffused."

Meanwhile, in Washington, efficiency is hardly the watchword when it comes to pushing through legislation. In the case of privacy legislation, even though Watergate made the topic a *cause célèbre*, no bills were reported out of committee, either House or Senate, during 1974.

Toward a less-cash society: going checkless

Transmatic Money Service

In Lincoln, Nebr., a unique experiment began in January 1974 that raises extremely important sociotechnical issues. After six years of R&D, the First Federal Savings & Loan of Lincoln went on-line in two locations with a revolutionary banking service called Transmatic Money Service (TMS). No highblown scheme, TMS has become a practical trial of a consumer-oriented electronic funds-transfer system (EFTS). Only in the U.S. could an experiment of this import take place in Hinky Dinky (that's right!) supermarkets (see Fig. 3 on page 64).

Supermarket terminals

What specifically is TMS? It is a banking service permitting the First Federal customer to deposit or withdraw money at a terminal located in a neighborhood supermarket. The $500 IBM terminal is hooked up to First Federal's central computer and the customer is "hooked up" through a magnetically encoded plastic banking card. The obvious advantages are imposing enough: Not only can the customer carry on transactions at a location where he can, simultaneously if he wishes, buy his groceries, but he can do this outside of normal banking hours. Moreover, as his money "resides" in the First Federal computer, it is earning interest! The service is equivalent to a checking account without checks that pays interest!

The benefits both to the Hinky Dinky supermarkets and to First Federal (too complex to be gone into here) have been similarly formidable—so formidable, in fact, that the entire system was shut down for more than six months by a raft of lawsuits instigated by competing banks and the Nebraska attorney general. But by September of last year the suits were being settled in favor of First Federal and the system is not only back on-line but expanding throughout the state and into neighboring states.

What exactly are the serious sociotechnical implications of this experiment? They are both subtle and complex and perhaps the best way to approach them is to imagine what a cashless society would be like. TMS represents a solid stride toward a cashless society. The prospect arising from TMS is one that, while obviously capable of efficiencies, may be threatening to the disenfranchised citizen. Milton R. Wessel, in a book

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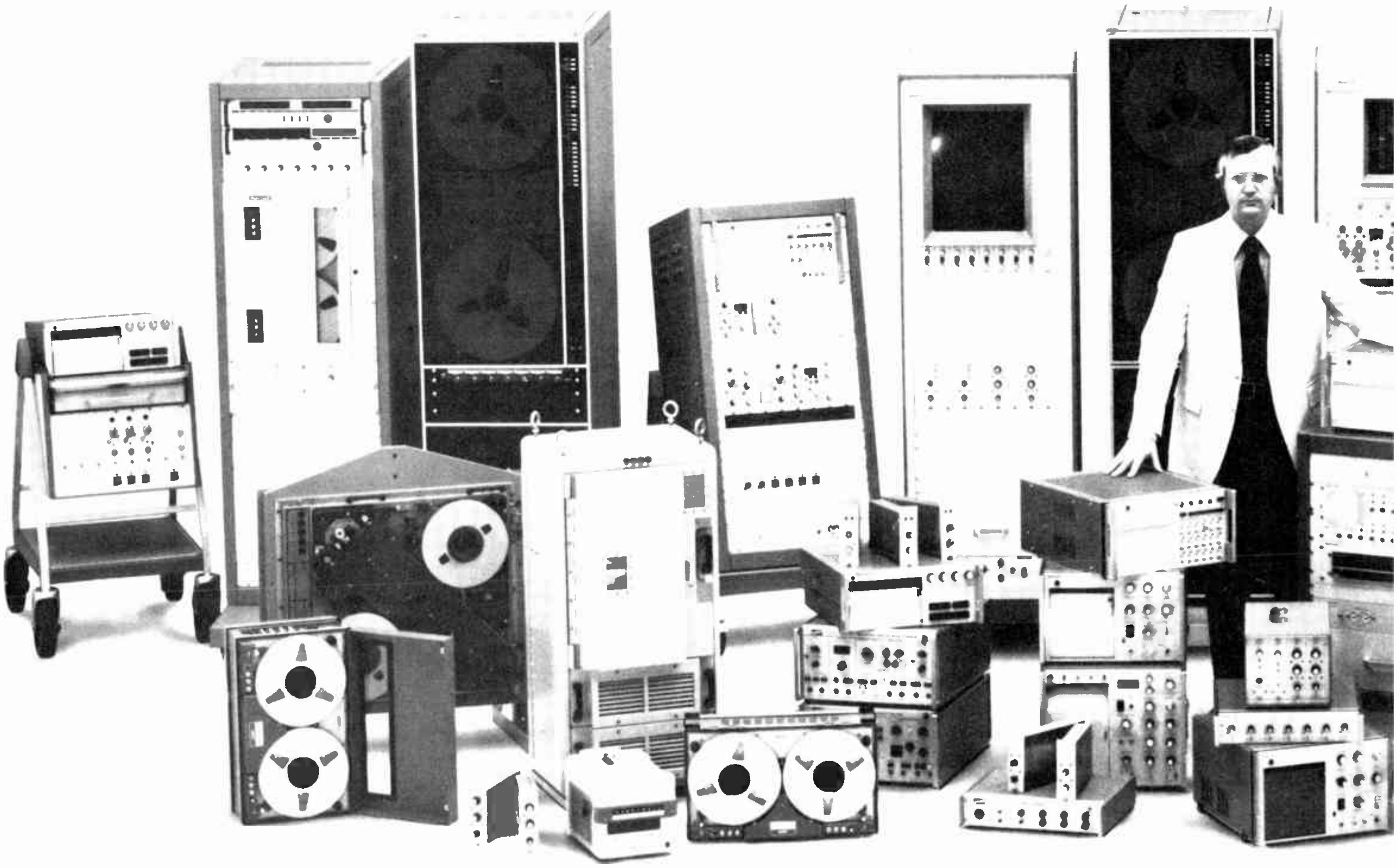


Hone

TEST INSTRUMENTS DIVISION

[3] A First Federal Savings & Loan terminal located in a Hinky Dinky supermarket permits "checkless" cash transactions on the spot.

for the layman entitled *Freedom's Edge: The Computer Threat to Society* (Addison-Wesley Co., 1974), wonders what would happen to a citizen who, for one reason or another, is denied a credit card or whose credit is, rightly or wrongly, stopped. (In the case of TMS, credit may not be at issue, but computer reliability most certainly is.) And as a former U.S. Department of Justice attorney who was deeply involved in the landmark prosecution of Mafia leaders apprehended at the "Apalachin meeting" in the late 1950s (and convicted largely on the basis of an accumulated record of small transactions—phone calls, hotel bills, etc.—proving perjury), Mr. Wessel has a second concern. He wonders what misuses a malevolent Federal establishment might make of a computerized system of records documenting each and every financial transaction. TMS in no way affords this kind of financial history, but as a potential forerunner of EFTS on a national scale, it raises the issue.

AEC cover-up

And if questions such as these seem too far off, their scale too imposing, Martin Ernst, a vice president of Arthur D. Little, Inc., asks: What happens to our society when "float"—or the ability to depend on delayed registering of financial transactions—is obliterated as it is by TMS and will be by any electronic funds-transfer system?

In the face of this apparently gathering tide toward EFTS in the U.S., however, the Federal establishment did manage one of its few positive actions in the sociotechnical arena. On October 28, 1974, President Ford signed into law a little publicized but potentially significant Congressional bill authorizing $2 million over the next two years to fund a yet-to-be-impaneled "EFTS Commission." To be comprised of Cabinet-level Government representatives and representatives of the financial/banking industry, the Commission is to study the whole range of implications that would flow from computerized finance.

EFTS Commission

Sociotechnological grab-bag

Finally, several developments are cited, not because they were of immediate, earth-shattering importance during 1974, but because they hold enormous implications for the future and are likely to become increasingly prominent, either in themselves or in the broader context of the issues they raise.

Perhaps the most complex of these involves recent charges that the U.S. Atomic Energy Commission (AEC) had, in the past, engaged in a cover-up both of its own scientists' concerns and of serious questions raised in nearly a decade's worth of in-house studies regarding possible nuclear reactor safety perils.

Recently released documents include, for example, a key study, kept from the public for seven years, estimating that the effect of a major reactor accident, should one occur, would approximate the effect of a "good-sized" nuclear weapon—that is, would be capable of killing up to 45 000 people across an area potentially as large as the state of Pennsylvania. Other documents include a raft of questions concerning the adequacy of safety devices designed and implemented during the last ten years.

In defense of the new defunct AEC, the Commission's last director of regulation conceded that there had been "bad examples" of secrecy in the past, but claimed that during its final three years, "we created a revolutionary openness."

Nevertheless, proliferating doubts concerning the apparent conflict of interest inherent in the AEC's dual role as regulator of atomic power development and promotor of its development led Congress to split

ywell

On Reader Service Card, Circle No. 28 for Information, No. 29 for Demonstration the Commission into two separate agencies—one to sponsor energy research and the other to monitor the nuclear industry.

While efforts are underway to improve safety features in nuclear power generation (see *Spectrum*, November 1974, pp. 78–82), questions persist. As *Spectrum* went to press, the controversy, much like a tropical storm, was gathering momentum. Whether the issue will abate or build to hurricane proportions remains to be seen.

Another potential tempest centers around the intensifying debate over the B-1 bomber. Advertised as capable of delivering twice the firepower in one third the time, the B-1 is itself under fire on several counts: that it is expensive (Pentagon cost estimates have been escalating from the beginning—the latest being \$76 million per aircraft, or \$14.5 million over the previous estimate); that it would be environmentally disastrous (like the SST, according to critics, too noisy and capable of reducing the vital ozone level); and that it is unnecessary. A "gamble" in the sense that the bomber was proposed in the 1960s for use in the 1980s, the B-1 may never sell . . . to the U.S. Government, at least; lately, Iran, now a Grumman Corp. investor, has shown considerable interest in the airplane.

A third issue of note arises from court action taken against the McDonnell Douglas Corp. in the aftermath of a DC-10 crash near Paris in March 1974 that took the lives of 346 passengers. Not directly affecting EEs, the issue at stake in a raft of suits and countersuits is reminiscent of those at the heart of the BART case (*Spectrum*, October 1974, pp. 69–76). It revolves around questions of negligence in design and development. The obvious question for *Spectrum* readers, as for engineers in general, is one of ethics. McDonnell Douglas does *not* contest the existence of a report prepared by one of its subcontractors, General Dynamics, indicating that the DC-10, as originally designed, was subject to a structural deficiency—one that may well have caused the crash. Thus, the problem remains: Why was nothing done, or, alternatively, were there engineers who covered up? The specific answer may be cleared up within the next year or two, but the implications are ones that may be faced with increasing frequency in the years to come.

DC-10 crash

Finally, a sociotechnical story that will be closely watched through 1975—and perhaps on through the decade—involves the sudden antitrust militancy of the U.S. Justice Department. The first case to hit the headlines concerned Justice's renewed efforts to break up IBM. A 337-page pretrial brief was filed toward the end of 1974 charging that IBM's 73-percent share of the U.S. computer market effectively stifled competition. But this suit is already six years old and when it will be resolved is anybody's guess.

B-1 bomber

Trust-busting Justice Dept. suits

Then, in late November 1974, the Justice Department shocked nearly everyone by instituting suit against AT&T to split off Western Electric and reconsider the status of Bell Laboratories and the Long Lines Division of the communications giant. Years will pass before the suit can even reach trial, but the implications of the action will begin to affect many segments of the U.S. society immediately. ◆

Information for this article came from many sources. Major contributors were: Herman G. Roseman, vice president of National Economic Research Associates, Inc.; Richard D. Grundy, executive secretary of the National Fuels and Energy Policy Study of the U.S. Senate Committee on Interior and Insular Affairs; and Charles A. Falcone, assistant to the executive vice president of Systems Planning at the American Electric Power Service Corp.

Consumer electronics

For tomorrow's buyer: new home videos, auto diagnostics, and refinements in calculators

The ongoing economic downturn has spelled reduced profits and even losses for manufacturers of consumer electronics. The resulting shakeout has been characterized by big operations assimilating smaller ones, and more than a few troubled businesses folding their tents permanently. A period of retrenchment with minimized expenditures for research and development has set in. What innovation remains is concentrated in those products most likely to pay a quick dividend—portable calculators, digital watches, digitally tuned color television, and continued exploration of several promising schemes for home video players. Serious attempts also continue toward the development of electronic control and diagnostic systems for automobiles. Perhaps a forerunner of pollution-free personal transportation, battery-powered delivery trucks are being field-tested by the U.S. Postal Service in California.

Don Mennie Associate Editor

Room in the middle

Over the last few months, there has been a definite shift in the mix of new calculator products being introduced. Those very expensive (and powerful) machines announced early in 1974 remain pretty much unchallenged, while manufacturers have concentrated on finding and filling performance "gaps" that exist between their own products and those of the competition. Hewlett-Packard, for example, found that a simpler type of business calculator was needed for the large number of nontechnical users who wanted more than four functions, but not the complexity of the original HP-80. Thus the HP-70 was produced, offering an attractive price and performance compromise. In the scientific arena, H-P has introduced the HP-55, a preprogrammed pocket calculator delivering 86 keyboard functions, 49 steps of program memory, and a built-in digital timer for $395. Among H-P's portable calculators, only the fully programmable HP-65 is more powerful.

Scientific calculators

Texas Instruments also expanded its engineering calculator line in similar fashion with the SR-16, announced in November 1974. List priced at $99.95 and offering scientific notation, the SR-16's capabilities fit nicely between the less expensive SR-11 sliderule, and Texas Instrument's fully scientific SR-50.

Where established calculators are concerned, the attention centers on the continuous wave of price "adjustments." Most such changes are reductions, with Casio's fx-10 at $79.95 and Sinclair's Scientific at $49.95 (in kit form) leading this trend among scientific calculators. Even Hewlett-Packard's prestigious HP-45 has been reduced $70, to $325. But the uneasy feeling remains that these price battles have become dangerously unprofitable. Bowmar, maker of the popular "Bowmar Brain," recently found it necessary to raise the price of its MX-100 scientific calculator $10, to $129.95.

Plug-in solutions

Most novel among recent calculator developments is the ac-powered desk-top PC-1002 from Sharp Electronics Corp., Paramus, N.J. Intended for engineering applications, this Japanese-made machine performs 15 scientific functions. In addition, this calculator offers up to four individual programs or a total of 256 steps which are controlled by four special keys (A, B, C, D). A plug-in programmable read-only memory (PROM) module contains the commands. When installed, the PROM becomes part of the calculator's hardwired system. With different PROMs, the functions of the special keys are changed, converting the calculator to user-specified applications.

Engineering education

Plug-in PROM

Four extra-function keys on Sharp's PC-1002 desk-top calculator are defined by plug-in PROM modules.

Standard chips are now available for statistics, mathematics, metric conversion, and surveying. Additional chips covering structural engineering, electrical engineering, finance, and other fields are currently in preparation.

Apart from the PROM function, the PC-1002 can be keyboard programmed up to 64 steps. The 15 functions provided by this calculator include trig, inverse trig, hyperbolic, exponential, logarithmic, factorial, power, azimuth, and area calculations. The unit offers ten-digit mantissa, two-digit exponent, and eight memory registers. Exponential display capacity is from 10^{-99} to 10^{99} and zero. Model PC-1002 weighs 1.2 kg and costs $645, including one standard PROM chip. Sharp will design and manufacture special PROM modules to order. There is an additional design charge for custom-made chips.

Also active with several new calculator products is Canon Inc., Lake Success, N.Y. Recently announced were desk-top, printing, and consumer calculators—plus the Palmtronic FC-80 for mixed measurement conversions. Handling metric and U.S. terms for length, weight, area, volume, or temperature, the FC-80 will make all desired conversions between any two units of the same parameter (miles to yards, miles to kilometers, etc.)—a total of 326 conversions in all. Featuring eight digits, floating decimal, zero suppression, and overflow indication, the $129.95 Palmtronic FC-80 also handles percentages, powers, and add-on and discount calculations.

The budget end of the calculator business is still solidly embraced by National Semiconductor's consumer products division and the Novus line of four-function calculators. The six-digit Novus 650 with a fixed decimal for dollars-and-cents calculations was recently discounted to $16.95 from $19.95.

One area strongly affected by the easy availability of scientific calculators is engineering education, according to Edwin C. Jones, Jr., professor of electrical engineering, Iowa State University. Dr. Jones told *Spectrum* that about one third of the juniors in electrical engineering at Iowa State owned scientific-type calculators by March 1974. Exams have proved one obvious point of concern, with some instructors or departments banning calculators outright, but Dr. Jones feels that this cannot last as an official policy.

A more important question is the effect of calculators on learning. Professor Jones explains that calculators really do not "save time," but instead allow students to do many more computational studies in the time that is available. With a calculator to handle the dogwork, students can undertake detailed numerical computations, increasing their understanding and ability to determine whether the results obtained are reasonable. Textbooks and literature notes are being revised to reflect this new reality.

Push to peek

Often heralded by the semiconductor industry as an upcoming replay of the calculator success story is the digital watch. Products introduced thus far are primarily prestigious fashion and gift items (with matching price tags). In fact, the Seiko Time Corporation, believing the digital watch market is basically limited, has pushed development of quartz crystal *analog* wristwatches. Many of the same companies with established technologies for producing personal calculators are committed to the digital watch.

Bowmar, for example, is introducing its solid stainless steel and gold-plated men's digital watches through jewelry shops and big-name department stores under both the Bowmar and Regulus brands. Retailing at from $225 to $295, the new timepieces contain a 32 768-Hz quartz crystal oscillator and a complementary metal-oxide semiconductor (CMOS) counting circuit that derives the hours, minutes, and seconds, plus the date. External push buttons activate the light-emitting-diode (LED) readout, which then shuts down automatically after 1½ seconds, conserving battery power. The internal 1½-volt cells last about one year and may be changed by the owner on Bowmar-brand watches.

Other recent entries in the digital timepiece market are the six models of electronic watches for men produced by Novus, National Semiconductor's consumer division. Like Bowmar's products, the Novus watches consist of a 32 768-Hz quartz crystal oscillator, CMOS electronics, and an LED display. But retail prices are lower, ranging from $125 to $220. Hours, minutes, and seconds are available on push-button command.

Limited production on CMOS modules for women's digital watches has been announced by Hughes Aircraft Company's microelectronics division. Since a woman's watch must maintain petite dimensions, a unique time-readout method is employed to overcome size limitations. Instead of driving a four-digit display to give hours and minutes, the Hughes module works with a two-digit display with hour and minute information given sequentially. The ion-implanted CMOS design also operates with a 786-kHz quartz crystal (as opposed to the more wide spread 32-kHz time base) that Hughes claims allows greater accuracy and lower current drain. Watches designed around the Hughes module are expected to sell for about $300.

A new liquid crystal display for digital watches has been introduced by Princeton Materials Science, Inc. Marketing is being handled through the Sprague Electric Co., North Adams, Mass. Reported input threshold is 1 volt rms (25 to 1000 Hz), with a 100-ms response time at room temperature. Current drain is 0.5 μA at 3 volts with all segments of four numerals activated, and device operation is claimed from −5 to 65°C. Low-current-drain liquid crystals can give continuous readings and need not be shut down to conserve battery power.

Digital watch

The rainbow with a future

For over fifteen years, video magnetic tape technology has struggled unsuccessfully to bring equipment and tape costs down to where a substantial consumer market could develop. Faced with this impasse, considerable effort is now in process on a new approach—the video disk.

Video disks

Video disks resemble the familiar phonograph record in size and shape; they are also made of plastic (usually mylar) and replicated by pressing. But there the resemblance ends. Though they may be flexible, transparent, or highly reflective, one common characteristic is a beautiful rainbow pattern of colors caused by a diffraction grating—the cheapest mass-produced diffraction grating ever devised. Information is packed on video disks at densities over 100 times that of audio long-playing records—adjacent grooves are only a few micrometers apart (center-to-center) rather than the 100 μm of a 20–30-minute audio disk.

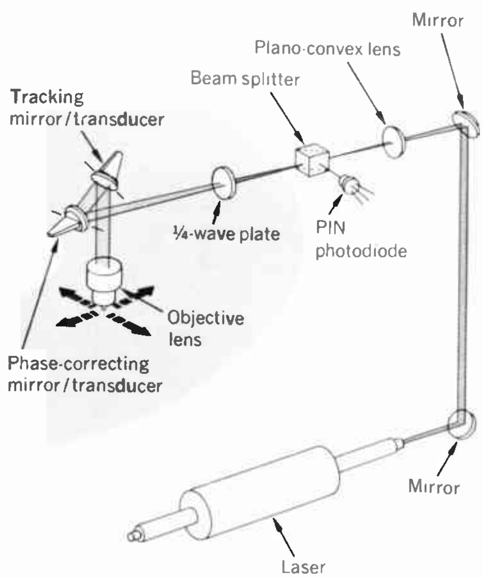
Diffraction pattern

If video disk systems are to become commercially viable, however, they must surmount lack of standardization and several related technical problems. Remarkable technical success has been achieved by many of the people working on such challenges.

Several large companies throughout the world are developing systems to make practical, low-cost video players that can attach directly to standard television sets (see *Spectrum*, Jan. 1974, pp. 78–79). Two of the largest, N.V. Philips of the Netherlands and MCA, Inc., a Los Angeles-based entertainment conglomerate, have combined their efforts during the past summer. This could give MCA's Disco-Vision the edge over competitive systems.

Liquid crystal display

Tracking and timing errors are probably the two most important variables video disk research seeks to



Home video disk players developed by MCA, Inc., and N. V. Philips derive all playback information from reflected laser light.

tame. And proposed solutions usually reflect a compromise between required minimum bandwidth (spatial resolution) and relative invulnerability to noise and distortion. Among the methods seriously considered for picking information off a fast-moving video disk, noncontacting optical systems seem to offer the best chance for success. (Typical rotation speeds are in the 1800-r/min neighborhood.)

Piezoelectric transducer

Generation of playback material for MCA's Disco-Vision player begins with a recording process that uses a laser beam to cut holes in the coating of a master disk. After processing, this master is used to produce replica playback disks.

Laser reader

The player reads the information on the playback disk by sensing the reflection of a 1-mW helium–neon laser beam, recreating an electrical signal corresponding to the original information. This signal is then used to modulate an RF carrier on an unused TV channel and this modulated carrier is connected to the TV set where it is amplified and detected within the set (in the usual manner) to produce a color picture and sound. A 40-minute Disco-Vision record has been publicly demonstrated.

Polarized light

The Disco-Vision player uses optics and a special servo system to null out the effects of mechanical errors. A linearly polarized "read" beam (laser light that initially carries *no* sound or picture information) is first optically "expanded" and aimed at a specially coated beam splitter. At this point, the beam's polarization allows easy passage through the splitter, to a quarter-wave plate that changes the beam polarization from plane to circular. Next, the beam is directed to the back of an objective lens by two special mirrors mounted on piezoelectric transducers. The objective lens focuses the laser beam to a small spot on the surface of the shiny, rotating video disk.

Aerodynamic stabilizing system

Reflected light (which has been modulated by the irregularities in the video disk's surface) is now collected by the objective lens, and returned along substantially the same path as the incoming beam. After a second pass through the quarter-wave plate, it is changed again to plane polarized light, but the reflected beam is now polarized at a right angle to the incoming beam. Finally, the beam splitter diverts the reflected beam to a PIN photodiode detector.

This PIN diode provides an electrical signal that is further processed by the player's electronics. The only other information needed for stable tracking comes from a silicon solar cell that continuously monitors the laser's output during its first pass through the beam splitter.

All-electronic color TV tuning from Magnovox incorporates a calculator-like remote control that delivers instant random access to all 82 channels. Sets with this option start at $995 list. A similar digital tuning system is also available from Plessey Semiconductors.

Compensation signals are applied as dc voltages to the mirror/transducers previously mentioned. One transducer is used to move the "read" beam in a radial direction to provide the high-speed tracking corrections required to follow the data track. The other mirror/transducer causes the "read" beam to move in a tangential direction on the video disk to provide the time-base corrections.

In practice, the compensation deviates somewhat from normal control theory techniques because of the need to compensate the high Q of the piezoelectric mirror/transducer that changes the radial position of the "read" beam. These high-speed tracking and time-base corrections are required because of video disk eccentricity, mechanical vibrations, etc.

Another important team effort toward developing a commercially practical video disk and optical player is being carried out by Zenith Radio Corp., Chicago, and the Central Research Laboratory of Thompson-CSF in France. During the 1974 Chicago Spring Conference held June 10–11, and sponsored by the Chicago Section of the IEEE and the Consumer Electronics Group, Zenith research scientist Robert Adler outlined the progress thus far in overcoming timing and tracking errors.

Like the MCA system, Zenith's video disk player also uses a 1-mW helium–neon laser, an intermediate lens, a tiltable mirror, and a photodiode. The video disk itself, however, is made of polyvinylchloride (PVC) 150 to 250 micrometers thick. An aerodynamic stabilizing system developed by Thompson-CSF keeps the disk surface positioned in a reference plane. This plane coincides with the focal plane of the final lens in the optical system. A single mirror/transducer that deflects about two axes takes care of radial and tangential corrections simultaneously.

Experiments were started using mechanically cut video disks, with grooves having a cross section like a shallow "V." An FM video signal is impressed upon these grooves as sinusoidal hill-and-dale modulation, which can be read out by monitoring the deflection of the light beam back and forth along the direction of the groove as the beam glides over the alternating slopes of the sine wave.

At the same time, the sloping groove walls deflect the light beam radially inward or outward if it is not perfectly centered, and this radial deflection can be used to produce a radial error signal in a pair of push-pull photocells.

Surprisingly, the same tracking and readout system also works with disks that carry the information in the form of discrete pits rather than continuous grooves, provided that the pits are of the right depth. The fact that mechanically cut grooved records and laser-cut records with pits act in such a similar manner is of great practical interest. These records are interchangeable and can be played on the same machine.

Timing errors are accounted for by deflecting the light beam tangentially. Zenith obtained excellent results in deriving the necessary error signal by using a pilot carrier, an unmodulated continuous wave signal recorded on the video disk. This signal, typically at about 3 MHz, is picked out by a tuned circuit, passed

The U.S. Postal Service is experimenting with several types of electric vehicles. Besides the Otis truck shown here, it has purchased 350 quarter-tonne vans from the AM General Corp., with delivery to start in February 1975. This represents the largest electric vehicle purchase ever placed in the U.S.

through a limiter, and fed to an FM detector. The output signal from this detector corresponds to the rate of change of the timing error; it is used to drive that portion of the mirror/transducer which moves the light beam tangentially.

The video signal most sensitive to timing error is the standard 3.58-MHz chroma subcarrier frequency. Permissible phase shift on playback is 10 degrees, maximum. Video tape machines solve the problem by locking the recorded chroma subcarrier to a crystal-controlled 3.58-MHz oscillator. Hopefully, such complexity can be avoided in a consumer video player, and Zenith's experiments thus far indicate that it should be possible to let the tangential mirror/transducer take care of correcting the chroma phase error.

LSI looks better unbuckled

On again, off again regulations, plus an angry controversy surrounding automobile seatbelt interlocks, marked the U.S. Government's entry into the unfamiliar waters of automotive design in 1974. Semiconductor suppliers have seen large orders for seatbelt logic circuits turn to lemon meringue, and consumers are seething at the thought of paying extra for paternalism à la solid state and Government mandate.

Progress, however, continues to be made toward developing automotive electronic subsystems that will prove helpful—and be welcomed by consumers. General Motors has several projects underway in this area, and Trevor O. Jones, director, advance product engineering for GM, briefly described each during a presentation at the SAE and IEEE International Colloquium on Automotive Electronics, October 29, 1974.

Beginning with the Alpha I System developed four years ago, GM has explored the feasibility of an onboard minicomputer to handle antiskid braking, wheel slip during acceleration, automatic door lock operation, transmission gear selection, fuel injection, monitoring of engine parameters, and even a combination lock feature to deter theft.

The most recent prototype, Alpha V, was oriented toward solving the minicomputer design problems, since many low-cost microprocessors potentially useful in this application had become available. While results are not yet complete, resolution of the problems affecting minicomputer architecture and its interface to the automobile (many needed transducers are not yet available) has made a "computer in the car" a practical concept.

Onboard minicomputer

Onboard diagnostic systems (Delta series) that alert the driver to critical conditions or reduced performance are also under development by GM. Such systems would also interface with more sophisticated test gear permanently installed in factory assembly lines, repair shops, or state inspection stations. Data collected at these facilities would permit prediction of incipient failure—besides detection and isolation of specific problems. Three experiments have so far been implemented, and the latest, Delta III, has expanded on-board diagnostics to include steering and shock absorber integrity, in addition to tire pressure and brake monitoring. Existing diagnostic systems, such as those employed by Volkswagen, are service-oriented, and work only with extensive outboard equipment.

Diagnostic systems

Another related automative electronic system is GM's Sigma series, which displays an instantaneous miles-per-gallon value in a digital format. Major components of the system are a fuel-flow transducer and a vehicle-speed transducer. The effects of quick starts, speed, trailer hauling, and hill climbing are made readily apparent. In a fourth experimental program (Beta), carried out in conjunction with the Alpha projects, equipment was developed to evaluate driver fitness electronically. Methods were explored for detecting intoxication, drowsiness, and even cardiac problems.

Miles-per-gallon

Electric cars: getting the lead out

Those who would like to see their transportation needs less dependent on the whims of giant oil companies and international politics will welcome introduction of a practical electric car. Unfortunately, the stumbling block today is identical with that facing the original Baker electric in 1916. The energy storage capacity per unit of weight and volume for the lead-acid battery (the only low-cost battery now available for electric vehicles) will not allow performance comparable to internal combustion engines in on-road applications.

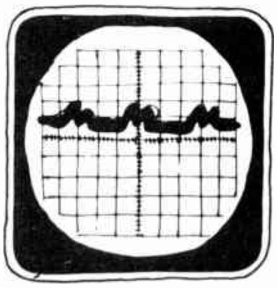
Energy storage capacity

A review of candidate batteries for electric vehicles prepared by Sidney Gross of the Boeing Aerospace Co., Seattle, Wash., shows that many promising electrode "couples" exist (in terms of theoretical watt-hours per unit of weight), but little experimental—let alone engineering—work has been done in developing them. A major manufacturer of lead-acid batteries, Gould Inc., Rolling Meadows, Ill., feels that more extensive vehicle applications using existing batteries must develop before big outlays for further research are justified.

Boeing study

The U.S. Postal Service has an ideal need that can be filled with existing techniques. Many of its mail-delivery trucks travel short, low-speed routes during a day's operation. Prototype battery-powered vans are now being tested by the Postal Service in California, with the prospect that eventual widespread use could provide the applications/customer base that battery companies are looking for. Gould expects that nickle-zinc battery development will provide a near-term replacement for lead-acid cells in such vehicles. ◆

Mail-delivery trucks



Technology in health care

Prosthetics, ultrasonic diagnostics, and computer-read ECGs move into clinical use

The path from initial concept of medical devices or systems to commercial availability is strewn with nonproducts—ones for which high hopes were held—that never made it to the finish line. Even those that do, often consume an agonizingly long time in the process. Recently, however, many significant biomedical engineering achievements have become available commercially—or will be available shortly—on a noncustom basis to those who need them. Notable among such products are a variety of aids to the blind, a neuromuscular assist device, and an inexpensive ultrasonic diagnostic instrument.

Aids to the blind

In another category of biomedical engineering achievement, noteworthy strides have been made in computer-assisted reading of electrocardiograms (ECGs). Telemed Corporation of Schiller Park, Illinois, for example, is now processing daily, with the aid of its own computer programs, 3000 to 4000 ECGs for 700 different subscribers. And the Mayo Clinic is handling 500 ECGs per day with the aid of a computer.

Computer reading of ECGs

Device legislation

Legislation to regulate medical devices in the U.S. has been brought one step closer to reality by the passage last year of U.S. Senate Bill S.2368, the Medical Device Amendments. The comparable House bill, at the time of this writing, is still in committee hearings. But it seems likely that there will be a new law enacted this year.

Progress report on the Optacon

Optacon reading aid

The Optacon, a direct translation reading aid for the blind, converts the visual images of letters into tactile forms that can be felt and identified with one finger. The usual intermediate step of transcription is eliminated, providing Optacon users with independence and privacy.

To read with the presently available Optacon, a blind person moves a miniature camera across a line of print with one hand while the index finger of the opposite hand is placed on the Optacon's tactile screen, a unit about 2.5 cm long and 1.3 cm wide. As the camera is moved across a letter, the image is simultaneously reproduced on the tactile screen by means of vibrating reeds. The reading finger feels the enlarged letter as it passes across the screen. For example, as the camera is moved across an upper case "E," the reader feels a large vertical and three horizntal lines moving beneath the finger.

The camera unit uses a custom monolithic silicon "retina" made up of 144 phototransistors. The stimulator unit uses custom MOS driving circuitry. A specially constructed array of vibratory piezoelectric reeds reproduces on the user's fingertip the material being read.

Since the Optacon reproduces exactly what is printed, it is not restricted to type style or language and a normal-invert switch on the unit changes the circuitry so that either white letters on a black background or a luminous display such as is found on electronic calculators can be picked up by the camera.

Over 1200 Optacons are now in use throughout the world. The device was conceived by John Linvill, chairman of the Electrical Engineering Department at Stanford University, in response to the needs of his blind daughter. After several years of research and development at Stanford University and Stanford Research Institute, the concept was proved, and Tele-

A blind person using the Optacon direct translation reading aid moves a small camera over a printed page with one hand and "reads" the print by feeling tactile forms of the letters with the index finger of the opposite hand.

Ronald K. Jurgen Managing Editor

sensory Systems, Inc., was founded to manufacture and distribute the device.

Although the first Optacons came off the production line in late 1971, recent work has concentrated on expanding the utility of the devices for various reading tasks and on development of a "one-hand" Optacon. The one-hand unit is still several years from production, but will be about the size of a pocket calculator with custom MOS circuitry now being designed at Stanford University.

Telesensory Systems, Inc., in addition to manufacturing the units, offers training courses for both blind students and sighted Optacon teachers.

Ultrasonic binaural sensing aid for the blind

Telesensory Systems, Inc., has just become the U.S. outlet for another aid for the blind called the Mark II Binaural Sensory Aid. Originally conceived by Leslie Kay and developed and manufactured by Wormald Vigilant Ltd., both of Christchurch, New Zealand, the Mark II is a sensing device which probes the immediate environment of a blind person and produces audible sounds which enable him or her to recognize certain gross features of that environment. It serves as a mobility aid supplement to the conventional long cane or guide dog.

The sensor consists of an eyeglass frame, into which are built ultrasonic sensors, and a control box which is coupled to the frame by a light-weight cable. Miniature earphones in the side arms of the frame generate audible sounds which are coupled into each ear by either an open type of ear mold or a simple plastic tube, neither of which produces occlusion of natural hearing if fitted correctly.

The device "illuminates" with ultrasound an area in front of the user, as shown in the accompanying illustration. The inaudible reflected signals are received by two special microphones in the eyeglass frame which detect the echoes and transform them into electric signals. The signals are shifted to a much lower range of frequencies and then converted into audible sounds by the earphones. The blind person hears these sounds and learns to recognize certain features of the immediate environment.

As the user turns his or her head, the beam of the device moves with the head to illuminate the region of interest. The two microphones are deflected outward slightly, one to the left and one to the right. This orientation causes the sounds produced by an object to the right of center to be louder in the user's right ear. Conversely, for an object to the left, the sounds produced are louder in the left ear.

Mobility aid

The direction of an object within the illuminated field is perceived as a difference between the signal loudness in each ear. Distance of an object from the blind person is conveyed by the pitch of the sound it produces; the more distant the object, the higher the pitch. An object that is 25 cm distant will produce a tone with a pitch about that of a middle C. The pitch rises by one octave for each doubling of the distance.

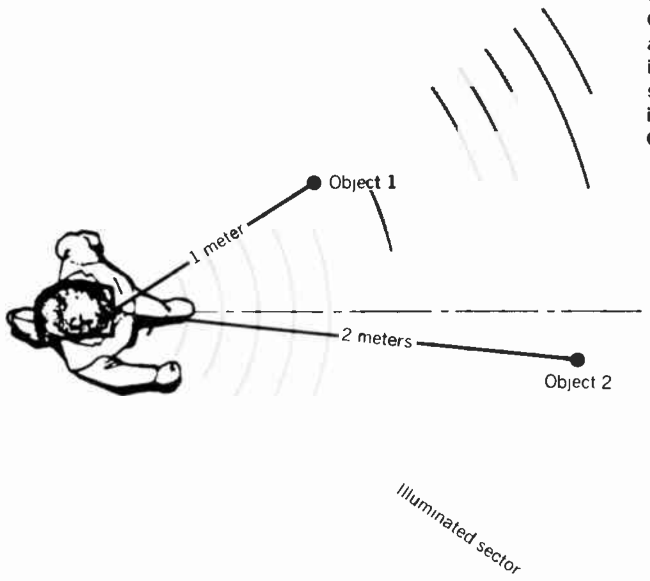
Automatic braille translators

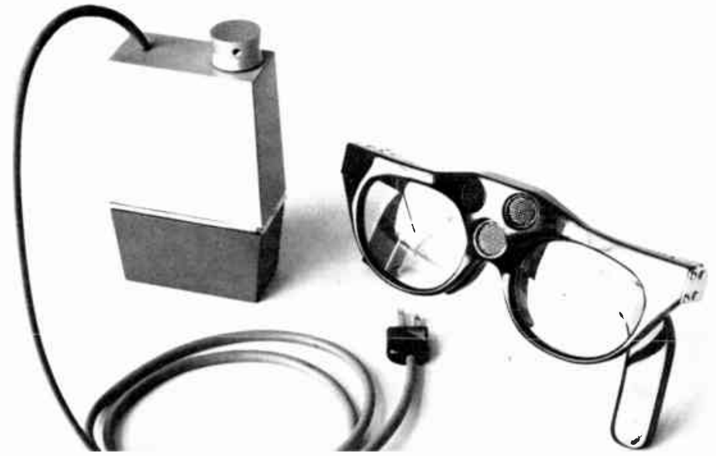
Triformation Systems, Inc., of Stuart, Florida, has been in business since 1970 producing automatic braille translators. The firm now has an extended line of products all aimed at making it possible for blind persons to obtain braille copies of inputs readily from such sources as teletypewriters, news tickers, visual display devices, and computers. As a result, the user becomes eligible for employment in a number of occupations previously closed to him.

Braille translators

Ultrasonic sensors

A portable model, the BD-3, is packed in a standard American Tourister briefcase. Braille is produced when the unit is tied in with a keyboard, digital equipment, a computer, or any device that uses ASCII, EBCD, BCD, Correspondence, Baudot codes (or any other code with 11 bits per character or less). The BD-3 uses standard teletypewriter punched paper tape and operates at up to 15 characters per second. A 2- by 3-dot matrix is standard for braille





Components of the Mark II Binaural Sensory Aid for the blind are shown below. In the diagram, two objects are indicated. Object 1 is 1 meter distant from the head of the user and to the left of the illuminated field. Object 2 is 2 meters distant and slightly to the right of center. Object 1 produces a tone whose pitch is two octaves above middle C and which is much louder in the left ear than in the right. Object 2 produces a tone three octaves above middle C and slightly louder in the right ear than in the left. By rotating his head to the left until the point is reached where the sound signals produced by Object 1 are of equal loudness in both ears, the blind person may face directly toward Object 1. Similarly, any other object may be located.

output. More elaborate units operate at speeds up to 120 characters per second and can produce unlimited braille copies in page format at the rate of one page every 8 seconds or 180 braille lines per minute.

A first attempt at computer assisted instruction for the blind using Triformation units is now taking place at the Overbrook School for the Blind in Philadelphia. Three units are connected to the teletypewriters used to communicate with the Board of Education's Hewlett-Packard hardware. Mathematics, English, and spelling are taught to elementary school blind children.

Braille plots

In another application, John Merz, an aeronautical engineering working at Vitro Laboratories Division of Automation Industries, Inc., Silver Spring, Md., has a braille terminal with which he communicates directly with an IBM 360/65 computer. He uses the terminal mainly to display the output of a large missile simulation program. A braille plot system, developed by Harold E. Wefald at Vitro, makes it possible to produce from the terminal such braille plots as a trajectory in the X–Y and Y–Z plane.

Neuromuscular assist device

Medtronic, Inc., Minneapolis, Minn., has begun commercial production of a neuromuscular assist device for treating equinovarus foot (footdrop) in stroke patients. The procedure was developed by medical and engineering personnel of the Rehabilitation Engineering Center at Rancho Los Amigos Hospital and the University of Southern California in collaboration with Medtronic.

The system consists of an external receiver/transmitter worn on the patient's belt, an antenna, an implant assembly, and a switch mounted in the heel of the shoe on the affected foot. Lifting the heel to take a step causes the heel switch to transmit a signal to the belt receiver. This unit sends an RF signal through the skin to an implant receiver sutured to the fascia of the thigh and, through a flexible lead in a subcutaneous tunnel, to an implanted electrode encircling the peroneal nerve. The stimulus causes the appropriate muscles to contract, bringing the foot up into its approximately normal walking position. The device can also be used as an exercise module to give the patient cyclic stimulation while resting, thereby strengthening the weakened muscles.

Candidates for the assist device must be ambulatory, with severe dropfoot, and individuals whose stroke has plateaued. Minimum time following a stroke before surgery is undertaken is three months.

A U.S.-wide evaluation program of the device at six selected centers is being conducted by the Committee for Prosthetics Research and Development of the National Research Council.

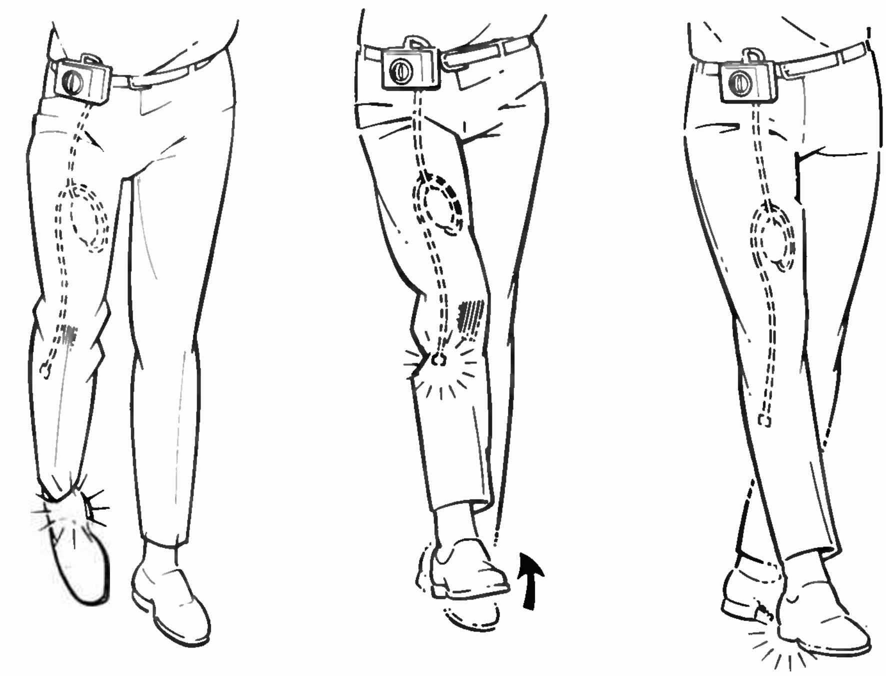
Ultrasonic diagnosis on the move

Advances in ultrasonic diagnosis in medicine continue at a fast pace with progress reported in obtaining much larger fields of view, better lateral resolution, and better tissue signature analysis techniques.

Many laboratory experiments of just a short time ago are now commercial products. Several firms are offering ultrasonic diagnostic products with gray scale imaging, a technique that makes possible improved diagnosis in obstetrics and detection of liver diseases.

Real-time ultrasound scanner

One newly available ultrasonic medical instrument is significant for its real-time imaging, ease of use, portability, and relatively low price. It is a real-time ultrasound scanner manufactured by Advanced Diagnostic Research Corporation of Tempe, Arizona. The scanner is priced at $14 600 or leasable at about $350 per month (other commercially available ultrasound scanners sell, typically, at prices from about $29 000 to $50 000), and combines the basic capabilities of existing gray-scale B-scan ultrasound instruments with the advantage of continuous imagery. With the instrument, a physician or technician can observe with clarity cross-sectional moving images of organs and structures within the body, including the fetus in utero, by noninvasive means. Events are seen in real time. In obstetrics, for example, the average time



A neuromuscular assist device for footdrop operates as follows. At the left, lifting the heel causes the heel switch system to activate a belt-suspended transmitter. In the center, the antenna delivers a pulse train through the skin to an implant, stimulating the peroneal nerve and dorsiflexing the foot. At the right, heel strike deactivates the heel switch system to terminate the stimulus.

Noninvasive blood-flow velocity indicator by Siemens operates at ultrasonic frequencies using the Doppler effect. With this instrument, stenotic disorders or functional incompetence of the venous valves can be diagnosed rapidly.

needed to measure the bi-parietal diameter of the fetal head (an accurate determination of gestational age) has been found to be only three minutes with the ADR scanner.

Although the ribs in the human body prevent effective detailed visualization of the entire heart, significant clinical applications of the ADR scanner to cardiology have been demonstrated in visualizing a left atrial tumor, mitral valve prolapse, pediatric congenital deformities, abdominal aortic aneurysm, and the relationship of cardiac structures.

The scanner is compatible with any closed-housing oscilloscope camera. The transducer of the scanner is a cophased linear array of 64 elements operating at 2.25 MHz, 3.5 MHz, or 5.0 MHz (7.5 MHz is under development).

Computer-assisted reading of ECGs

It has been predicted that by 1980 there will be 1500 computer-assisted ECG processing systems in operation in the U.S. (there are now about 50), handling 100 million ECGs out of a total of 170 million that will be administered. According to a survey by Frost and Sullivan, Inc., of New York City, that volume of computer-assisted ECG processing represents a $1.5 billion market annually, requiring computer systems worth $220 million and related peripherals worth $135 million.

One of the yet-to-be-solved problems with such systems, however, is the comparing of old records. If the patient has more than one ECG, the careful electrocardiographer usually compares them. So far, no commercially available computer programs have this talent. Technology presently exists, however, for implementing comparison ECGs on a limited basis and, with some soon-to-be-delivered mass storage systems, comparison ECGs could be a reality in as little as two years' time.

Much of the already achieved success of computer reading of ECGs is due to the ability to transmit them over telephone lines. Transmission of the data to the computer is usually accomplished by direct online transmission over private or dial-up circuits, although hand-carried or mailed magnetic tapes (or cassettes) produced by a data acquisition instrument, or magnetic tapes (or cassettes) batch-transmitted by telephone, are also used to advantage.

Blood-flow indicator

Medical device regulation

Many physicians and medical-device manufacturers continue to be concerned about the regulation of medical devices under pending legislation. At a conference in Washington, D.C., in November of last year, sponsored by The Association for the Advancement of Medical Instrumentation and the Food and Drug Administration, some of these fears were aired.

Physicians, by and large, feel obligated to make new devices available to their patients. The doctors know that perfection in these devices is not possible, but they feel that the benefit–risk ratio is high. In fact, many of them say that a medical device is safe if it is safer than the disease it corrects. Pending legislation, however, if enacted, could result in the FDA keeping "high-risk" products off the market or, indirectly, preventing them from becoming commercially available because the regulatory process would make it too expensive to do so. The expense would be a major consideration for the smaller, traditionally innovative firms.

Medical device regulation

Vincent L. Gott, professor of surgery, and cardiac surgeon-in-chief, Johns Hopkins University School of Medicine, cited an apropos case history. Battelle Columbus (Ohio) Laboratory had developed for Johns Hopkins a catheter bonded with heparin for use in certain types of heart surgery. A small company was interested in manufacturing the catheter. But since the market for the catheter would be only about 500 units per year at $30 per catheter, the firm decided not to go ahead. The decision was based, according to Dr. Gott, not on the small market potential per se but rather on the fact that it would have cost the company about $200 000 and taken about 18 months time (anticipating the enactment of medical device legislation) to conduct the necessary tests to get FDA approval for a product that would only bring in $15 000 per year.

Even though there are ways, under the pending legislation, by which the expense and time involved in marketing a new medical device can be held down, it seems likely that the pace of commercial introduction of such new products may be slowed considerably. ◆

ECG analysis

Information for this article came from many sources. Major contributors were: Robert Plonsey, president of the IEEE Group on Engineering in Medicine and Biology; Robert W. Mann, chairman of GEMB's Committee on Prosthetics and Sensory Aids; and Michael Cudahy of Marquette Electronics, Milwaukee, Wis.

Industrial electronics

Controllers get smarter, thyristors make inroads, hardware/software goes standard

Computer numerical control

More automation and computer hierarchical and direct control in manufacturing and testing mark the present and the near future in industrial electronics. The energy crunch is being felt, both directly and indirectly. Energy-conserving testing systems for automobiles are being devised and programmable controllers are being applied in industrial processes to increase efficiency and economy. Power semiconductor devices are growing bigger and getting smarter. The new buzzword is "standardization," both in instrumentation and in software. CAMAC, a standardized scheme for interfacing computers to data transducers and actuators in on-line systems, and for the design and use of modular electronic data handling equipment, has begun to play a role in industrial control and measurement, both in the U.S. and in Europe. And a unified industrial FORTRAN computer language is in the works.

Numerical control can do more

While no new types of numerical control (NC) systems were introduced during 1974, nearly all vendors made significant strides in offering new or improved versions of NC or computerized numerical control (CNC) systems.

Most conventional NC today is designed for one specific machine type. As a result, the trend has continued toward lower-cost control systems, offering a greater number of functions for one specific machine type. Examples of this trend in 1974 have included General Electric's three numerical control models, named "Mark Century"—the 550 MPM, for two- and three-axes milling machines, along with models 550 MC, for three- and four-axes machining centers, and 550 TX, for two-axes turning machines. Computer construction techniques and devices are being implemented even in controls that are considered to be hardwired. For instance, Superior Electric's SLO-SYN, Sperry Rand's UMAC 7, manufactured by the company's Vickers UMAC division, and GE's 550 TX hardwired controls are available with semiconductor memories for storage of parts manufacturing programs. These machines also have the ability to edit the stored program, correct programming errors, or add parts features not originally contemplated.

Direct numerical control

A noticeable trend in many NC systems is the inclusion of an increased number of features and functions, leading, probably, to an eventual similarity of NC with computerized numerical control (CNC). A leading manufacturer of both NC and CNC systems regards this development as a healthy one, as it will cause buyers of NC systems to concentrate more on the value of control features and functions and less on the details of implementation of such control.

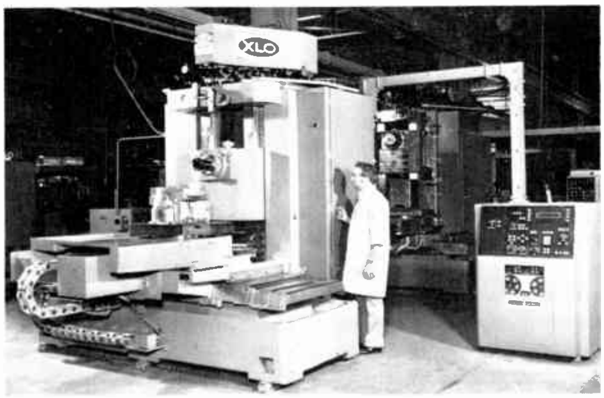
CNC, which first appeared in 1970 in Allen-Bradley's model 7300 and Bendix's System 4, has matured with both companies introducing during 1974 improved versions—the 7360 and System 5—of their original minicomputer-implemented CNC system. Another recently introduced second generation CNC system based on a minicomputer is GE's Mark Century 1050, described as a "distributed-processor" CNC and including a multiple parts-program storage. In this unit, several microprocessors work simultaneously, each on a specific task of the total control function. All microprocessors share one data-distribution bus and one main memory system. In addition, read-only and "scratch-pad" memories are available to the central control microprocessor, for control of the system, storage of intermediate results, and additional task assignments.

Disguised computers in CNC

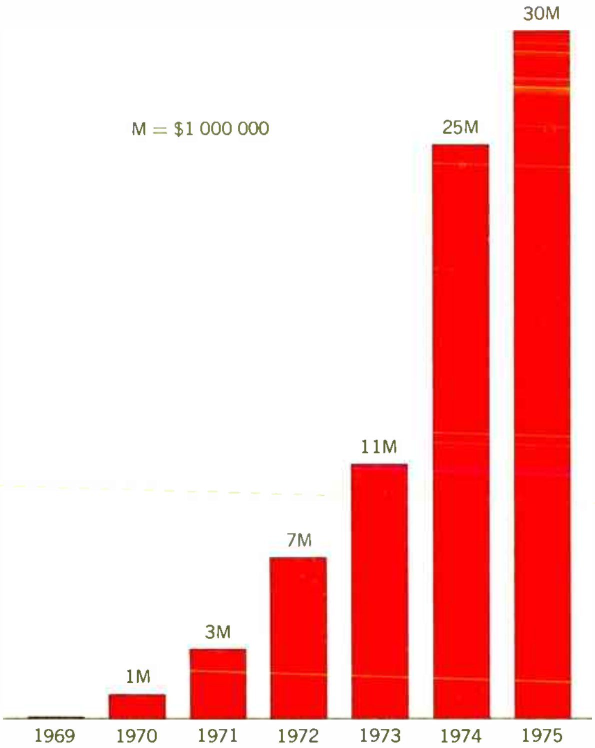
Increased application of computerized numerical control is not proceeding without problems. A psychological block to CNC implementation is the 'computer phobia' of many machine operators, who are used to conventional numerical control. To eliminate these fears, manufacturers have recently been masking the CNC computers. For example, operator's interface (input/output) looks like that of familiar machine numerical control systems and machine diagnostics is provided in English and not in computer codes. GE's Mark Century 1050 Microprocessor CNC is a case in point.

Direct numerical control (DNC), where a master library of parts manufacturing programs is stored in a

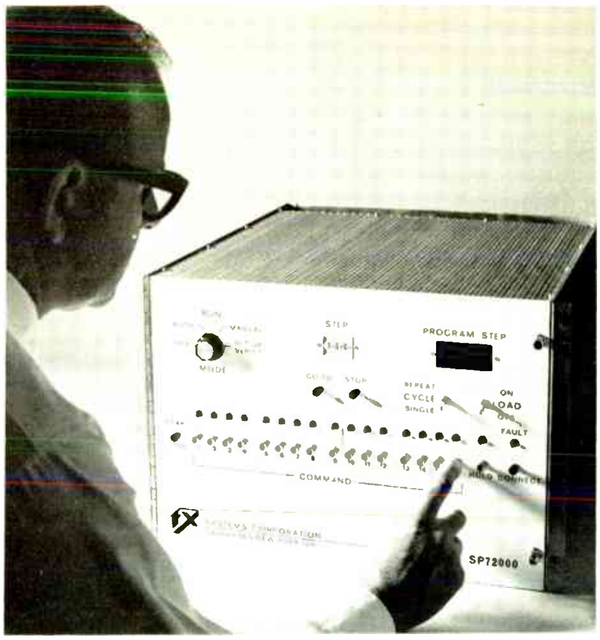
Ex-Cell-O 408 Work Center controlled by General Electric's computer numerical control—Mark Century 1050.



Gadi Kaplan Associate Editor



The programmable controllers' market has been steadily increasing since its start in 1970. The increase projected for 1975 is relatively smaller, based on the status of present economy. Sales figures are estimated by a leading programmable controllers' manufacturer.



FX Systems' SP-72000 programmable controller was improved in 1974. Time base can now be programmed by instruction instead of using hardwire jumpers, and all input/output (I/O) modules have been included in the main unit, eliminating the separate I/O chassis. One option previously not available on the SP-72000 is the capability of running up to four parallel programs simultaneously.

central memory bank and distributed on command to individual machine-control units (NCs or CNCs), has recently managed to overcome its growing pains. Users, particularly large corporations, now play an increasing role in DNC applications, by adding to such systems many functions not provided by the manufacturers' hardware and software packages.

More programmable controllers

Unlike the maturing and consolidating NC, CNC, and DNC, production of programmable controllers continued to grow rapidly in 1974. Developed primarily for the automotive transfer line, programmable control techniques have now found broad acceptance in major applications—conveyor and crane control, plastics machinery, mix batch and weigh applications of bulk material, and limited process control. As a result, programmable controllers are now beginning to be used by many new industries including rubber, plastics, chemicals, steel, lumber, foundries, cement, and appliances.

As control engineers in these diverse areas learn more about programmable control and become involved in initial applications, new features and functions are identified which, in turn, guide the manufacturers to the development of new programmable control products or extended features for existing products. As a result, two significant product/technology trends have been developing during 1974.

Getting smaller, selling cheaper

Perhaps the most visible of trends has been the introduction of new, very small, low-priced programmable controllers (e.g., the Modicon 284, in its version for 20 inputs and ten outputs, measuring about 50 by 50 by 29 cm and costing about $1275). Generally designed to replace about 15 to 40 relays, these controllers are usually restricted to relay replacement and basic timing and counting functions. Often, the latter functions have to be provided for by additional hardware. (The Modicon 284, however, has internal timers and counters).

Memory erasure techniques

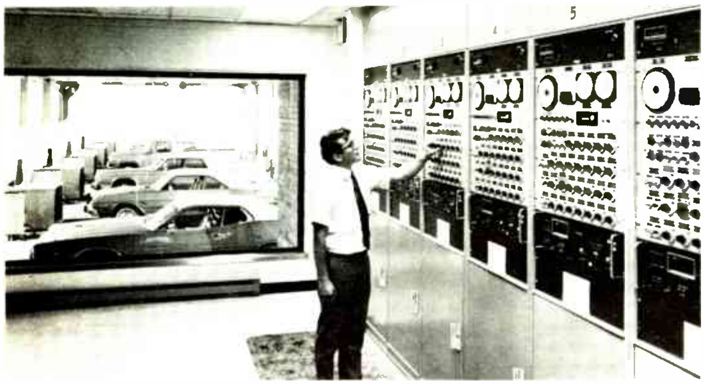
Small controllers use mostly low-cost, integrated circuit read-only memories (ROMs), offering, unlike semiconductor random-access memories, an advantage

Major memory technologies

Technology	Data Retained After Readout?	Data Lost on Power Shutdown?	Cost (¢/bit)
Plated wire	Yes	No	2.0–3.0
Ferrite core	No	No	0.2–0.8
Semiconductor			
Random-access memory			
P-channel MOS	Yes	Yes	0.4–0.8
N-channel MOS	Yes	Yes	0.2–1.0
Bipolar MOS	Yes	Yes	1.0–4.0
Read-only memory	Yes	No	0.08–0.5
Programmable ROM	Yes	No	0.5–5.0
Reprogrammable ROM			
Erasable by ultraviolet light	Yes	No	1.0–5.0
Erasable by electric voltage, called also electrically alterable ROM (EAROM)	Yes	No	1.1–2.5

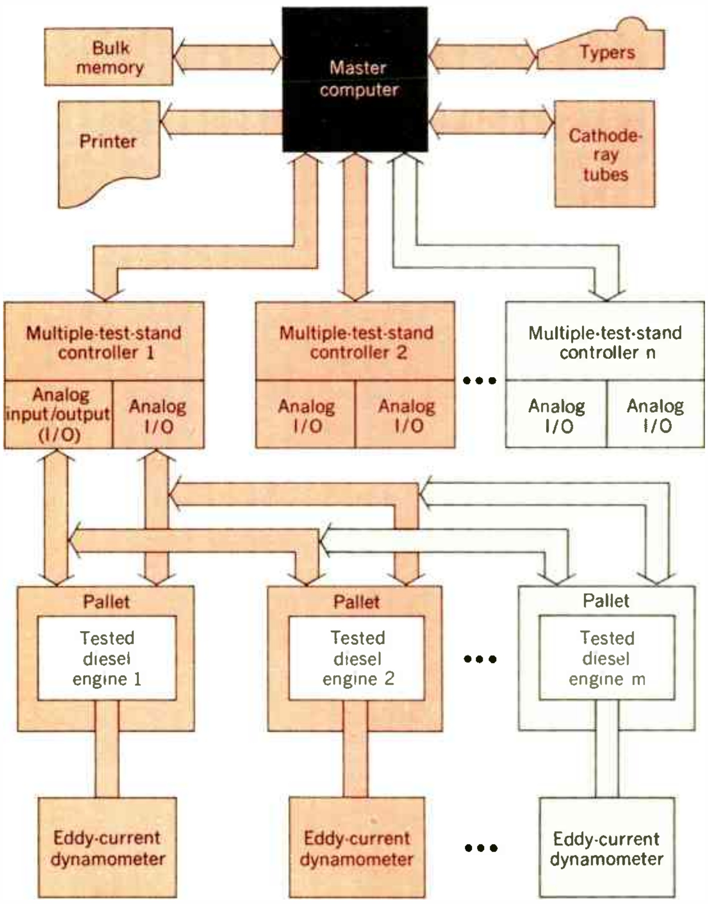
of retaining their contents in power shutdown, a feature identified as 'nonvolatility.' Some ROMs can be erased by applying ultraviolet (UV) light, permitting flexibility in program changing, while retaining the nonvolatile features. Even better reprogramming features are offered in FX Systems' MCA series of programmable controllers, introduced in October 1973.

The electrically alterable ROMs (EAROMs), used in the series, are based on changing the threshold voltage in the MNOS p-channel memory transistors comprising the EAROM. This change of threshold is created by a charge tunneled into and trapped within the oxide–nitride interface at the gate insulator of the MNOS transistor upon an application of a negative voltage input. This threshold is sensed when the memory is read. The memory is erased by applying a positive voltage input to the memory device. EAROM can thus be instantly erased by pushing a button on the programming panel. UV-light erasure of ROMs, on the other hand, takes at least six to eight minutes, and the light has to be precisely directed at the chip to be erased.



Computer-controlled "mileage-accumulator" for passenger cars and trucks at Chrysler's Chelsea Proving Ground permits programmed accumulation of 80 000 km, according to the requirements of the Environmental Protection Agency (EPA). During deceleration periods, the energy absorbed from each vehicle is used to drive a cooling fan facing the vehicle, simulating opposing wind.

Computer hierarchies in a production testing system for diesel engines.



Large controllers become smarter

A second, more subtle trend is the continued introduction of large programmable controllers (from about 150 inputs up) with extended functional capability, as well as a greater variety of input–output options. New large controllers by Allen-Bradley, Westinghouse, and Square D were introduced in 1974, while GE has extended the functions of its Logitrol controller, introduced in 1972. New features in large controllers include counting, addition, subtraction, comparison of numbers, and, sometimes, even the ability to perform multiplication and division. Adding shift registers to all these capabilities, as has been done by some vendors, extends the range of application of such controllers to conveyor control—only one example—where a shift register can be used to keep track of a position of an object on a conveyor belt. Other possible applications of the added computational features are crane control, in-process gaging, and limited process control.

Also, the large controllers are now incorporating a more sophisticated programming panel permitting the programmer to see a visual display of circuits on a line-by-line basis and to make any necessary modifications. Some of these programming panels include troubleshooting features, which permit the isolation of faults within the controller, as well as the maintenance of the controller by the operator himself.

Input/output varieties and multiplexing

Regarding input/output (I/O) specifications in large programmable controllers, one can now find a wide range of ac and dc inputs, from logic level to 220 volts ac or 115 volts ac or dc, whereas earlier equipment was offered in 115-volt ac input and output only. Another I/O development in many large controllers is remote multiplexing, permitting the removal of I/O racks from controller units, using a single interconnecting multiconductor cable between rack and programmable controller. Such an arrangement slashes both installation and copper wire costs associated with the large amount of hardwire I/O connections to large controllers.

Memories

Dominating features in current large programmable controllers are big memory and read/write capability. Various memory technologies are used by different manufacturers, yielding plated wire, ferrite core, and semiconductor memories. Among key features that have to be considered are retention of data on a

Programmable controllers—specifications and what's beyond them

When is a 4-kb memory like a 2-kb one? What is the operational meaning of "scan time"? How can you modify a programmable controller's program? How is a program debugged? Bewildered users of programmable controllers, faced with an overwhelming number of competing products and, often, too fuzzy specifications, have to answer these questions, among others, before making their choice.

Assistance in analyzing programmable controllers' specs along these lines is offered by an article in the May 1974 issue of *IEEE Transactions on Industrial Electronics and Control Instrumentation.* Among key factors, discussed by the author, D. C. Smith, in his paper, "The problem with programmable controllers," is equipment safety. Mr. Smith stresses the need for adequate malfunction detection, as well as an adequate shut-down system, either within a programmable controller or external to it. This is essential for prevention of uncontrolled motions by machines that are governed by a faulty programmable controller—movements that can endanger both the machine itself and operating personnel. According to Mr. Smith, programmable controllers, unlike relay or solid-state dedicated control circuits, are 'centralized' in structure. Thus, a malfunction of a central processor, memory, or data bus in a controller of this type can affect all outputs. Though fail-safe logic design has already been used by some manufacturers, such design is not yet a common practice among all vendors of programmable controllers.

Other topics, like the pressing need for standardization and prompt documentation in programmable controllers, are also discussed by the author in his IECI *Transactions* article.

power shutdown, destructiveness of stored information when read, and the cost per bit. As costs drop, semiconductor memories become advantageous for many applications. However, random-access memory (RAM)—whether p-channel, n-channel, or bipolar MOS—is limited by its volatility, and has to be backed up by batteries in the event of a power shutdown. Ferrite core, on the other hand is nonvolatile, but the data in a core memory is lost when read out and has to be immediately "rewritten," necessitating a special circuit for this purpose. Plated wire memory has the advantage of being both nonvolatile and nondestructive upon readout, but is expensive relative to core and most semiconductor memories, and was introduced into programmable controllers only last year.

User aides

The increasing variety of controllers' applications has created a pressing need for program storage, documentation and programming aids. Although many large users and original equipment manufacturers (OEMs) prefer to document their programs on their own, some vendors of programmable controllers have been offering computer-produced program documentation. One example is a computer-program package by GE, developed for the company's MARK-III time sharing system and available to users of GE's logitrol programmable control. This software package provides a complete program listing, ladder diagrams, input and output cross-reference listing, as well as several aids for editing and storage of controller's programs.

Programmable controllers' applications are not restricted to manufacturing. During 1974, many testing systems incorporated programmable controllers in various degrees of sophistication. Advanced testing programs, particularly in the motor-vehicle industry, have been stimulated by both consumer demand for better and more reliable products and governmental demand for socially acceptable manufactured goods.

Energy conservation in testing

Motor-vehicle testing

Representative models of all new motor vehicles are required to pass an "80 000-km test," as prescribed by the U.S. Environmental Protection Agency (EPA).

In "mileage accumulators," recently installed in Chrysler's Chelsea Proving Ground facility, and intended for such testing, an important feature is a "power pump-back system." In this system, energy acquired by the tested vehicle during various phases of the test is used to drive a cooling fan facing the front of the car and simulating opposing wind.

Diesel-engine testing

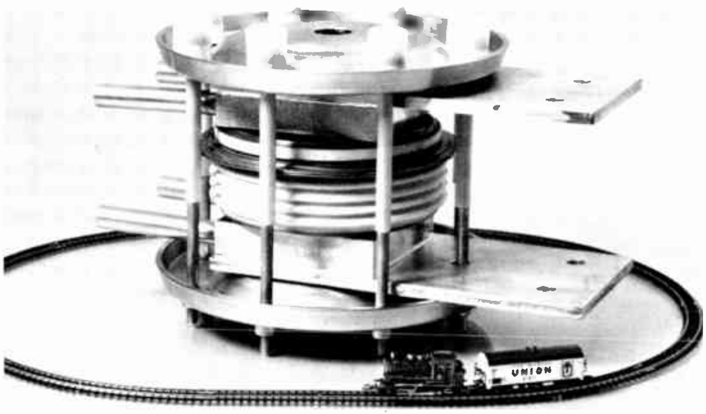
In response to recent demands for energy conservation, some testing systems for diesel engines, too, are being provided with power-recovery equipment. This is accomplished by using direct current dynamometers that can function either as motors or as generators, depending on whether they deliver energy to, or absorb it from, the tested engine. The absorbed dc power is collected on a voltage bus, inverted into 60-Hz ac power, and returned to the plant's power distribution system, thereby reducing the total plant's demand on the electric utility. Conventional eddy current dynamometers were more wasteful, dissipating as heat the ac power they absorbed from the system.

Computer hierarchies in testing

Computer Hierarchies

To control dynamometer tests of diesel engines on a large scale, computer-directed systems using various

Power Semiconductor's 102-mm thyristor, PSI Cosmo Pack, claimed the world's largest semiconductor device, mounted in a water-cooled heatsink. The world's smallest toy locomotive is included for comparison.



Computers in control—terminology, status, and trends

To help computer users orient themselves in a computer market crammed with jargon, an author of a paper in the 1974 Conference and Exhibit of the Instrument Society of America (ISA) has defined a few key terms. A *minicomputer* is, according to author V. A. Kaiser of Profimatics, a computer "mainframe" typically selling under $25 000, and having 16- (or 8-, 12-, 18-, 24-, or 32-) bit word length, a 4- to 32-k-word semiconductor or magnetic core memory, and a cycle time of 0.2 to 8 μs. A *naked minicomputer*, according to Mr. Kaiser, is a minicomputer stripped of cabinet, console, and power supplies, and typically packaged on a single printed-circuit (PC) card at a cost of less that $1000 in quantity.

A *microcomputer*, says Mr. Kaiser, typically consists of a microprocessing unit, usually assembled on a single PC board; a memory; power supplies; auxiliary circuits; console; and cabinet. It is usually smaller, slower, and has less computing power than a minicomputer. For these reasons, microcomputers normally sell for under $5000.

Using large-scale integration (LSI), *microprocessors*, major building blocks of microprocessing units, can be fabricated on a single chip. According to Mr. Kaiser, 16-bit microprocessors with 2- to 3-μs instruction times are now available in chip form for about $150.

From "do-it-all" to distributed systems

Mr. Kaiser maintains that computer control has matured, and that the forces of change in this area have become increasingly subtle. Advances in LSI reduce computer prices, allowing more "decentralization" in computer control. Functions like data acquisition or operator communication can be performed by auxiliary mini- and microcomputer systems, relieving the central computer for major control tasks.

The trend is therefore from "do-it-all," single-computer system packages to customized, multiple-computer configurations, with equipment distributed physically and operations distributed functionally.

In digital communication between instrument and computer, use of high-speed data transmission, to improve control dynamics, as well as optical isolators, to insure immunity of low-voltage (5-volt) solid-state logic circuits to stray surges, has continued to increase, with optical isolator prices ranging between $2–3 a piece.

As for analog signal transmission, author Kaiser reports no dramatic change, but indicates that solid-state analog multiplexers are being introduced at a high rate to replace electromechanical relay multiplexers used for switching high-level signals.

Man–machine communication

Communication between operator and plant-control computer requires both display and some operator means of requesting information from the computer, says Mr. Kaiser in his ISA paper. Most operator console requirements today are met with cathode-ray tube (CRT) displays and alphanumeric keyboard terminals, or with CRT displays incorporated in standard hardwired functional consoles. Some vendors had been trying to "standardize" hardwired consoles, Mr. Kaiser says, but that approach had later to be abandoned, as it could not fit specific users' needs.

CRT display is here to stay—for a while

Of many display technologies examined and available today (see *Spectrum*, October 1974, pp. 90–95), CRT is still considered to be most appropriate for plant monitoring, and Mr. Kaiser expects no viable successor in the immediate future.

In harmony with this view, *Spectrum* has verified that CRT display features are continuously improving. For example, Leeds & Northrup recently announced a 7-color video display system, the Mark III. The system can display up to 128 different characters, compared to 64 in the CRT in the company's LN5000 display package.

Spectrum has found that current developments in display techniques may eventually lead to adoption of ac plasma panels, investigated by GTE Laboratories, or thin-film electroluminescent panels, developed in Japan by the Central Research Laboratory of Sharp Corp. Another possibility, already demonstrated by Hughes Aircraft, is liquid-crystal cell display.

Standardization and computers

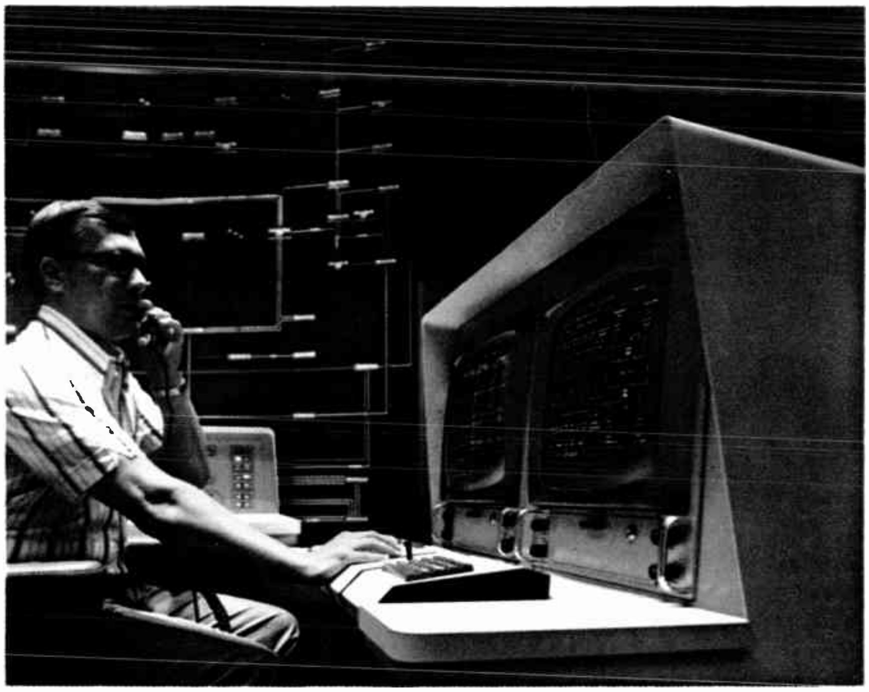
A related topic, not elaborated on by Mr. Kaiser in his ISA paper, involves standardization. Displays, computer peripherals, and instruments for measurement and control are so abundant that a major problem that faces computer-controlled plant operations is compatibility of various instruments with computers and within themselves. A standard scheme for interfacing computers to data transducers and actuators in on-line systems, and for design and use of modular electronic data-handling equipment, was originated about 10 years ago in Harwell Laboratory in England. Called CAMAC, later interpreted as "computer automated measurement and control," this scheme has been aimed at introducing some order into the increasing instrumentation interface chaos. Recently, CAMAC standards have been gathering momentum. Instruments according to these standards are manufactured and used both in Western and Eastern European countries, as well as in the U.S. and Canada.

Among applications of computer CAMAC-based systems reported at the CAMAC conference in Luxemburg, December 1973, were data logging and alarm systems in a fossil-fueled power plant in Budapest, Hungary; a water-pump station control by SEN Electronique in Geneva, Switzerland; and continuous thickness measurement of plastic ribbons, by Schlumberger Instruments et Systèmes, Bagneux, France. A typical advantage cited by the latter two vendors is the potential capability for easy expansion due to the modular concept employed in CAMAC.

CAMAC-compatible instruments, commercially available, include motor and synchro drivers, analog to digital (A/D) and D/A converters, stepping motors, power supplies and crates, encoders, registers, trial units, multiplexors, buffers, clocks, and many other instrument types.

Toward computer Esperanto?

Standardization is now becoming a software problem too. Computer proliferation and soaring software costs have been raising many problems relating to compatibility and interchangeability of computer programs, between different computers. Realizing this undesirable situation, both the Instrument Society of America (ISA) and the American National Standard Institute (ANSI) have recently encouraged efforts toward a standard industrial computer language. Formulation of a standard industrial FORTRAN has already been initiated, but it will involve some tradeoffs in language capabilities, and more important, the process control industry must still make up its mind whether it really wants a unified computer language.



Seven-color, computer-controlled cathode-ray tube (CRT) display, the Mark III, by Leeds & Northrup. The CRT offers 5760 graphic character positions, and can display up to 128 different graphic symbols.

control hierarchies have recently been implemented. In a typical system, diesel engines are placed in test cells with pallets that provide connections to fuel, water, electrical power, and instrumentation and mechanical coupling to dynamometers. The test cells themselves are grouped, and each group is controlled by a single controller. All controllers, in turn, are directed by a master computer.

Hierarchical set-up is also applied in automatic testing of automatic transmission, before shipment to vehicle assembly plants. The control of a series of tests relating to converter fill, idle pressure, converter stall, wide-open throttle shift, and light throttle shift is carried out at test stands by dedicated programmable controllers; data analysis and test acceptance functions on multiple test stands are performed by minicomputers, while information gathering and data-base functions are performed by a master computer.

Thyristors get bigger, more clever

While computers provide control for complex testing sequences, actual power delivered to drives in many industrial applications is mostly regulated by thyristors. In 1974, thyristor power handling capacity increased along with the devices' physical size. Current ratings of up to 1950 amperes (rms) have been announced, with reverse blocking voltages of 1800 volts. Power Semiconductors has recently introduced a family of thyristors based on a 52-mm-diameter silicon chip—one unit of this family can pass up to 2700 amperes (rms) and has a blocking voltage of 400 volts at 150°C. The company has also been testing a 76-mm and a 102-mm unit. The large area of the silicon chip permits the inclusion of integrated circuits on the chip.

Two possibilities being examined are the addition of temperature protection circuits or gate-pulse control circuits, to reduce sensitivity and avoid false triggering due to noise. Using the "smart" thyristor, many conventional components can be replaced by the integrated circuit added on the thyristor. In a typical application, six 102-mm integrated thyristors replaced 42 conventional power devices (including diodes and protection fuses) in a control system delivering about 6000 amperes.

High-voltage dc power transmission

Thyristor applications have been broadened recently to include high-voltage power dc transmission, as well as high-speed rail transportation control. Thyristor converters controlling 500-kV dc power-transmission lines are expected to go into operation in 1976 in a project in Zaire, Central Africa. Thyristor controllers will also be used to maintain the separation between car and rail in a levitation train system model. (In such a system the train is suspended on magnetically repelling force between train and guideway.) The model is being built by Ford Motor Company in Dearborn, Mich., for the U.S. Department of Transportation.

Material handling

Thyristors

Power thyristors are playing a role in material handling too. Thyristors have recently been incorporated in the design of a mammoth crane (with handling capacity of about 1100 tonnes), that will be placed in service in a U.S. shipyard during 1975. The thyristor power supplies control two 300-hp motors, providing a continuous operation from 14.4 meters per minute at no load to 2.4 m/min at full load. Thyristor-controlled power supplies are also used for the two trolleys and eight 60-hp motors, driving the wheels on each leg of the "goliath" crane. ◆

Information for this article came from many sources. Major contributors were: Edward Rich, Richard Miller of General Electric, and other members of the Industry Applications Society of the IEEE; Robert Mayer and others from the Industrial Electronics and Control Instrumentation Group of the IEEE; Robert Wilson, President of FX Systems, Saugerties, N. Y.; and Jack Blaeser, Vice President of Marketing, Modicon, Andover, Mass.

Transportation progress

A banner year in the art of people moving saw California's BART go transbay

Increasing speeds and more comprehensive automatic control of systems operation marked progress in rail transportation during 1974. In the United Kingdom, five-hour express service was inaugurated on the newly completed all-electric London–Glasgow British Railways run. Very-high-speed vehicles racked up thousands of kilometers in test runs on the French National Railroads. And in Sao Paolo, Brazil, a new mass transit service was inaugurated using an ATC (automatic train control) system similar to that of San Francisco's Bay Area Rapid Transit (BART).

Undercant compensation

At the same time, in the U.S., BART closed the loop for almost complete automatic operation along the system's full 114 route kilometers. The Washington, D.C., Metro system moved toward limited service in 1975. And the longest digital-computer-controlled rail traffic complex in the U. S. was being readied in the Pittsburgh–Johnstown area.

British Rail: HSTs and APTs

'Electric Scots'

Last May 6, Queen Elizabeth inaugurated service on one of the world's longest—and newest—all electric (25-kV, 50-Hz) "Inter-City" routes, London–Glasgow. The trains are generically referred to by British Rail's Inter-City division as the "Electric Scots," making the run daily and in each direction—with one or more intermediate stops—in 5 to 5¼ hours. Among the crack high-speed trains (HST) is the "Royal Scot," which covers the 645 km (400 mi) in five hours, at an average speed of 130 km/h (80 mi/h). The trains are hauled by a Class 87 four-axle, 80-tonne locomotive that has a continuous rating of 3700 kW at a maximum speed of 200 km/h (125 mi/h). Mark III passenger coaches, specially designed for this high-speed service, in conjunction with the Class 87 all-electric or diesel-electric locomotives, comprise the trailing load.

New French rail lines

Meanwhile, British Rail's advanced passenger train (APT) is being developed by scientists and engineers at the Railway Technical Center in Derby, to enable existing rail lines to handle 250 km/h (150 mi/h) passenger service without extensive modification to the rights-of-way. Research into the fundamental dynamics of rapidly moving vehicles has led to the development of an energy-efficient high-performance prototype train that exploits improved guidance techniques and body-tilt to negotiate curves at high speed.

Prototype APT-E

The prototype APT-E (experimental) consists of two power cars and two trailer cars that are extensively fitted with instrumentation. Since September 1973, this gas-turbine-powered train has been subjected to the most stringent test program ever devised for a railway train. In 1974, the APT-E ran for some 200 hours and covered almost 6000 km (3600 mi) on both British Rail's mainlines and special test track. To date, it has reached a maximum speed of 205 km/h (128 mi/h) and has negotiated a curve of 1140-meter radius at a speed of 161 km/h (100 mi/h), with a cant deficiency of 8° (see *IEEE Spectrum*, pp. 60–62, March 1974, for an explanation of coach-body tilting).

Gordon D. Friedlander Senior Staff Writer

According to the British Railways Board, the ride quality at maximum speed "is up to specification" except for a high-frequency vibration component that was probably produced by the coupling arrangement between coaches. Modifications to correct this problem are now being made. The first gas-turbine/electric revenue passenger service of the APT is scheduled for 1977.

The map opposite indicates the Glasgow–London electrified mainline (placed in service last year), as well as the other mainline electrified and nonelectrified HST and APT routes that are projected over the next decade.

The French direction

The predominant direction of French ground transportation, in both suburban commuter and mainline rail, is a combination of ever higher speed coupled with more and more automatic (cybernetic) control of train operations and movements. There is also a continuing trend toward the construction of more all-electrified mainlines, especially at 25 kV, 50 Hz. Among the electrification projects completed in 1974 were

1. The 32-route-kilometer Paris–suburban line from Noisy-le-Sec to Tournan (energized at 25 kV, 50 Hz), on which revenue service began in January.

2. The 90-km-long 1500-volt dc line between Chambery and Modane (in southern France, near the Italian border), scheduled to begin revenue service this month.

In addition, a modernization program is underway to update and adapt many of the older existing catenaries for very-high-speed passenger service. The French National Railroad's (SNCF) heavy-duty class "CC 6500" and "CC 21000" six-axle 122-tonne locomotives will be used on both the modernized and newly completed mainline electrified lines. These two classes of all-electrics (the 6500s operate only on the 1500-volt dc routes, while the 21000s, as two-current machines, can be used in service on both the dc lines and the 25-kV, 50-Hz electric divisions) are among the most powerful (5900-kW continuous rating) and fastest (220 km/h, 135 mi/h) passenger locomotives presently in revenue operation. The CC 6500 locomotive is the class that hauls the famous TEE-train "Le Mistral" between Paris and Nice. Several more of its class CC 21000 counterparts were added to the SNCF fleet during 1974.

New Paris–Lyon line

In early 1974, the French Government approved the construction of a new electrified mainline rail link between Paris and Lyon. It represented a significant step in launching the SNCF into the initial era of very-high-speed rail transportation. To be completed in 1980, this new line will be built at an estimated cost of $460 million, and will be used exclusively by passenger trains running at average speeds of 270 km/h (165 mi/h). This speed will put Lyon less than two hours from Paris; Geneva, 3¼ hours; and Marseilles, 3¾ hours.

Although a great deal of thought was first given to the use of a new generation of turbo trains, the recent energy crisis was the deciding factor in the SNCF's decision to opt for electrification of the line. However, the *Très Grande Vitesse*, or Very High Speed, TGV-001 (the experimental prototype turbo train), which has already covered more than 160 000 kilometers (100 000 miles) at speeds as high as 320 km/h (200 mi/h), is still regarded in transportation circles as one of the greatest accomplishments in modern railway technology. Quieter inside than a jet airliner, it has excellent stability and suspension—and, through continual modifications and retrofit—the TGV served to solve many of the major problems of steel wheels on steel rails at speeds above 240 km/h (150 mi/h).

Unfortunately, the operational economics of the TGV-001 did not indicate a favorable cost effectiveness, since its energy consumption per passenger/seat is 40 percent higher than that of an all-electric train running at the same speeds. And, with energy comprising 12 percent of operating costs—and probably 15 or 16 percent in view of increasing fuel prices—electrification, although it requires heavy initial capital investment, is expected to prove less expensive in the long run. Nevertheless, the all-electric high-speed trains that will run on the new Paris–Lyon route will be similar in exterior design and interior ambiance concepts to the most recent turbo trains.

Other overseas developments

In Brazil, last September 11, Sao Paolo—the largest city in South America (population more than 7 million)—opened the first section of its new subway system for limited revenue service. The initial run of the north–south downtown line is about 6-km (4-mi) long and comprises six stations. At present, the line carries passengers only between the hours of 9:00 a.m. and 1:00 p.m., and may actually be considered as functioning in "demonstration mode." The ATC system was supplied by Westinghouse Electric Corp. and is a scaled-down version of the cybernetic equipment used on San Francisco's BART service.

Capable of a maximum speed of 100 km/h (60 mi/h), the Sao Paolo subway vehicles were built in Brazil by a licensee of the Budd Company. The propulsion motors are chopper-controlled and collect power from a 750-volt dc conductor. Friction braking is supplied by Westinghouse Air Brake Company (WABCO).

Full service along the projected 16-km-long (10-mi) route is scheduled for August of this year, when day and night operation will be in effect. The ATC, however, will be used only at night; manual operation will be employed during the day. An east–west line is contemplated for construction in the future.

Milan's Metro

In Italy, the Milan town council last June approved the Metropolitana Milanese's recommendation to let contracts for the new "red line" subway extension from the existing "QT8" terminal to the city line.

British Rail's HST and APT routes—both electrified and nonelectrified—projected to 1985. Along the west coast may be seen the London–Glasgow electrified line that began passenger revenue service on May 6, 1974.

Random notes

State-of-the-art car (SOAC):

The SOAC program, sponsored by the Urban Mass Transportation Administration (UMTA) was an initial breakthrough for the rail-transit industry. The testing program in 1974 consisted of running the SOAC on the subways and/or commuter lines in several eastern cities—including New York, Boston, and Cleveland—to ascertain the capabilities of this type of vehicle.

Linear-induction motor project:

At the Department of Transportation's Pueblo, Colo., testing ground, a world's speed record for steel wheel on steel rail was achieved during 1974—410 km/h (256 mi/h), with turbojet assistance.

Amtrak locomotives:

General Electric's Transportation Systems Division in Erie, Pa., is building 26 class E60CP three-current (25-kV, 60-Hz; 12.5-kV, 60 Hz; and 11-kV, 25-Hz) passenger locomotives that will be compatible with existing catenary power sources in the U.S. The initial changeover from one system to the next will be made by the locomotive operator. Purchase of these locomotives by Amtrak represents a policy decision in using head-end traction power instead of the multiple-unit train set concept for intermediate speeds up to 200 km/h.

Amtrak is also buying 150 diesel-electric (six-axle, 2200-kW) units from General Motors' Electro-Motive Division that have the capability of operating on five separate railroad rights-of-way: Santa Fe; Union Pacific; Illinois Central; Penn Central; and Richmond, Fredericksburg & Potomac. These locomotives will have cab-signal and train-control flexibility required for the diversified signal and communication systems on these railroads.

Other traction equipment:

GE-Erie is building 500 diesel-electric locomotives of various types and rail gages for shipment to railways in the U.S. and overseas.

Stored-energy rail-transit car:

A flywheel-type stored-energy car was tested last year by the New York City Transit Authority. The energy conversion scheme was tried on Budd Company type R-32 subway cars.

Multiple units:

GE's Erie division completed the last of its 144-unit order of "Cosmopolitan" MU cars for the New Haven division of the Penn Central. These two-current vehicles are equipped with both pantographs and contact shoes for overhead current collection at 11 kV, 25 Hz; and 650-volt dc at the third rail. Included in this order were 20 deluxe bar/lounge (café) cars for the comfort and convenience of commuters.

In addition, GE is building 214 MU cars for the Southeast Pennsylvania Transit Authority (SEPTA) and New Jersey's Department of Transportation projects. About 100 of these vehicles were delivered by the end of 1974.

Washington Metro

The construction will be mainly cut-and-cover, with the exception of a tube section where it passes beneath the Olona River. The extension will include four new stations. The line will primarily serve the residential northwest area of the city which contains many high-rise apartment projects. The new stations will feature "park-and-ride" facilities for the convenience of commuters coming in from the suburbs along the nearby northwest motorway. The estimated cost of the project is 16 billion lire (about $28 million).

Recently, the Italian government granted 100 billion lire ($175 million) to modernize the Ferrovie Nord Milano's suburban commuter rail system. The improvements will entail the upgrading of rights-of-way, the construction of new stations, grade-crossing elimination, the incorporation of ATC systems, and the purchase of new high-speed rolling stock. The suburban system will eventually connect directly to the subway "red-line" extension. (In 1972, the Ferrovie Nord Milano system carried 28 million passengers, and this figure is increasing annually at a rate of about 6 percent.)

In Switzerland, an experimental inverter locomotive (class Be 4/4), built jointly by Brown, Boveri (BBC) and Swiss Federal Railways (SBB), has been in regular service—hauling scheduled trains—during all of 1974. Both BBC and the SBB believe that the operation of this locomotive in scheduled hauls provides an excellent opportunity to test the function and performance of its electrical equipment under actual traction-load conditions. The builders believe that caternary-fed inverter traction vehicles, with static frequency converters, can be considered as significant progress toward a future generation of advanced traction vehicles. The salient feature of the specially built Be 4/4 is that it has a "commutatorless" traction motor on each of its four axles.

Domestic notes from the underground

There is encouraging news from the San Francisco Bay Area. The controversial BART system, after a long delay, finally began service through the 5.75-km-long (3.6-mi) Transbay tube—the underwater link connecting San Francisco and Oakland—to complete virtually full system service throughout the 114-route-km (71-mi) rapid transit line in San Francisco, Alameda, and Contra Costa counties. Trains are now operating at regular 12-minute intervals (irrespective of time of day) under ATC—with certain restraints imposed by the Public Utilities Commission—from about 6:00 a.m. to 8:00 p.m.

In the first week of BART's transbay service, more than 550 000 trips were taken by new and regular system patrons. This marked an increase of about 200 000 trips over the prior week.

With the installation of a $1.3 million sequential occupancy release (SOR) system—designed by Hewlett-Packard—to the existing ATC, BART hopes eventually to bring the train headway down to 100 seconds during peak hours. By next month, or in March, the entire line may be operating 20 hours per day.

Finally, last September, Nello J. Bianco, president of the BART board of directors, conferred with DOT's Urban Mass Transportation Administration officials regarding funds for future extensions of BART rail lines.

Elsewhere, in Washington, D.C., last fall, production was completed on the first pair of Rohr-built METRO cars for the Washington Metropolitan Area Transit Authority (WMATA); these vehicles represent the initial completion in a contract for the construction of 300 cars for the system. (Rohr, incidentally, is the builder of the BART vehicles.)

The WMATA hopes to inaugurate limited service this year in a downtown Washington section of the 158-km-long total system, between Union Station and Farragut North (see *IEEE Spectrum*, pp. 50–54, Nov. 1972).

2nd Avenue subway

And in New York, a 12-year-long construction project finds the largest city in the U.S. pouring $4 billion into a very large hole—for the construction of its long-delayed Second Avenue subway line. Eventually, the new system will add 52 route kilometers (32 miles), for a 15-percent increase in the size of the city's overall subway grid. Included in the project are

- A "split-level" tube beneath the East River that will greatly increase the number of commuter and subway trains to midtown Manhattan from Queens and Long Island.
- A terminal on Manhattan's east side for increased and more efficient commuter flow during peak hours.
- High-speed air-conditioned subway and commuter vehicles (whose cost, alone, may be close to $1 billion).

Computers and electronics

Cybernetic system for Penn Central

The largest digital-computer-controlled rail-traffic system in the U.S. may be placed in service this year by the Penn Central Transportation Co. in the Pittsburgh area. The control system is designed to provide automatic, safe train movement, over a broad industrialized area of western Pennsylvania, and to reduce operating expenses significantly. It will be part of the "Pittsburgh Consolidation" in which 32 interlockings from Johnstown, Pa., to Pittsburgh will be controlled from one point.

This section of the Penn Central is one of the nation's busiest traffic arteries: daily, there are 65 freight trains, four passenger, and four mail trains. They carry an average of more than 100 million tonnes of freight annually.

All control will be centered at Pittsburgh's Penn Central station, where a number of local control stations, along 240 km (150 mi) of rights-of-way that approach Pittsburgh from the northeast and southeast, will be consolidated. The heart of the project is the $1 million control and communications system built by WABCO's Union Switch & Signal Division. This equipment, specified as WABCO System 600—a programmable system for centralized traffic control (CTC)—consists of a control console, display board, digital computer, CRT display, and field equipment racks.

Military and aerospace

Space Shuttle holds top priority at NASA; inflation-crippled military seeks $-efficient defense

DOD spending

Despite a record-breaking $82.7 billion Congressional appropriation for defense in fiscal year (FY) 1975, U.S. Department of Defense officials are so squeezed by inflation and fixed obligations that they are looking forward to a lean year. On the other hand, research and development areas seemed to face a somewhat brighter budget future, but it is feared that here too inflation will erase some of the apparent gains.

Military R&D

In the teeth of procrustean budget limitations, however, key areas of U.S. military/aerospace technology have seen significant recent progress. The space program has continued to register new achievements in exploring the planets, enhancing worldwide communications, and paving the way for future space-shuttle programs.

Work has also continued on basic and strategic defense weapons, including that B-1 bomber, the Minuteman III intercontinental ballistic missile, and the Trident submarine—commonly known as the *Triad*. Two low-cost Mach-2 lightweight fighter prototypes—the YF-16 and YF-17—promise to revolutionize future-generation supersonic flying (see Box, page 88). On the sea, the Navy's multimillion dollar versatile avionics test system—VAST—finally went operational. And in man's second oldest profession, the Army Electronics Command reported such developments as a laser minirangefinder, a millimeter-wave integrated circuit (IC) receiver, a flying electronic warfare lab, and a traveling-wave tube priced at less than $100 (see Box, page 89).

Marce Eleccion Associate Editor

Belt-tightening for DOD and NASA

Budget cutbacks

For Government agencies, the runaway inflationary spiral in 1974 was compounded by the need to work with fewer dollars than had been hoped. Late in the year, President Gerald R. Ford requested $4.6 billion in budget cutbacks as part of a program to curtail deficit spending. The effects of these cutbacks continue to reverberate in 1975 budgets. One result has been an additional $72 million deferred from the newly approved NASA budget; at DOD, Secretary James R. Schlesinger has authorized 111 military base realignments and closings, hoping to reduce support

I. 1974 NASA mission launches

Date	Name*	Vehicle	Test Range†	Mission/Remarks
Jan. 18	Skynet II-A	Delta 100	ETR	United Kingdom communications satellite (unsuccessful; second-stage failure)
Feb. 11	Centaur proof flight	Titan III-E/ Centaur	ETR	Test flight of Viking Mars mission booster rocket (unsuccessful)
Feb. 18	San Marco 4	Scout	SM	U.S./Italy cooperative mission to conduct air-density experiments
Mar. 8	UK X-4	Scout	WTR	United Kingdom scientific satellite
Apr. 13	Westar I	Delta 101	ETR	First domestic (Western Union) communications satellite
May 17	SMS-1	Delta 102	ETR	First operational geostationary meteorological satellite (low orbit because of Delta malfunction)
May 30	ATS-6	Titan III-C	ETR	Public communications satellite (to be moved in 1975 to relay Apollo/Soyuz Test Project communications and TV)
June 5	Hawkeye (Injun-F)	Scout	WTR	University of Iowa geomagnetic/solar-wind scientific experiment
July 16	AEROS-2	Scout	WTR	Orbiting, spin-stabilized satellite for upper-atmospheric measurements (W. Germany)
Aug. 30	ANS-1	Scout	WTR	To study celestial X-ray and UV sources (Netherlands)
Oct. 10	Westar II	Delta	ETR	Western Union communications satellite
Oct. 15	UK-5	Scout	SM	To investigate galactic and extragalactic X-ray sources (U.K.)
Nov. 15	NOAA-4 (ITOS-G), with INTASAT and and Oscar-7 piggy-back missions	Delta	WTR	Polar-orbiting meteorological satellite (NOAA), with two piggy-back payloads—INTASAT (Spain) for ionospheric data, and AMSAT-Oscar-7 for public-service/educational communications
Nov. 21	Intelsat IV	Atlas/Centaur	ETR	Sixth in a series of international communications satellites (COMSAT) with an average capacity of 6000-voice/12-color-TV channels; placed over the Pacific
Nov. 22	Skynet II-B	Delta	ETR	U.K. communications satellite
Dec. 8	Helios-A	Titan III-E/ Centaur D-1T		Joint U.S./West German ten-experiment solar probe to approach within 45 million kilometers of the sun
Dec. 17	Symphonie-A	Delta	ETR	Educational communications satellite (France, West Germany) in synchronous orbit

* Suffix letters indicate prelaunch nomenclature, becoming numerals after launching.
† ETR = Eastern Test Range (Kennedy Space Center, Fla.); SM = San Marco (Indian Ocean) platform; WTR = Western Test Range (Vandenberg Air Force Base, Calif.).

costs by over $3.3 billion within a decade.

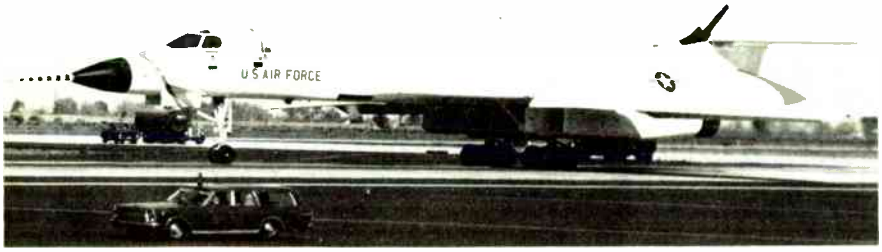
Electronics spending

Department of Defense officials insist that inflation and fixed obligations such as military pensions will eat up most of the apparent FY 1975 increases, resulting in what DOD claims is actually one of the smallest military budgets of the last decade. For space exploration, the handwriting is even clearer—NASA's $3.2-billion budget (FY 1975) is the second lowest since the 1965 all-time high of $5.25 billion.

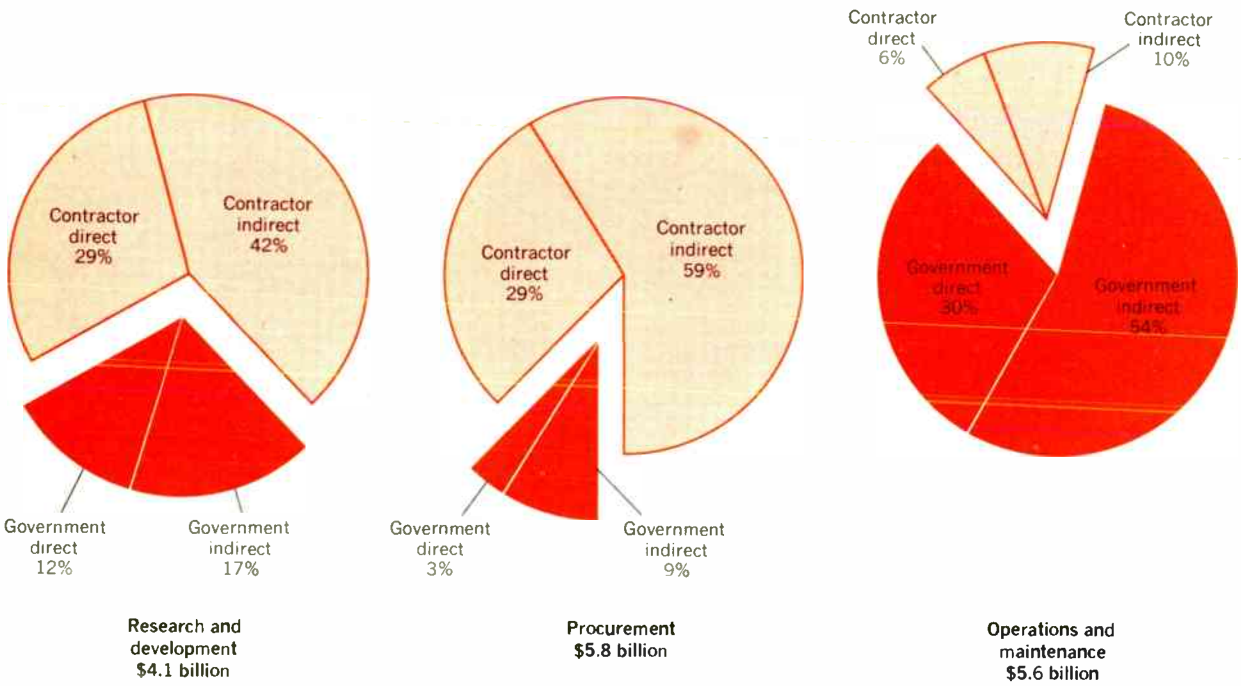
According to U.S. Representative Bob Wilson (R–Calif.), third ranking member of the House Armed Services Committee, $4 billion of defense buying power were lost to inflation last year. As a result of the greatly diminished power of the dollar, those in charge of defense spending are now, more than ever, looking to save money through the purchase of more reliable systems with minimal support costs. For the first time, DOD has even begun to examine the feasibility of imposing system warranty guidelines as a means of encouraging contractors to produce systems with lower support costs.

In an analysis of the cost distribution of the FY 1974 electronics budget (see Fig. 1)—estimated at $15.5 billion—Robert E. O'Donohue, Assistant Director (Planning), Defense Research and Engineering, revealed the startling fact that rising acquisition costs, along with poor field reliability and fixed spending, are resulting in shrinking quantities of weapons systems. Of the total electronics budget, over one third ($5.6 billion) is used to support present systems—almost as much as the cost of the systems themselves; according to a recent ARPA (Advanced Research Projects Agency) report, the present "in-use" electronics inventory is $31 billion.

In a keynote address at the 1974 IEEE Automatic Support Systems Conference on October 30, Jack L. Bowers, Assistant Secretary of the Navy (Installations and Logistics), noted that not only is the cost of new-



Making its debut on October 26, 1974, at Palmdale, Calif., Rockwell International's B-1 bomber took its maiden flight during Christmas week. Scheduled to begin replacing the Air Force's aging B-52 bomber fleet in 1980, the variable-sweep-wing B-1 is 2/3 the size of the B-52, but will carry almost twice the payload and can attain greater than Mach-2 speeds.



[1] Total distribution of the 1974 military electronics expenditure.

generation weapon-systems electronics rising at rates between 15 and 20 percent a year, but "it appears that the ratio of support expenditures to procurement expenditures continues to increase."

At the beginning of 1974, R&D advocates could scarcely contain their joy at the announcement of a $1.7 billion increase in R&D spending for FY 1975—the largest in ten years. By the end of the year, however, economic inflation had forced President Ford to cut the total $19.6 billion R&D budget (including the increase) by $300 million, all of which was to come out of the almost $10 billion apportioned for civilian R&D.

Even for those areas that got the lion's share of the R&D budget—the military ($9.6 billion), NASA ($3.2 billion), and energy ($1.8 billion)—it was feared that inflation would eat up any new gains.

In the existing budget, historic patterns of spending were not to be denied and continued their steady trends from previous years—with the possible exception of astronautics, where support dropped precipitously from its 1974 level (see Fig. 2). R&D allocation for missiles now comprises almost 25 percent of the total military R&D budget, with aircraft and select equipment running a close second and third. It is interesting to note that 1974 marked the first time civilian atomic power R&D surpassed the weapons-related military atomic R&D budget—a direct result of the nation's changing energy priorities.

Atomic energy R&D

If immediate prospects were clouded by inflation and tighter budgets, the long-term outlook may be a happier one for the industry. In an end-of-the-year forecast of Government markets to 1980, the Electronic Industries Association (EIA) recently predicted a somewhat bright future for communications and electronics in general; in EIA's estimation: "With fewer weapons being procured and greater emphasis on qualitative improvements, the use of electronics systems and devices both in ground and airborne systems will increase. High priority on command, control, and communication support systems also dictate greater use of the electronic technology."

Market forecasts

Space exploration

Space Shuttle

In 1974, as sensational results were received from the Mariner and Pioneer unmanned space probes, the many Space Shuttle contractors (see Box, page 86) raced to complete their schedules in the face of stiffening opposition by space scientists defending their own fiscal needs and growing arguments that space traffic in the 1980s would fall short of justifying the Shuttle's high cost. Meanwhile, of the 19 missions launched by NASA in 1974 (see Table I), ten were scientific in nature and eight were communications satellites—including the Westar II on the cover.

NASA launches

Manned space flight—earthbound but still go!

Despite NASA's intention to focus the next decade of deep-space missions on unmanned probes, man will continue to play an active role in space missions as the much-heralded Space Shuttle program nears completion. Slated to spend almost a third of NASA's budget in FY 1975 (see below), the Space Shuttle not only accounts for the major portion of space-supported jobs (estimated at 110 000, in contrast to 400 000 jobs during the peak of the Apollo program), but has much support in Congress, which overrode an attempt two years ago to kill the program.

Scheduled to become operational in 1980, the Space Shuttle will be the product of some 55 major contractors, and will provide a relatively inexpensive means of placing, repairing, and retrieving payloads in space. According to the latest analysis, the distribution of space activity in the 1980s will be:

- Applications (earth resources, communications, navigation, materials processing, etc.) 35%
- Science (astronomy, physics, life sciences, lunar, and planetary) 34%
- Military (Department of Defense) 31%

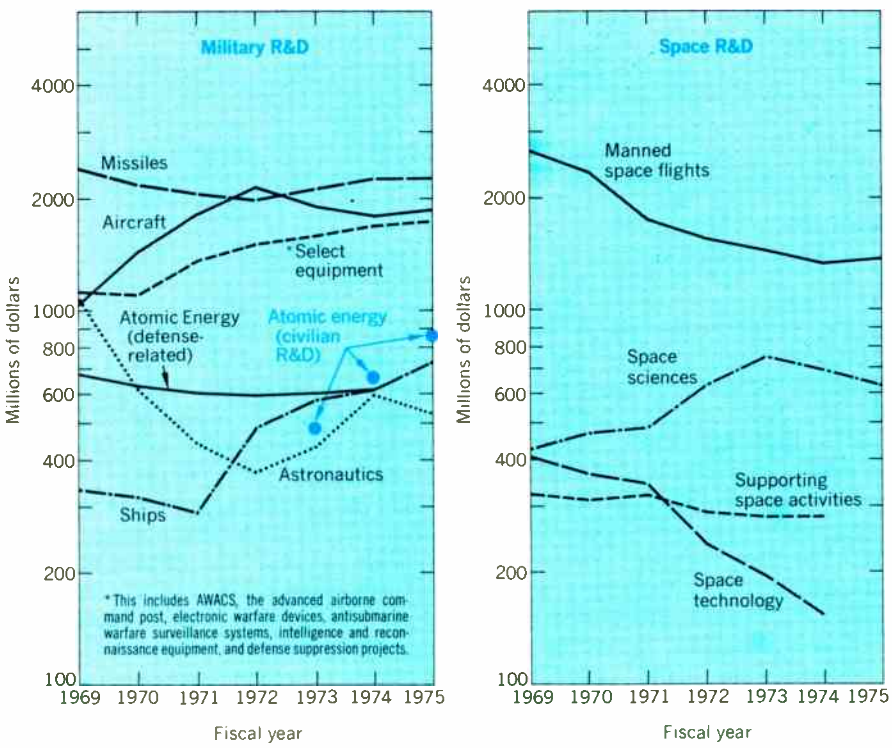
NASA estimates that 60–70 shuttle missions per year will be required to handle the volume of space payloads in the coming decade.

Aside from the Apollo/Soyuz Test Project (scheduled for launch on July 15, 1975)—a joint U.S.–U.S.S.R. mission to conduct space experiments and test docking system compatability—all other manned space flight activity over the next decade involves the Shuttle program (see Fig. 3). The Spacelab (to be developed by nine European countries), is a space laboratory (carried in the Shuttle payload bay) that will allow nonastronaut scientists and engineers the chance to conduct experiments in space for the first time.

Other projects include the Space Tug, a reusable stage with its own payload and the capability of being launched from the Shuttle to even higher orbits (the Shuttle can transport 29.5 kg or 65 000 lb to an 800-km orbit), and the Air Force's reusable Upper Shuttle Orbit-to-Orbit Stage for extended operation, which should be operational by 1980.

Space Shuttle program appropriations

Fiscal Year	R&D	Facilities	Total
1970	$ 12.5M	—	$ 12.5M
1971	78.5M	$ 1.5M	80.8M
1972	100.0M	18.5M	118.5M
1973	198.6M	27.9M	226.5M
1974	475.0M	56.3M	531.3M
1975	800.0M	77.0M	877.0M
	$1664.6M	$181.2M	$1845.8M



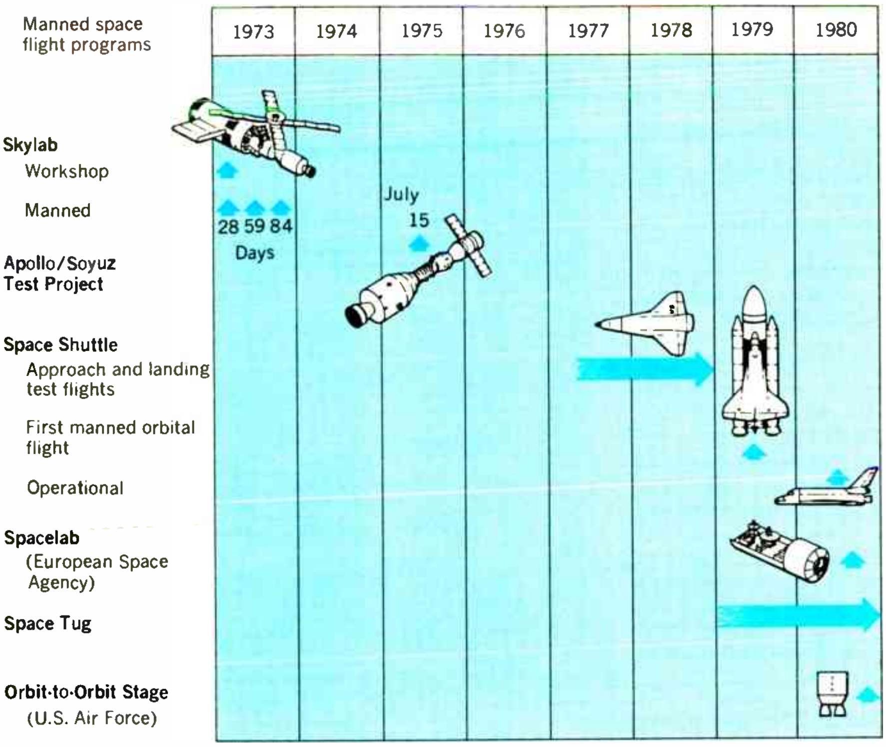
[2] This function breakdown of military and space R&D costs (gleaned from NSF and other sources) shows government priorities in terms of actual program spending. As a comparison, civilian atomic energy R&D has been added in color.

Unmanned probes

The unrivaled success of the Mariner and Pioneer missions, along with debilitating budget inflation, may have been a prime factor in deciding the future fate of space exploration. In the opinion of NASA Director James C. Fletcher, the major thrust of the U.S. space program during the coming decade will consist of unmanned exploration of the solar system, with earth-orbiting manned space shuttles providing new impetus to such space science applications as materials processing.

Of important significance was Dr. Fletcher's revelation late in the year that NASA would *not* play a vital role in energy resource development, ground transportation, or any other nonspace technology.

NASA's involvement with manned space flight activity for the next decade is charted in Fig. 3. In the period from 1973 to 1980, only 1974 and 1976 are inactive manned flight years, although land-based R&D on the Space Shuttle, which was started in 1971, will continue through these years, with plans already started



[3] A look at the manned space flight activity schedule for the coming decade indicates the dramatic departure from the extraterrestrial lunar visits of the Apollo era; note that all manned programs will be confined to earth orbit, mostly based upon Space Shuttle development.

Safeguard—systems experiment or politician's delight?

As part of a ballistic missile defense program worth close to $6 billion, the Safeguard ABM system, completed in October 1974 at Nekoma, N.Dak., has the distinction of being both the greatest systems effort to preoccupy the nation since Apollo and the fulcrum of perhaps the most important bilateral agreement of the nuclear age—the U.S.–Soviet strategic arms limitation talks (SALT). One of the nation's most controversial military programs, Safeguard has been heavily funded over the years and has engaged a plethora of engineering talent in some of the most sophisticated technologies ever developed. The system's true importance, however, may lie in its bartering value during the SALT negotiations, which have limited the mutual deployment of both offensive and defensive missiles.

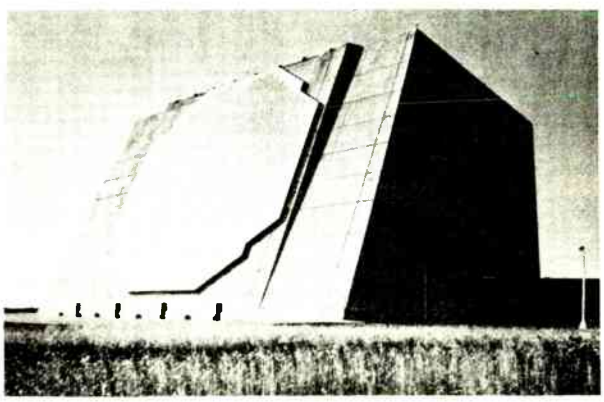
Designed to protect the Minuteman ICBM fields at Grand Forks, N.Dak., Safeguard—an antiseptic labeling that originated in the Nike-Zeus project of two decades ago and evolved through the Nike-X and Sentinel programs—is made up of five major components: 30 long-range *Spartan* interceptor missiles (McDonnell Douglas), 70 high-speed *Sprint* missiles (Martin Marietta), a 120-degree 1800-mile-range phased-array perimeter acquisition radar (General Electric) housed in a nuclear-hardened concrete structure, an omnidirectional 300-mile-range phased-array missile site radar (Raytheon) contained in an underground building, and a central logic and control computer (Bell Laboratories, IBM) to evaluate data accumulated by both radars.

Under the guidance of Bell Laboratories, prime contractor for the entire system, Safeguard has incorporated a number of unique features. Both radars have the ability to track many targets with their thousands of solid-state elements (impossible with conventional slow-response dish radars), with the system still operable even after hundreds of elements are destroyed.

While developmental testing of the Spartan and Sprint missiles has been completed, system tests using the missile site radar were conducted at Kwajalein Atoll in the Pacific during 1974. By the beginning of August, 47 of the test results proved successful, two were partially successful, and five failed.

The Safeguard program in North Dakota (and eventually the Minuteman fields at Malmstrom, Mont.) is but the first step in a site defense development program that cost $110.1 million in 1974; further funding would increase to $160 million in 1975, not including $60.8 million for RDT&E to complete Safeguard research and development.

Safeguard's long-range perimeter acquisition radar.



on the European Spacelab, the Department of Defense's Upper Shuttle Orbit-to-Orbit Stage, and NASA's Space Tug (see Box, page 86).

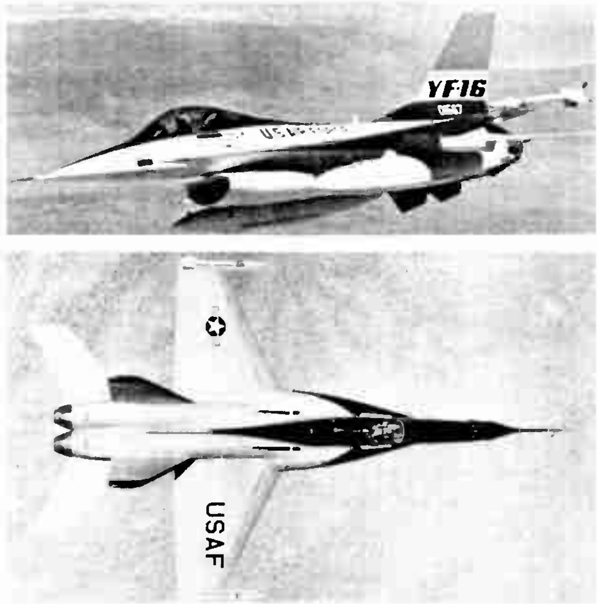
The pattern in manned space flight has been obvious: in 1969, when Space Shuttle activity was nonexistent, the Apollo program consumed over half of the entire NASA budget; by 1973, the last Apollo year, Skylab was accounting for almost 20 percent of the budget; with the splashdown of Skylab 4 on Feb. 8, 1974, the emphasis shifted to the Space Shuttle, **Skylab 4**

F-15, F-16, F-17 . . . tomorrow's fighter today

Almost as soon as the Air Force's new F-15 air-superiority fighter was delivered on November 14, 1974, it seemed that the year-long test evaluation of the prototype YF-16 and YF-17 lightweight fighters at Edwards Air Force Base, Calif., was about to initiate a new era of low-cost air combat planes as "alternatives to high-cost tactical aircraft," in the words of Defense Secretary Schlesinger.

Designed to replace the F-104 Starfighter, F-4 Phantom, Mirage F-1, and F-5 aircraft presently in service throughout the world, one of these two air-combat fighter (ACF) planes will be selected this month by the Air Force as the new-breed fighter of the future—small, light, agile, and, most important, more economical to own and operate than any fighter now flying (see Table). The winner of this competition stands to gain up to $20 billion in both original and follow-up orders. Representatives of four NATO countries have already appraised the two prototypes in a search for a fighter of the 1980s. The F-15's greater sophistication and firepower still make it the plane to beat, however.

The most radical innovation of the YF-16 and YF-17 is their use of a fly-by-wire flight control system that replaces all mechanical linkages from cockpit to control-surface actuators via redundant electronic channels. Consequently, one of the most promising new design technologies—CCV or control configured vehicles—is now a reality.



Test flights of the YF-16 (top) and YF-17.

Comparison of new Air Force Mach-2 fighter planes

	F-15 Eagle	YF-16	YF-17 Cobra
Prime contractor:	McDonnell Douglas	General Dynamics	Northrop
Type:	Single/double-seat air-superiority fighter	Single-seat air-combat fighter	Single-seat air-combat fighter
First test flight:	July 27, 1972 (3300 flights to date)	Feb. 2, 1974 (253 flights to 10/9/74)	June 9, 1974 (200 flights to 11/15/74)
Speed:	Mach 2.5	Mach 2	Mach 2
Range:	Over 3000 miles ferry range	500+ miles combat range; 2000+ miles ferry range	500+ miles combat range; 2600+ miles ferry range
Weight:	40 000-lb combat-ready	17 500 lb combat; 27 000 lb maximum	23 000-lb takeoff weight
Engine:	Two Pratt & Whitney F100-PW-100 turbofans (25 000-lb thrust each)	One Pratt & Whitney F100-PW-100 turbofan (25 000-lb thrust)	Two General Electric YJ101 turbojets (15 000-lb thrust each)
Weapons:	20-mm M-61 cannon 4 AIM-9 Sidewinders 4 AIM-7 Sparrows	20-mm M-61 cannon 2 AIM-9 Sidewinders	20-mm M-61 cannon 2 AIM-9 Sidewinders
Dimensions:	64 ft long; 43-ft wingspan	47 ft long; 30-ft wingspan	56 ft long; 35-ft wingspan
Features:	• Visual head-up display • Automatic built-in test • Central digital computer • Operational redundancy • 30% titanium	• Visual head-up display • Fly-by-wire controls • Automatic leading-edge flaps • Look-up/look-down radar • Blended-wing body	• Visual head-up display • Fly-by-wire controls • Leading and trailing edge flaps • Twin-canted vertical stabilizers
Comments:	• Same size, but 6000 lb lighter than F-4E Phantom; 40% less maintenance; 3 times more reliable	• Thrust-to-weight ratio 1:1.3 • Combat radius 3 times the F-4, with twice the acceleration rate	
Cost:	$7.5 million	$3.5 million	$4.5 million

which represented almost one fifth of NASA's appropriation, and is now not quite a third.

NASA's most dramatic results during 1974 were in the area of space science—a category that includes the deep-space unmanned satellite probes. After passing Venus on February 5, Mariner 10 then used the "slingshot" effect produced by that planet to propel its way toward Mercury, passing that planet on March 29, the first such visit by any spacecraft. After several Earth-controlled adjustments, Mariner 10 then reencountered Mercury on September 21. A third encounter is planned for March 16, 1975, but no additional pictures will be taken.

On the heels of 1973's Pioneer 10 flyby of Jupiter, Pioneer 11 encountered that planet on December 5, 1974, speeding up to a sizzling 169 000 km/h (106 000

ECOM—in the forefront of military R&D

One of the major commodity agencies of the Army Materiel Command, the Army Electronics Command (ECOM) has been famed for its military electronics systems for over half a century. In appraising the "most noteworthy technical achievements" of 1974, Director Robert S. Wiseman selected the following:

In completing the design of a laser minirangefinder, ECOM has established a new family of such aiming devices for directing the firepower of small weapons. Capable of giving accurate range information of up to 1 km, this device will not only be miniaturized, but will contain a throwaway low-cost *Q*-switched laser cartridge.

Now under experimental use for secure communications systems, an all-solid-state compact 60-GHz IC receiver represents the culmination of prior efforts to develop a family of millimeter-wave silicon devices. The new receiver eliminates the need for very costly metal waveguides now used.

A laser crosswind system (LCS) can now measure winds that are transverse to the path of interest. Intensity fluctuations in the light are analyzed as they are carried past the detector by the wind.

The "Big Crow" airborne electronic warfare (EW) lab, a flying electronic laboratory, successfully completed flight testing in 1974 and will provide the Army with the capability of creating electronic warfare environments for the susceptibility/vulnerability analysis of missile and support systems.

A normal traveling-wave tube (TWT) design using printed microwave circuits within the tube envelope was developed for *S*-band operation. The new 2-kW tube features a simple electron-gun design, deposited circuitry, and minimal parts. Production cost is expected to be less than $100, in contrast with the $1000 for conventional TWTs in wide use today.

mi/h) as it passed. Whereas Pioneer 10 is the first man-made object to head completely out of the solar system to cruise interstellar space (crossing the orbit of Pluto in 1987), Pioneer 11 will be the first spacecraft to use one outer planet to "kick" itself to another; in September 1979—after traveling over 2 billion miles—the satellite will begin sending back to Earth the first closeups of Saturn and its rings.

Earth—the communications platform

As seen in Table I, all NASA launches during 1974 carried earth-orbiting payloads. With almost half of these shots communications-oriented, man drew closer to the day of a completely worldwide automatic communications network.

Westar I, the first successful communications launch of the year, also happens to be the first U.S. domestic communications satellite. Made up of 12 separate transponders, *each* able to relay data at 50 Mb/s (8 million words/s), one color television channel with audio, or 1200 one-way voice channels, Westar I was joined by a second Hughes-built satellite—Westar II—six months later. When completed, the Western Union system will operate three satellites and five associated Earth stations via a microwave link that covers all 50 states and Puerto Rico. With Westar-1 becoming operational July 16, 1974, it was estimated that the new system would cut current terrestrial communications costs by as much as 50 percent.

On May 30, NASA launched the most versatile and powerful communications satellite ever built—the 1402-kg (3084-lb) ATS-6. Designed to transmit health and educational TV programs to small low-cost ground receivers located in isolated communities throughout the world, the geosynchronous $180 million satellite (developed by Fairchild Industries) contains more than 20 experiments that will be deployed over the next few years, including instructional programming to such areas as Appalachia (U.S.) and India. ATS-6 will also be used for tracking and relaying data from the Apollo/Soyuz mission later this year.

The sixth in a series of commercial communications satellites launched by NASA for the Communications Satellite Corp. (COMSAT), Intelsat IV is the second to be placed over the Pacific to facilitate telephone, TV, and data transmission traffic over that area. Capable of 6000 voice or 12 color-TV channels per satellite, the system serves over 100 countries through 120 antennas at 80 stations in 58 nations.

Economizing air flight

As the oil crisis loomed, the aerospace industry looked for better ways to conserve this precious commodity. At NASA, two new developments in wing design promised to revolutionize future air flight.

An advanced swing-wing design—which provided solutions to a number of transport aircraft problems—takes the form of a wing-fuselage combination configured much like the two halves of a pair of scissors (with the fuselage one blade and the full-wing length the other). The straight wing is mounted above the body and is turned to the oblique angle that gives best performance at a specific flight speed. At slow flight, the wing is fixed at right angles to the fuselage, allowing landings and takeoffs with a minimum of power and noise. A needle-nosed version of the swing-wing design would be able to operate at speeds from 800 to 1400 km/h (500 to 900 mi/h). Because of such operating efficiency, shorter flight times could be obtained with less fuel consumption. Although under investigation for several years by Boeing, the concept was converted into an integrated design for jet aircraft for the first time in 1974.

And presently under test at Langley Research Center, a new airfoil for light aircraft called the GAW-1, a derivative of the supercritical airfoil, has demonstrated a potential for up to a 30-percent increase in lift over present general-aviation wings. Flight-tested on a Piper Seneca aircraft, the new wing design has a 25-percent reduction in area, and an increase in lift-to-drag ratio of 50 percent.

Information for this article came from many sources. Major contributors were: Donald L. Zylstra at NASA Headquarters and Sajjad Durrani of Goddard Space Flight center, as well as sources in the Pentagon.

Westar I

ATS-6

Intelsat IV

Instruments and test equipment

Simplicity and sophistication are bywords as portables shrink and systems instrumentation grows

1973 trends like increasing computational power at eroding prices continued through 1974 despite runaway inflation in the rest of the world economy. Advances in digital- and analog-IC technologies, as well as in discrete and hybrid components, were primarily responsible. And one of the principal advances involved the microprocessor, introduced in laboratory instruments during 1973 and gathering momentum through 1974. Looking back over the year, highlights in instrumentation technology included:

Systems instrumentation

- Fierce price competition among manufacturers of low-cost instruments (digital multimeters, function generators, oscilloscopes, and frequency counters) due to wider use of LSI (large-scale-integration) ICs. (Prices have been diving as low as $100 to $200 for some digital multimeters and function generators.)
- The emergence of a strong programmable-, systems-instrument trend indicating that the systems byproduct of automatic testing is the answer to better product reliability and lower manufacturing costs.
- The proliferation of a new class of instruments—digital logic analyzers—for analyzing, understanding, and troubleshooting complex digital logic circuitry.
- The gathering impact of the microprocessor on instrument design. (More powerful and flexible microprocessor-based instruments can be expected.)

Automatic testing

- Continuing efforts to improve and expand instruments into the microwave regions.
- An increase in storage-oscilloscope writing speeds, and a combining of other instrument functions with that of the oscilloscope.

Lowering cost with LSI

The LSI IC has meant more instrument functions on the same chip, resulting in a lower component count (within the instrument), lower power dissipation, and better reliability, all of which mean a lower instrument price tag. Device manufacturers are nevertheless still plagued with low LSI yields and reliability problems, both of which have been improved.

Instrument interface bus

Manufacturers are constantly trying to make instruments—notably digital multimeters—even tinier by cramming circuitry onto as few chips as possible. Hewlett-Packard's Model 970A autoranging probe multimeter with a 3½-digit display is an example. It consists of a single hybrid IC and 21 additional components. The instrument easily fits into a pocket and is so small, the manufacturer had to sell a security cradle to prevent pilferage.

Tiny digital multimeters

Low-cost, miniature portable instruments that became commercially available during 1974 abound. (A few significant ones are listed in the box on p. 91.) What low prices have meant is that no laboratory need be devoid of basic measurement instruments, even on tight budgets. For roughly $1000 to $1500, a complete set of basic instruments may be had, compared to an outlay of roughly $5000 only four to five years ago for similar-performance instruments.

Roger Allan Associate Editor

Automatic systems instruments

The big challenge to future instrument designers is not so much to produce better-performance instruments, nor to build cheaper ones. It is and will be to design instruments that interact with one another in a system. Two to fifteen years ago, instrument systems were unsophisticated. Few instrument companies were able to build systems. Those systems that were designed were usually one-of-a-kind specials that rarely fulfilled a customer's performance objectives even though they met design goals. Few designers understood such factors as systems noise, interactions, and interfacing. There simply wasn't any systems technology, nor were there enough systems built—hence, few dollars were available to refine designs and discover causes of noise and interactive effects.

Today, systems technology is receiving increasing attention. Layout, cabling, interfacing, cooling, electrical interactions, noise generation and sensitivity, and calibration are being left less to chance and are being dealt with on a design basis.

Hewlett-Packard, supported by most instruments manufacturers, has taken a major step forward in simplifying the problem of instrument interfacing with its HP-IB interface bus (see *Spectrum,* Nov. 1974, pp. 52–57). A standard within the company itself, it was the model for the draft document released in Bucharest, Rumania, in October 1974, by Technical Committee 66 of the International Electrotechnical Commission (IEC) for balloting among IEC member nations.

The interface bus solves the fundamental problem of interfacing from a hardware standpoint (connectors, cables, drivers, receivers, etc.) and provides a protocol that enables interconnected system components to communicate effectively.

Currently, the list of equipment compatible with the HP-IB bus is growing rapidly and covers a wide range of applications. An example of an assembled package with such an interface bus is in Fig. 1.

As for automatic testing itself, the vast majority of instrument systems developed so far are for testing digital circuits on the printed-circuit board. A few analog and hybrid-circuit (both analog and digital) test systems exist; however, general-purpose programmable testers for analog components are much more

Some low-cost, 1974 instruments

While a complete listing of all 1974 low-cost, miniature instruments is not possible, the following are representative of the trend:

Dana Laboratories' Danameter with a 3½-digit, liquid-crystal readout sells for $195 and runs off a 9-volt transistor-radio battery for one year's normal use. It is a small instrument with dimensions of 10.16 by 18.42 by 5.72 cm. Tekelec's Model TA357, a 3½-digit, $179 multimeter measures 24.13 by 6.35 by 13.34 cm and weighs just 5.6 kg. This unusual instrument includes a 20-kV dc probe, measures leakage current to 10-pA resolution, and conductance to a sensivity of 10^{-12} mhos. Its battery operated companion, model TA 356, sells for $289, which includes the batteries and a charger.

Other tiny digital multimeters came from Data Technology and Ballantine Laboratories. The former's model 21, which also measures capacitance, is the size of a hand-held calculator at 15.24 by 8.26 by 4.45 cm and weighing a scant 0.34 kg. The dimensions include a carry pouch that fastens onto one's belt. Cost of this 3½-digit multimeter is $269. Ballantine's model 3/24 is a 3-digit, pocket-sized unit that weighs 0.57 kg, and has dimensions of 14 by 6 by 18 cm. It retails for a low price of $195.

Wavetek introduced a 200-kHz, $149.95 trifunction generator (model 30) that also operates from a 9-volt transistor-radio battery (with dimensions of 13.31 by 6.99 by 21.92 cm. Exact Electronics' model 195 function generator is a similar unit with the same price.

Tiny oscilloscopes, like Tektronix's $775 model 221, a single-trace, 5-mV/division (0.51 cm per division) instrument that weighs a mere 1.6 kg, including batteries, and has dimensions of 7.6 by 13.3 by 22.8 cm, demonstrate how integrated device technologies have helped make instruments truly miniature. This "miniscope" follows several others that Tektronix, Vu-data, and Phillips Instruments have introduced in the last three years.

Low cost wasn't necessarily restricted to portable, miniature instruments. Many bench-top instruments have been dropping in cost. Examples during last year include Data Precision's model 1450, a 4½-digit, $325 multimeter; United Systems' Digitec model 2110, a 3½-digit, $219 multimeter; Dynascan's B&K model 282, a 3½-digit, $200 multimeter; and Tekelec's model TA355, a 3½-digit multimeter at $289, and model TA365, a 4½-digit multimeter at $395.

Frequency counters for 1974 also dropped in price. Fluke's $349, 80-MHz model 1900A and $299, 40-MHz model 1941A were examples. So were Hewlett-Packard's model 5381A/5382A,' 80/255-MHz, $249/$450 counters, and United Systems' Monsanto 8700 series which included a 150-MHz model 8720 counter for $595.

There were even oscilloscopes available for less than $700 for large bandwidths. Examples included Systems Electronics' models 77 (single-trace) and 87 (dual-trace) 20-MHz (updated from 15-MHz), 10-mV/cm oscilloscopes costing $550 and $625, respectively. Both have 10.16-cm CRTs. Simpson introduced models 455 (single-trace) and 459 (dual-trace) 15-MHz units with 10-mV/cm sensitivity and 12.7-cm CRTs at $325 and $450, respectively. RCA's WO-3313 with a 5-MHz bandwidth, 3.9-nV/cm sensitivity (p-p) and 7.62-cm CRT sells for $229. The Scopex 4D-10 (distributed by Jermyn Industries) is a 10-MHz, 10-mV/cm instrument with a 6- by 8-cm CRT and a $456 price tag.

difficult to design than those for digital components, whose bistate (ON or OFF) levels and transistors are much easier to generate and test than an unlimited number of possible analog waveforms.

Fault simulation

Fault-simulation systems seem increasingly to be the answer. Such computer-based, software systems simulate assemblies to be tested and pinpoint specific component faults, regardless of whether circuit components are digital, analog, or both. The only drawback with such systems is that they cost too much—as much as $100 000 or more. Hopes are high that the growing use of the microprocessor—particularly lower-cost, higher-speed ones—will drastically reduce such systems' prices, as the microprocessor takes on more of the computer's tasks.

Logic analyzers

As digital logic circuitry became more complex, and attained higher speeds, traditional oscilloscopes, which themselves had been increasing in bandwidth (500 MHz in real time for Tektronix's Model 7904 and 1 GHz at reduced sensitivity by direct access to the CRT), were not sufficient for analyzing and understanding the complex timing and amplitude relationships of digital logic circuitry. Thus, logic analyzers were born.

The newest such instrument, announced in March of 1974, is Biomation's model 8200 digital logic recorder with a 200-MHz data rate. Joining a pair of earlier (1973) entries—Hewlett-Packard's model 1601L logic state analyzer and E-H Research's model AMC 1320 Digiscope—it completes the most advanced trio of instruments for digital logic analysis. It should be emphasized that the 1601L analyzes logic states only, whereas the 1320 and 8200 analyze asynchronous timing relationships among logic signals as well. All three make use of a CRT screen for displaying the analyzed digital data (see *Spectrum*, Nov. 1974, pp. 85–86, and Dec. 1974, pp. 63–70).

The early hand-held digital logic analyzers have gone well beyond simple go/no-go checks in capability. For example, Computer Product Service and Research and MITS introduced two advanced hand-held analyzers—models 0617B and MS-416 Mitscope, respectively. The former measures, stores, and displays up to 20-MHz data on 32 light-emitting diodes

[1] **Hewlett-Packard's model 3042A automatic network analyzer system shown with an oscilloscope and an X:Y plotter, all tied together with the company's new HP-IB instrument interface bus, a proposed interface standard.**

(LEDs) in two rows of 16 bits each. The latter uses 64 LEDs in four equal rows, at up to 500 kHz.

The microprocessor revolution

While several instruments were introduced last year using microprocessors, the microprocessor's role in instrument design is only in its infancy. But expectations of lower prices and greater variety are inspiring designers to incorporate them in almost every type of instrument. By containing all input and output, as well as signal-processing functions on the same chip, the microprocessor allows an instrument designer to add, expand, reconfigure, or totally change an instrument's measurement functions, quickly, inexpensively, and without worrying about adding large components to the basic instrument.

High-speed storage

Specifically, the microprocessor is expected to increase greatly measurement accuracy and resolution, by increasing measurement speed, thereby reducing the effects of drift with time and temperature. Simple diagnostic subroutines with microprocessors will allow instruments to self-check for improper operation due to internal faults or lack of calibration and possibly to take corrective action (in case of lack of calibration). All this means lower service costs.

The increasing use of electronic equipment by non-electronic personnel calls for equipment that is easy to operate. The microprocessor can be expected to perform all the front-panel functions such as range changing, function changing, and interpretation of displayed results.

One of the greatest potential benefits of the microprocessor is low-cost interfacing of several instruments with little or no external interface circuitry.

Micro-processor in a scope

Instruments using microprocessors last year included:

- Hewlett-Packard's model 1722A dual-channel, 275-MHz oscilloscope (Fig. 2) which, in addition to its analog trace display, has a digital LED readout of voltage magnitude, time interval, signal frequency, as well as a number of other parameters.
- Boonton Electronics' model 76A capacitance bridge (Fig. 3), which measures capacitance and conductance, and converts both parameters via microprocessor programs to display digitally such things as dissipation factor, Q, equivalent series capacitance, and equivalent parallel resistance.
- Hewlett-Packard's model 3580A low-frequency spectrum analyzer; its model 3551A portable test set; and its model 3805A distance meter.

The microwave domain

Progress in microwave instrumentation has always been in the forefront of the measurement sciences, and in 1974, there was no exception to the rule. More stable power meters, higher-frequency spectrum analyzers and counters for time and frequency measurements, wider-band microwave sweepers, and coaxial connectors to 40 GHz were last year's highlights (Table I).

"Smart" microwave instruments

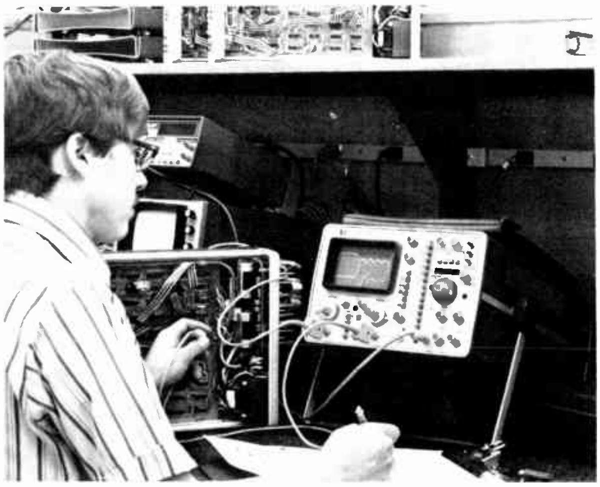
There were "smart" microwave instruments as well. Systron-Donner's model 7100 Data Normalizer with a digital memory is used to improve sweep-system accuracy and greatly speeds up the testing of microwave components. The 7100 normalizes input data vs. frequency.

From Pacific Measurements, model 1038 transmission and reflection test set also includes a digital-data linearizer.

There were advances in the power-dissipation levels of microwave resistor films, resulting in coaxial attenuators with higher-power ratings at no increase in physical size. The SQUID (superconducting quantum interference device) was employed at the National Bureau of Standards for both low-level power and high-accuracy attenuation measurements. This cryogenically cooled device allows −50-dBm measurements to 1 GHz at ±3 percent; and loss measurements to 45 dB within ±0.002 dB relative to primary piston attenuator standards.

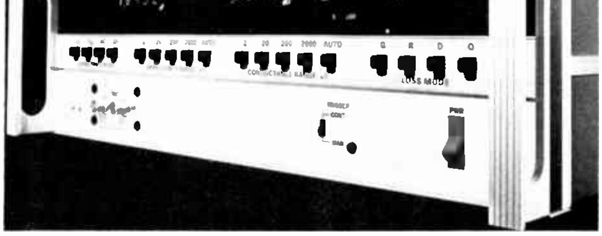
Oscilloscope storage rates are rising

The concept of storage in oscilloscopes began in the early 1960s. Since then, oscilloscope manufacturers have been trying to push storage writing speeds to new heights (Fig. 4) while at the same time developing newer storage techniques (Table II). Hewlett-Packard and Tektronix are responsible for nearly all



[2] The microprocessor has invaded the oscilloscope. Hewlett-Packard's model 1722A is being used to measure propagation delay through a digital logic board. By adjusting the two waveshapes on the CRT screen's display so that they cross each other at a 50-percent point, the operator can read out digitally, on the front panel, the exact amount of time delay between them. Several other parameters may be read out directly.

[3] This capacitance bridge from Boonton Electronics uses a microprocessor that converts both capacitance and conductance parameters to dissipation factor, Q, equivalent series capacitance, and equivalent parallel resistance. Model 76A displays all measured values digitally.



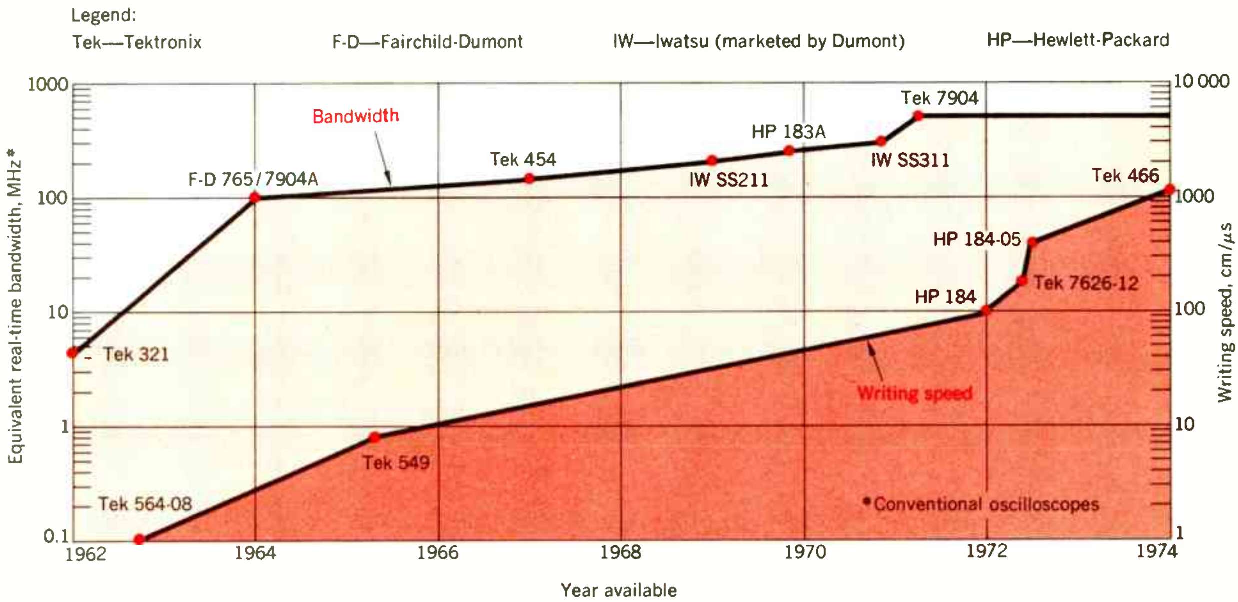
I. A sampling of microwave-instrument development highlights in 1974

Measurement Function	Performance Highlights	Instruments	Trend
Impedance measurement	Slotted line with 1.005:1 maximum total VSWR over 2–18 GHz	Weinschel Engineering Model 1024 with precision 7-mm connector	More repeatable, longer-life, and accurate precision connectors without calibration correction
Power measurement	Low-VSWR thermoelectric RF head (1.2:1 maximum over 30 MHz to 12.4 GHz, and 1.3:1 maximum over 12.4 to 18 GHz)	Hewlett-Packard's Model 8481A sensor	Less drift at low power levels, increased sensitivity, reduced mismatch uncertainty, and higher-frequency ranges
	Drift-free high sensitivity (from 30 μW to 100 mW full scale in ten ranges)	Hewlett-Packard Model 435A power meter with internal 1.00-mW (50-MHz) calibrator	
	Increased frequency range (10 MHz to 22 GHz) of SMA connector	General Microwave Model 440-A thermoelectric power meter	
Spectrum analysis	Frequency range of 1 MHz to 22 GHz with 10-GHz window. Single ranges of 2–12 and 12–22 GHz	Ailtech Model 70710-004 spectrum analyzer	Higher frequency, larger window, smaller bandwidth, higher sensitivity, and digital storage of data
	Frequency range of 30 Hz to 1.8 GHz, —128-dBm sensitivity, 30-Hz resolution	Tektronix Model 7L13 spectrum analyzer plug-in with model 7613 oscilloscope mainframe	
Time and frequency measurements	—30-dBm sensitivity, 40 MHz FM p–p worst case, and 200 MHz FM p–p best case. Range of 20 Hz to 18 GHz.	EIP Model 351D frequency counter	Automatic single-range operation, high frequency, better sensitivity, more accuracy in the presence of large FM signals, and higher-resolution time measurements
	Single range of 10 Hz to 23 GHz	Hewlett-Packard Model 5340A frequency counter with option	
Swept-frequency measurements (multiband)	+10-dBm output at 0.01 to 18 GHz	Weinschel Engineering Model 4310A/K-16 sweep oscillator	High-output-power multiband leveled sweep frequencies over 1–18 GHz
	+7-dBm output at 1 to 18.5 GHz	Narda Microwave Model 9535 sweep oscillator	
	+10-dBm output at 2 to 18.5 GHz	Wiltron Model 6237/610C sweep oscillator	
	+13-dBm output at 1 to 18 GHz	Singer Model 1100/9514E/9515E sweep oscillator	
(Medium-power, solid-state)	YIG-tuned sources: 50 mW at X and Ku bands	Varian Associates	Higher power, wider bands, faster switching, greater linearity, and less temperature sensitivity
	Leveled, 30-mW output over 1–8 GHz in three bands;25 mW over 8–12.4 GHz; and 20 mW over 12.4–18 GHz	Weinschel Engineering Models 431-AP-1 through 435-AP-1 sweep oscillators	
(Above 18 GHz)	+7-dBm output over 18–22 GHz	Wiltron Model 6132C YIG-tuned RF source	+7-dBm output power over 18-26 GHz; full-waveguide bands including leveling
	4-GHz bands from 32-40 GHz and 10-GHz band from 40–90 GHz. Output powers of 100 to 250 mW (50–75 GHz), and 50 to 200 mW (75–110 GHz)	Hughes Aircraft IMPATTRF sources	
Frequency synthesis measurements	Octave-band, programmable, over 0.5–18 GHz (in six ranges) with output from 20 to 10 dBm. —15- to —20-dB harmonic content	Watkins-Johnson Model 1250-1 through -6 frequency synthesizer	Single wideband range, multiple-band coverage, 10-dBm output, rapid programming
	Five-range, programmable 0.1–18 GHz with +3-dBm output and —65-dB harmonic content, +3-dBm output to 12 GHz and 0 dBm 12–18 GHz	Microtel Model SG-800A frequency synthesizer	

II. A comparison of the four leading oscilloscope storage techniques*

Storage Technique	Maximum Writing Speed	Storage Duration	Capabilities	Applications
Bistable phosphor	Above 5 cm/μs	Hours	Split-screen; long view time	Mechanically generated slow-step responses
Variable persistence (halftone)	Above 400 cm/μs	Seconds to minutes	Brighter traces of low-repetition-rate signals; gray-scale image	Noisy signals; low-repetition signals
Fast transfer	Above 1300 cm/μs	Seconds to minutes	Fastest oscilloscope writing speed	Fast, step responses; fast single-shot events
Digital	Depends on technique; ranges from 10–8000 cm/μs	Indefinite	Pretriggering; numerical processing; data logging	Extremely fast transients inputs to be digitized; long digital sequences

* Source: Tektronix



[4] Oscilloscope storage writing bandwidths have been rising rapidly in the last ten years. A comparison of storage writing speeds with bandwidths of real-time oscilloscopes shows storage to be closing the speed gap (Source: Tektronix.)

of these oscilloscope developments.

At last year's INTERCON, Tektronix introduced its model 466 storage oscilloscope with a 100-MHz nonstorage bandwidth and a storage writing rate of 1350 cm/μs (in a reduced-scan mode), the all-time high for a direct-view storage oscilloscope (Tektronix's R7912 transient digitizer has an equivalent writing speed of 8 million cm/μs, but it is not a direct-view instrument). As can be seen, the storage writing speed actually exceeds the bandwidth of the oscilloscope's vertical amplifier.

Hewlett-Packard's model 1722A microprocessor oscilloscope and Tektronix's DM43/465 multimeter/oscilloscope could be the start of a trend: adding multimeter capability to the oscilloscope. While the former measures voltage amplitude and time differentials, the latter (DM43) can be used atop any Tektronix model 464, 465, 466, or 475 oscilloscope to measure voltage amplitude, resistance, temperature, and differential time-delay intervals.

Last year, Tektronix introduced the SC501 oscilloscope plug-in as a complement to the already existing, large number of plug-ins in the company's TM500 line. These include a function generator, a digital multimeter, a frequency counter, and a pulse generator, among others. ◆

Information for this article came from many sources. Major contributors were: Marco Negrete of Hewlett-Packard, Bruno Weinschel of Weinschel Engineering, and Peter Richman, private consultant.