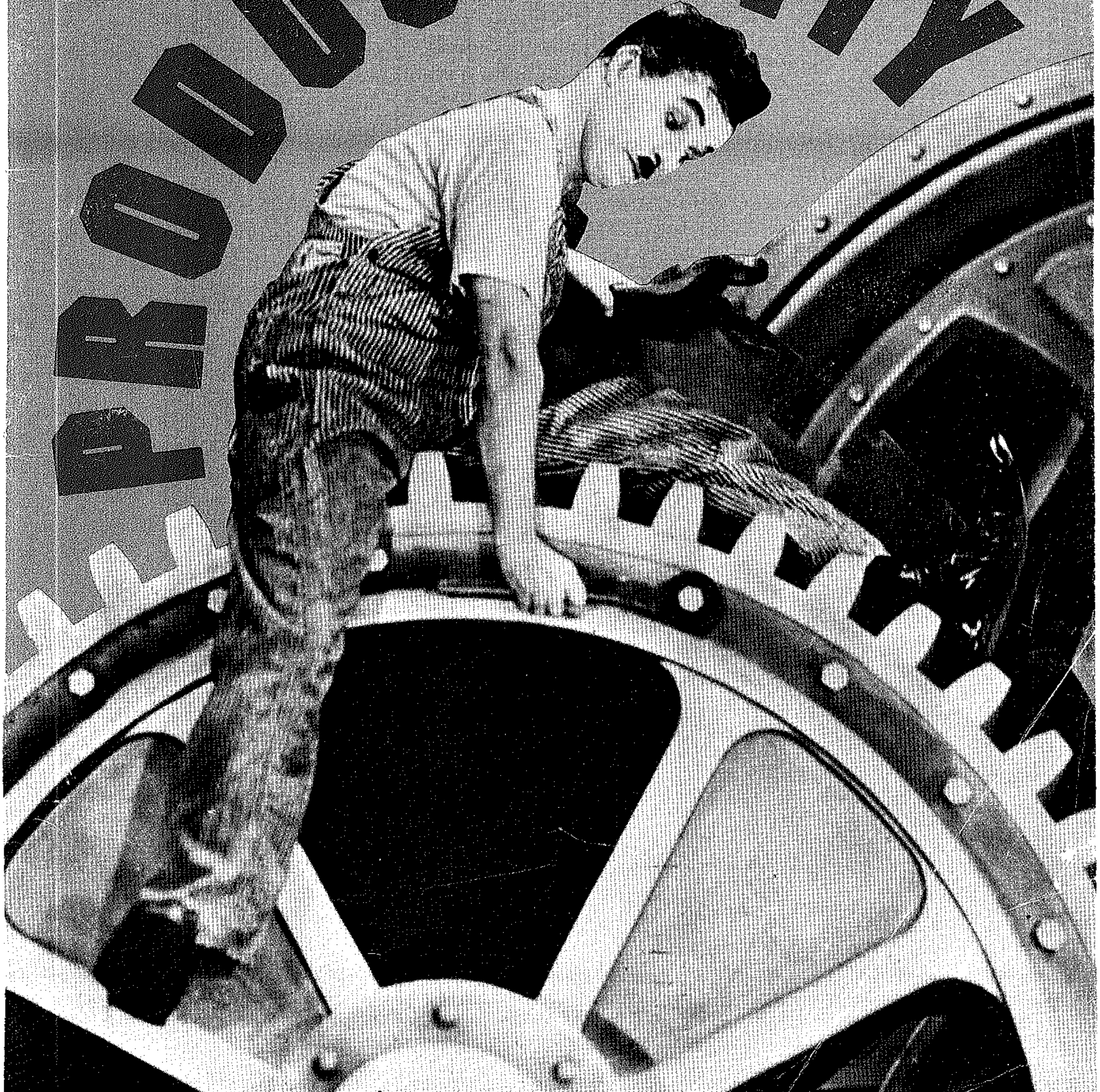
IEEE
spectrum

Special
issue

PRODUCTIVITY



BER 197 THE INSTITUTE OF ELECTRICA INC.

VOLUME 15 ☐ NUMBER 10 OCTOBER 1978

IEEE spectrum

the cover

Called by some "a triumph of efficiency and exploitation," the automatic feeding machine from Charlie Chaplin's 1936 film, "Modern Times," symbolizes the ambivalence with which technology and productivity, the theme of this special issue, are seen even today.

articles

Applications

Special report: Productivity

departments

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SCIENCE/SCOPE

"The greatest contribution to communications since the synchronous satellite" was the promise made by a Hughes official for the tri-service Joint Tactical Information System (JTIDS). It is being developed to deliver critical command-control-communications securely, with resistance to countermeasures. In a totally interoperational manner for the Joint Chiefs of Staff, the system could feature three basic terminal types: Class I for large platforms like the USAF/Boeing E-3A Airborne Warning and Control System and the Navy's Naval Tactical Display System carriers; Class II for air superiority aircraft such as the F-14, F-15, A-10 and F-4; Class III for Manpack radios and remote piloted vehicles.

Orbiter's 300 million mile journey to Venus ends, and its scientific mission begins on December 4. Then this first of two Pioneer Venus spacecraft, with its dozen scientific instruments, goes into orbit around the planet. While circling, Orbiter will determine the detailed structure of the upper atmosphere and ionosphere. It will look for variations in the gravitational field, and use remote sensing to survey Venus' atmosphere and surface. A cloud polarimeter will provide visible- and ultraviolet-light pictures resembling those taken of the earth by weather satellites. A Hughes-developed radar mapper will pierce the dense cloud cover to make pictures of Venus' surface.

The spacecraft will orbit for at least one Venusian day (243 earth days). Data obtained should help scientists understand Venus' weather patterns, and provide new insights into causes of the earth's complex weather cycles. Orbiter and its sister ship, Multiprobe, were built by Hughes for NASA's Ames Research Center.

Hughes' Space and Communications Group seeks engineering people to design advanced systems and components for communications satellites, earth resources and meteorological satellites, and scientific exploration spacecraft. Openings exist at all levels of experience in: Guidance and Control, Propulsion, Space Vehicle Design and Integration, Communication Systems and Components, Structural Analysis, Power Systems, Telemetry, Computers and Data Processing, Systems Engineering and Analysis, and Microwave Systems and Components. Please send your resume to D.T. Stewart, Hughes Aircraft Company, P.O. Box 92919, Los Angeles, CA 90009.

Television broadcasting direct from satellites to schools, hospitals, hotel and motel chains, and other institutional users may be one result of a new NASA program. Hughes will develop for NASA's Goddard Space Flight Center a low-cost, mass-producible 12-GHz receiver for TV reception from broadcast satellites. Objective: a smaller, less expensive receiver to sell for under $1000. Current ground terminals are in the 4-GHz frequency range, and cost between $20,000 and $30,000. The higher frequency range has already been approved by the FCC for domestic TV satellite systems.

Creating a new world with electronics

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HUGHES AIRCRAFT COMPANY

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IBM splits its Systems Mfg Div into two units for medium and big systems... **FORD AEROSPACE & COMMUNICATIONS** wins $19M increment of **US AIR FORCE** Atec communications monitoring and fault detection system... **ZENITH RADIO** raises prices on its 17-, 19- and 25-inch color TV sets ... **WESTERN DIGITAL** and **NATIONAL SEMICONDUCTOR** agree to exchange data on WD's data communications circuits and National's industrial control systems... **HEWLETT-PACKARD** is awarded $3.3M contracts to supply Model 8640B signal generators to **US AIR FORCE** and **US NAVY**... **BROWN-BOVERI** and **GOULD** form joint venture to operate Gould's Electrical Systems group... **HONEYWELL** introduces Model 101 portable tape recorder for use with scientific instrument sensors... **MOTOROLA** will unveil its first group of switching power supplies this fall... **MICRODATA** introduces Vantage, a small business system for the first-time user market... Sales of computers and peripherals are expected to increase by 20 to 25% annually in Israel for the next five years... **INTERDATA** cuts price of its Pack 160 packaged system by 10.6%... **SPERRY UNIVAC** offers new family of terminals for OEMs and end users... Shortage of C/MOS circuits for LCDs is forcing some suppliers to turn down parts orders from watchmakers for '78 delivery... **OPTRON** markets infrared LEDs in 0.2-inch diameter plastic pack... **SIGNETICS** introduces two 8-bit, MPU-compatible digital-to-analog converters... **PANASONIC** announces line of miniature electrolytic capacitors from Japan... **MATERIALS RESEARCH CORP** enters the plasma etching field... **SPECTRA STRIP** sells its flexible circuits product line to **UNIVERSAL CIRCUITS**...

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3.

DIGITAL SYSTEMS, 2nd Ed.

Hardware Organization and Design

Fredrick J. Hill & Gerald R. Peterson, *both of the University of Arizona*

The Second Edition of this successful text describes hardware organization and system architecture by involving readers in the design process. Borrowing a technique from software, control sequences are written in higher language form. The authors use a register-transfer and control-sequence design language—AHPL (A Hardware Programming Language)—to explore the design of a wide variety of digital hardware systems. They illustrate the implementation of each important subsystem of a digital computer in terms of this language and present concrete design examples. In this new edition, AHPL has been revised and made even more systematic to further clarify its relationship to hardware.

One of the most important changes in this edition is the replacing of a control unit based on control delays with one based on standard memory elements or flip-flops. The control unit is thus tied to traditional sequential circuit theory and is implementable in terms of standard integrated circuit parts. A new chapter has been added to provide examples of interface design and to consider, for the first time, digital communications at the logic design level. Another new chapter presents a thorough treatment of microprocessors within a systematic design framework. In addition, material on memories has been reorganized and consolidated and input/output intersystem communications sections have been expanded.

0 471-39608-7 1978 701 pp. $23.95

4.

COMPUTER ARITHMETIC

Principles, Architecture, and Design

Kai Hwang, *Purdue University*

This book presents a comprehensive and up-to-date treatment of machine arithmetic theories, computing algorithms, processor architectures, logic design and implementation techniques for the design, construction, and applications of high-performance arithmetic processors in modern digital computer systems.

Topics covered include: machine arithmetic characteristics; internal number representations; digital arithmetic devices; high-speed fixed-point adders/subtractors, multipliers, and dividers; signed-digit arithmetic; cellular arithmetic arrays; multioperand addition; multiplier recoding; SRT and convergence division methods; floating-point arithmetic and error analysis; axiomatic rounding theory; multiple-recision computation; evaluation of elementary functions; pipe-lined arithmetic design, and error control techniques in arithmetic processors.

Case studies include arithmetic processor in IBM System/360 Model 91, ILLIAC III, Texas Instruments ASC, and Control Data STAR-100.

There are over 230 illustrations, up-to-date reference lists and bibliographic notes at the end of each chapter, and over 100 problems to help your students comprehend the essential points in the text.

0 471-03496-7 1978 approx. 528 pp. $21.95 (tent.)

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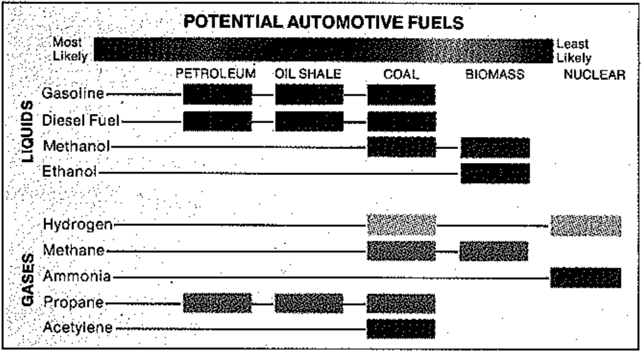
Circle No. 11

There's no fuel like the old fuel. But there are alternatives.

By the end of this century, when the world's demand for petroleum will exceed what it can produce, alternative fuels will have already begun phasing into the energy picture.

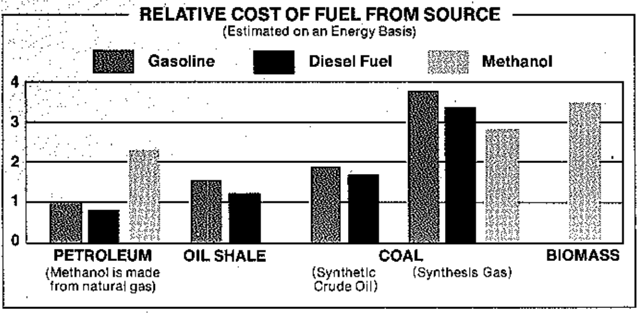
What will these new fuels be? Scientists here at the General Motors Research Laboratories long ago started exploring the possibilities. They've conducted engine studies with hydrogen, methane, ammonia, propane, acetylene, methanol, ethanol, and with liquid hydrocarbons from coal and oil shale.



Although the principal aim was to understand the combustion process, the overall system — from resources in the ground to power at the wheels — was also considered.

So what have we learned? Hydrogen, for example, behaves well enough in an engine. However, storage and control problems in a car severely limit its prospects.

Methanol, on the other hand, is more manageable. And we have modified production vehicles to run on this fuel. But methanol poses a serious starting difficulty below 5° C. Moreover, it would be costly.



Which brings us to gasoline and diesel fuel derived from oil shale. Environmental, social, and political factors may favor other alternatives. But our studies, based on energy efficiency and economics, indicate that these two derivatives have the greatest potential for being the automotive fuels of tomorrow.

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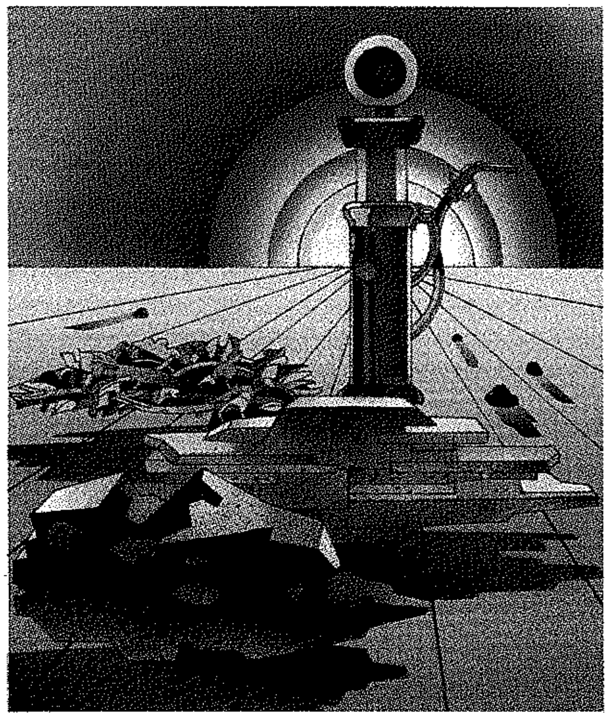

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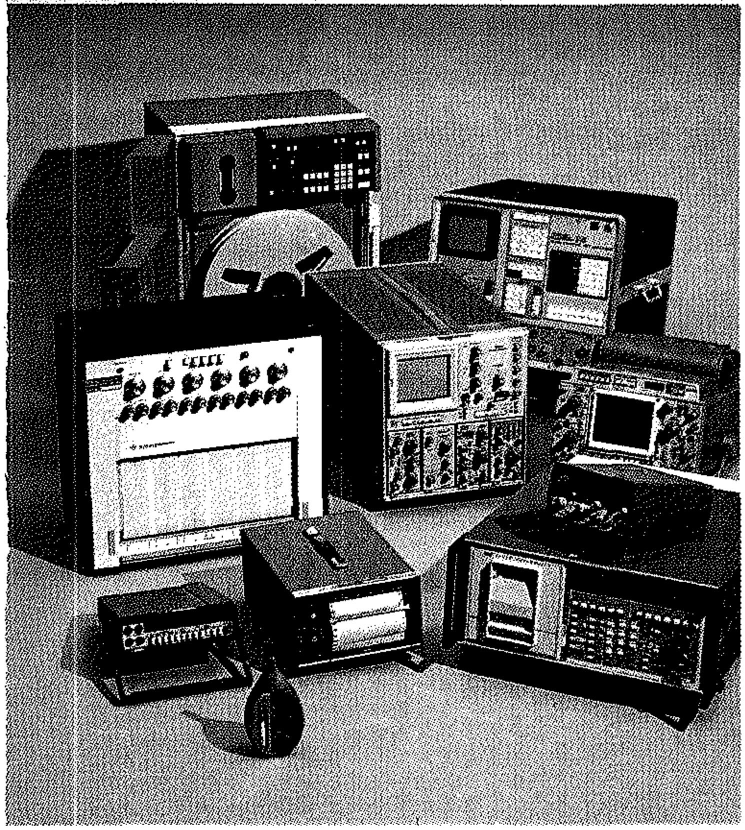

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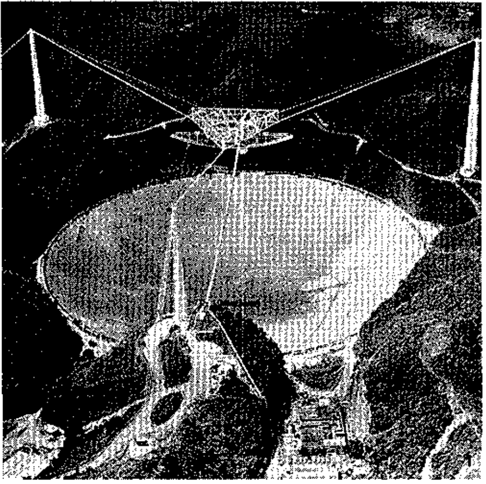
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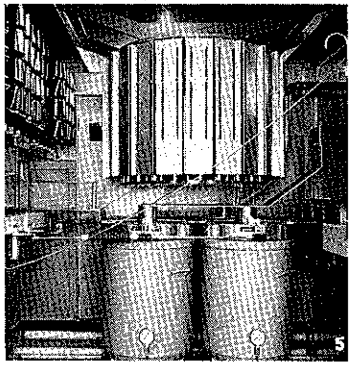
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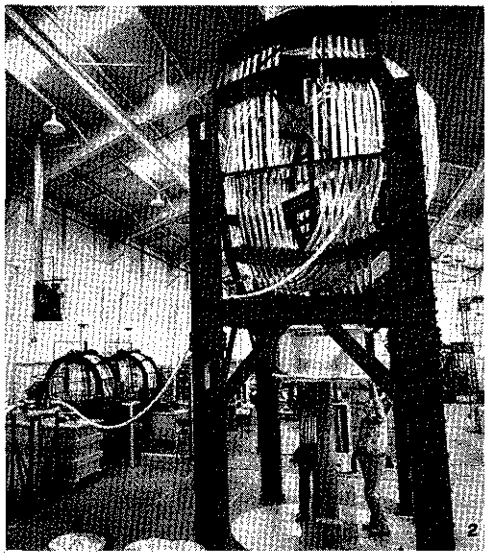
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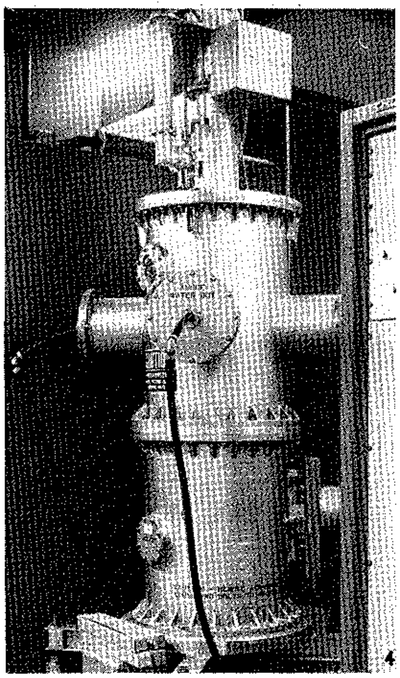
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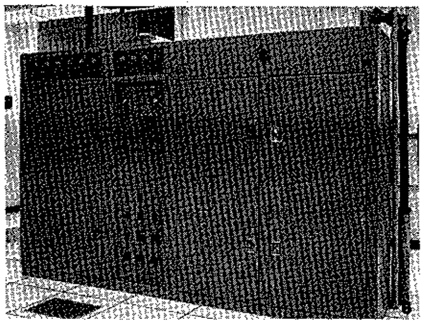

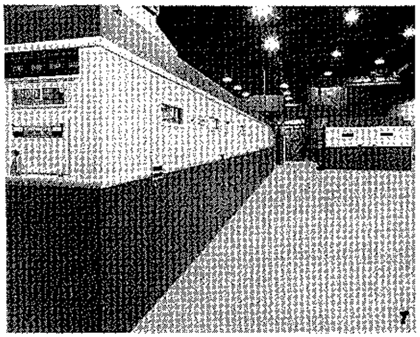
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Continental Electronics specializes in the design, development and production of high power rf equipment for communications, radio broadcast, radar and scientific research applications. Since 1946, Continental has built and installed transmitters for a variety of unique projects around the world. **1** 450,000 watt S-band radar transmitter for Cornell University at the National Science Foundation Arecibo Observatory. **2** Continental has designed many unique rf components for use in high power transmitter systems. This variometer coil provides inductance variation for tuning a VLF antenna. **3** Continental's 2,000,000 watt VLF transmitter built for the U.S. Navy and installed in Australia. **4** FERMILAB's Linear accelerator is powered by nine rf amplifiers **5** GAS-CAP fixed and variable pressure capacitors are used in high power VLF, LF and MF transmitters and antenna systems. Continental's Torusolenoid, shown at the top of the picture, is a self-shielding, high-Q, adjustable inductor. **6** Continental's AN/FRT-85 40,000 watt PEP HF ISB communications transmitter. **7** 2,000,000 watt AM MW broadcast transmitter during factory test at the Continental plant in Dallas, Texas. For information on these and other unique high power rf products, write for a copy of our booklet, "Specialist in high power"; Continental Electronics Mfg. Co.; Box 270879 Dallas, Texas 75227

Continental Electronics

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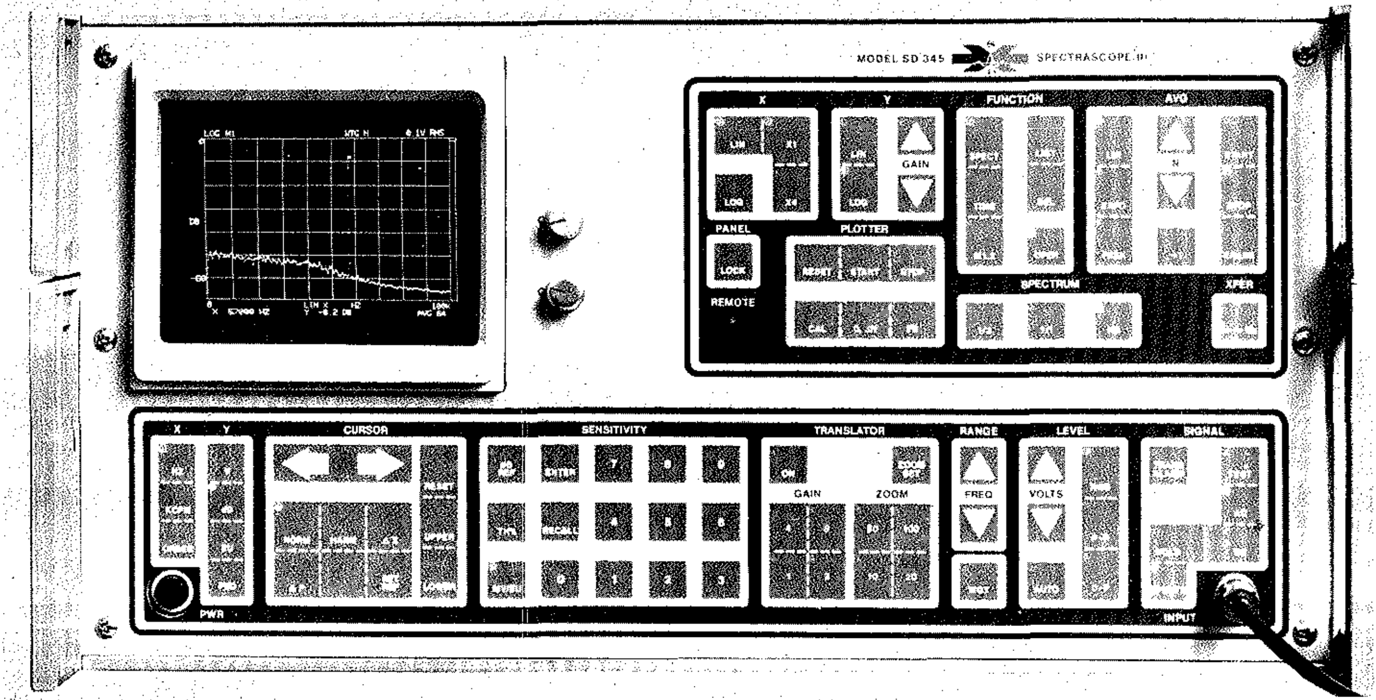

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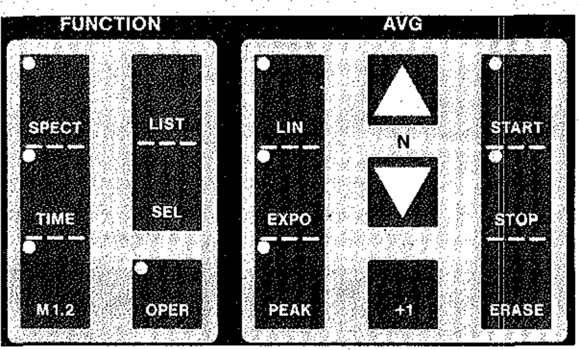

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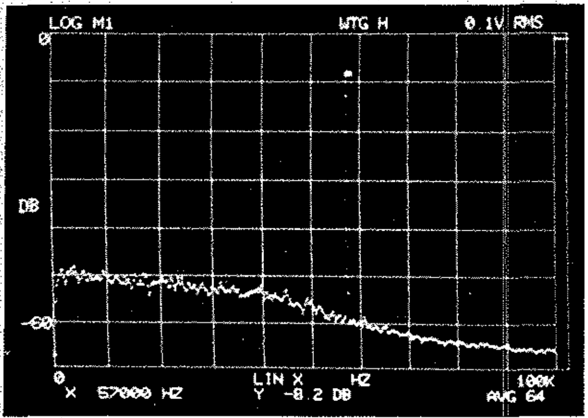

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Circle No. 205

News from Washington

OMB TIGHTENS UP ON RETURN OF UNUSED R&D GRANTS

A little-noted directive from the head of the Office of Management and Budget is likely to have a big fiscal impact on institutions that receive Federal grants for research and development. Addressed to the heads of Government departments and agencies, the directive requires that funds remaining unexpended at the completion of a project be returned promptly to the U.S. Treasury, rather than kept on hand by the recipients until the project is officially reported as completed. Since the time lag between the actual end of a project and the completion of paperwork formally closing it down may be considerable, the new requirement terminates what has been, in effect, an interest-free loan system that many institutions have found beneficial.

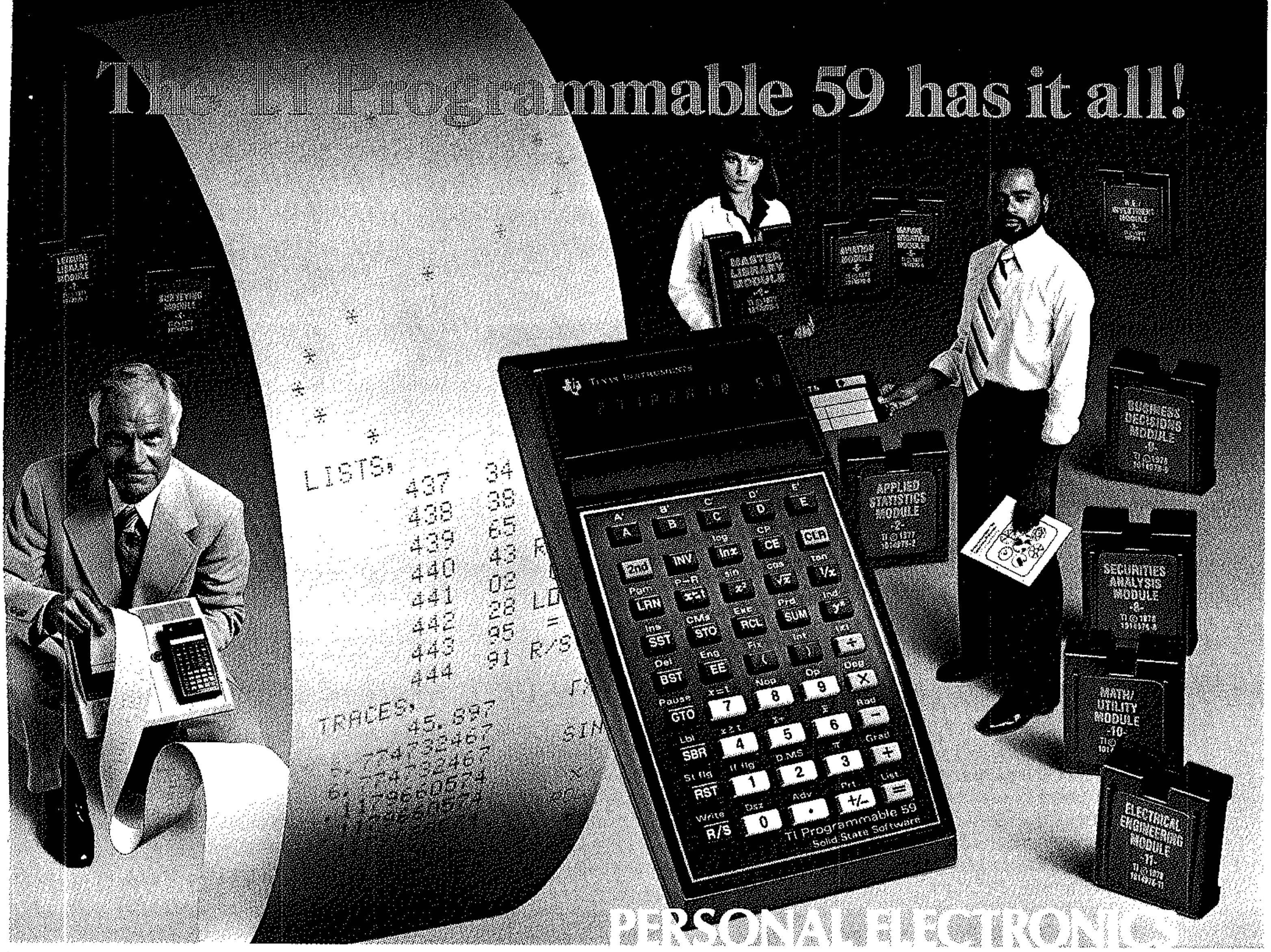
As stated in the directive by OMB Director James T. McIntyre, Jr., "It has come to our attention that grant closeouts in a number of agencies are running behind schedule. This sometimes means that funds advanced to grantees, but not spent for program purposes, are held by them awaiting closeout." Mr. McIntyre said that many millions of dollars may be involved, adding, "There is no reason why Federal funds should be held outside the Treasury awaiting closeout of a grant."

ACADEMY SAYS INVIVIDUAL CHOICE SHOULD GUIDE DEALINGS WITH U.S.S.R.

The Committee on Human Rights of the National Academy of Sciences, which has deplored Soviet repression of dissident scientists, has urged the scientific community to refrain from attempting to develop any blanket rule on contact with Soviet individuals and organizations. In a policy statement issued last month, the committee said that although it is seeking to induce the Soviets to release three recently imprisoned dissidents, it feels that "each American scientist contemplating a visit to the U.S.S.R. (or asked to host a Soviet scientist in the U.S.) must determine his or her own course of action." It noted, however, that cooperation with the Soviets cannot "be commanded" and that "a tide of spontaneous response" is causing U.S. scientists to reconsider their relations with Soviet colleagues "in the absence of some judicious and humanitarian actions by Soviet authorities."

NUCLEAR STOCKPILE BECOMES ISSUE IN BAN NEGOTIATIONS

Key officials of the Defense Department and the Department of Energy are arguing that periodic testing of nuclear components of stockpiled weapons is necessary for maintaining the reliability of the U.S. nuclear arsenal, and, therefore, a comprehensive test ban would threaten U.S. security. This argument, which was stated before the House Armed Services Committee last month by Donald Kerr, acting assistant secretary at DOE, has drawn a sharp rejoinder from several persons long associated with the U.S. nuclear weapons program--among them, Norris Bradbury, director of the Los Alamos Scientific Laboratory from 1945 to 1970. In a joint statement with Richard Garwin, of IBM, and Carson Marks, former head of the Theoretical Division at Los Alamos, Mr. Bradbury argued that "proof testing" heretofore has been a rarity and can be safety replaced by nondestructive testing techniques.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Calendar

For additional information, write or call the listed contact; or IEEE Conference Coordination, 345 East 47 St., New York, N.Y. 10017; (212) 644-7895.

IEEE-sponsored meetings

Technology of Electroluminescent Diodes (QEA, S-ED) Nov. 1-2, 1978. Sheraton-Fisherman's Wharf, San Francisco, Calif. Contact: R. N. Bhargava, Phillips Lab., Briarcliff Manor, N.Y. 10510 (914) 762-0300

Conference on Cybernetics and Society (S-SMC, Tokyo Sect.) Nov. 3-7, 1978. Tokyo, Japan. Contact: M. S. Watanabe, Management Science Dev. Fund, Seikyo Kaikan Bldg., 4-1-13 Sendagaya, Shibuya-ku, Tokyo, Japan

Symposium on Compter Applications in Medical Care (Northern Virginia Sect., Comp-Soc, G-EMB) Nov. 5-8, 1978. Mariott Twin Bridges Hotel, Washington, D.C. Contact: F. H. Orthner, George Washington Univ., Dept. of Clinical Engineering, 2300 K Street, N.W., Washington, D.C. 20037 (202) 676-3866

Chicago Fall Conference on Consumer Electronics (S-BCCE, Chicago Sect.) Nov. 6-7, 1978. Ramada-O'Hare Inn, Rosemont, Ill. Contact: R. Podowski, Zenith Radio Corp., 1000 N. Milwaukee, Glenview, Ill. 60025

12th Annual Asilomar Conference on Circuits, Systems, and Computers (CompSoc) Nov. 6-8, 1978. Pacific Grove, Calif. Contact: G. G. Hsieh, 5855 Naples Plaza, Suite 301, Long Beach, Calif. 90803 (213) 438-9951

Advanced Techniques in Failure Analysis (Reg. 6, Los Angeles Council) Nov. 6-9, 1978. Marriott Hotel, Los Angeles, Calif. Contact: R. J. Kolb, TRW Defense & Space Systems, 1 Space Park R6/2184, Redondo Beach, Calif. 90278 (213) 536-3430

Position, Location and Navigation Symposium—PLANS (S-AES, San Diego Sect.) Nov. 7-9, 1978. Hilton Mission Bay, Los Angeles, Calif. Contact: N. Harnois, Cubic Corp., P.O. Box 80787, San Diego, Calif. 92138 (714) 277-6780 ext. 555

Conference on Pattern Recognition (ComSoc) Nov. 7-10, 1978. Kyoto International Conference Hall, Kyoto, Japan. Contact: Prof. Makato Nagao, Dept. of EE, Kyoto Univ., Sakyo, Kyoto 606, Japan

Computer Software and Applications Conference—COMPSAC '78 (CompSoc) Nov. 13-16, 1978. The Palmer House, Chicago, Ill. Contact: H. Hayman, Computer Society, P.O. Box 639, Silver Spring, Md. 20902

Magnetism and Magnetics Material Conference (S-Mag) Nov. 14-17, 1978. Stouffer's Inn on the Square, Cleveland, Ohio. Contact: J. J. Rhyne, Reactor Radiation Div., National Bureau of Standards, Washington, D.C. 20234

International Electron Devices Meeting (S-ED) Dec. 4-6, 1978. Hilton Hotel, Washington, D.C. Contact: Susan Henman, Courtesy Associates, 1629 K Street, N.W., Washington, D.C. 20006 (202) 296-8100

National Telecommunications Conference (CSCB, Alabama Sect.) Dec. 4-6, 1978. Hyatt Hotel, Birmingham, Ala. Contact: H. T. Uthlaut, Jr., NTC-78 General Chairman, P.O. Box 771, Birmingham, Ala. 35201 (205) 321-4469

* Asterisk denotes new listing

Winter Simulation Conference (S-SMC;NBS) Dec. 4-6, 1978, Deauville Hotel, Miami Beach, Fla. Contact: L. G. Hull, Code 533.1, Goddard Space Flight Center, Greenbelt, Md. 20771 (301) 982-5308

MIDCON (Los Angeles & San Francisco Councils, Reg. 6) Dec. 12-14, 1978. Dallas Convention Center, Dallas, Tex. Contact: W. C. Weber, Jr., EEEI, 999 N. Sepulveda Blvd., El Segundo, Calif. 90245

* **Third Biennial University/Industry/Government Microelectronics Symposium** (Reg. 5, South Plains Sect.) Jan. 3-4, 1979. Texas Tech University, Lubbock, Tex. Contact: W. M. Portnoy, Dept. of EE, Texas Tech University, Lubbock, Tex. 79049 (806) 742-3532

* **Conference on Decision and Control** (CS) Jan. 10-12, 1979. Islandia Hyatt House, San Diego, Calif. Contact: Dr. R. E. Larson, Systems Control, Inc., 1801 Page Mill Rd., Palo Alto, Calif. 94304 (415) 494-1164

* **Reliability and Maintainability** (R) Jan. 23-25, 1979. Shoreham Americana, Washington, D.C. Contact: D. F. Barber, P.O. Box 1401, Branch PO, Griffiss AFB, N.Y. 13441

* **Power Engineering Society Winter Meeting** (PE) Feb. 4-9, 1979. Statler Hilton Hotel, New York, N.Y. Contact: J. G. Derse, Bedminster, N.J. (201) 725-4388

* **Aerospace and Electronic Systems Winter Conference—WINCON** (AES, Los Angeles Council) Feb. 6-8, 1979. Los Angeles, Calif. Contact: S. Jones, Aerojet Electrosystems, P.O. Box 296, Azuza, Calif. 91702 (213) 334-6211

* **International Solid-State Circuits** (SSC) Feb. 15-17, 1979. Sheraton Hotel, Philadelphia, Pa. Contact: L. Winner, 301 Almeria Ave., P.O. Box 343788, Coral Gables, Fla. 33135 (305) 446-8193

* **Optical Fiber Communication** (QEA, OSA), Mar. 6-8, 1979. Shoreham Americana Hotel, Washington, D.C. Contact: Optical Society of America, 2000 L St., N.W., Suite 620, Washington, D.C. 20036 (202) 293-1420

* **Particle Accelerator Conference** (NPS) Mar. 12-14, 1979. Sheraton Palace, San Francisco, Calif. Contact: R. B. Neal, SLAC, P.O. Box 4349, Stanford, Calif. 94305

* **Simulation Symposium** (C; ACM, SCS) Mar. 14-16, 1979. Tampa, Fla. Contact: J. Clema, Simulation Tech., 4124 Linden Ave., Dayton, Ohio 45432

* **4th Annual Control of Power Systems** (Houston Sect.; Texas A&M Univ.) Mar. 19-21, 1979. Texas A&M Univ., College Station, Tex. Contact: B. D. Russell, Electric Power Institute, Dept. of EE, Texas A&M University, College Station, Tex. 77843

* **Florida-Electric '79** (Florida Sects.) Mar. 22-23, 1979. Florida Institute of Tech., Melbourne, Fla. Contact: G. F. McClaure, Martin Marietta Aerospace, P.O. Box 5837, MP-362, Orlando, Fla. 32855 (305) 352-2782

* **Vehicular Technology** (VT) Mar. 27-30, 1979. Arlington Heights, Chicago, Ill. Contact: A. Goldstein, Motorola, Inc., 1301 E. Algonquin Rd., Schaumburg, Ill. 60196

Other meetings of interest

* **Optical Society of America 1978 Annual Meeting** (OSA) Oct. 30-Nov. 3, 1978. Jack Tar Hotel, Golden Gateway Holiday Inn, San Francisco, Calif. Contact: Optical Society of America, 2000 L St., N.W., #620, Washington, D.C. 20036 (202) 293-1420

Cherry Hill '78 Test Conference, Oct. 31-Nov. 2, 1978. Cherry Hill, N.J. Contact: Pat Regan, Secretary/Registrar, Test Conference Committee, P.O. Box 2340, Cherry Hill, N.J. 08034 (609) 983-3100

* **Conference on Computer Graphics in CAD/CAM Systems** (M.I.T.) Nov. 1-3, 1978. M.I.T., Cambridge, Mass. Contact: Conference Coordinator, M.I.T./Center for Advanced Engineering Study, Bldg. #9, Rm. 268, 77 Massachusetts Ave., Cambridge, Mass. 02139 (617) 253-7411

International Workshop on Biomedical Transducers and Measurements, (Nov. 6-11, 1978. Hotel Melia Castilla, Madrid, Spain. Contact: M. R. Neuman, Biomedical Electronics Resource, Engineering Design Center, Case Western Reserve Univ., Cleveland, Ohio 44106

Optical Data Display Processing and Storage Symposium (SPSE) Jan. 23-26, 1979. Marriott Inn, Orlando, Fla. Contact: R. H. Wood, Society of Photographic Scientists and Engineers, 1411 K Street, N.W., #930, Washington, D.C. 20005

6th Annual Conference on the Physics of Compound Semiconductor Interfaces (Office of Naval Research, Army Research Office, American Vacuum Society) Jan 30-Feb. 2, 1979. Asilomar Conference Grounds, Pacific Grove, Calif. Contact: R. S. Bauer, Xerox Palo Alto Research Center, 3333 Coyote Hill Road, Palo Alto, Calif. 94304 (415) 494-4118

4th International Symposium on Computer Performance, Modeling, Measurement, and Evaluation (IFIP Working Group 7.3) Feb. 6-8, 1979. Vienna/Laxenburg, Austria, Contact: M. Arato, SZAMKI, P.O. Box 227, H-1536, Budapest, Hungary; or H. Kobayshi, IBM Research, Yorktown Heights, N.Y. 10598

1979 San Diego Biomedical Symposium (San Diego Biomedical Society) Feb. 7-9, 1979. Kona Kai Club, San Diego, Calif. Contact: San Diego Biomedical Society, Inc., P.O. Box 80543. San Diego, Calif. 92138

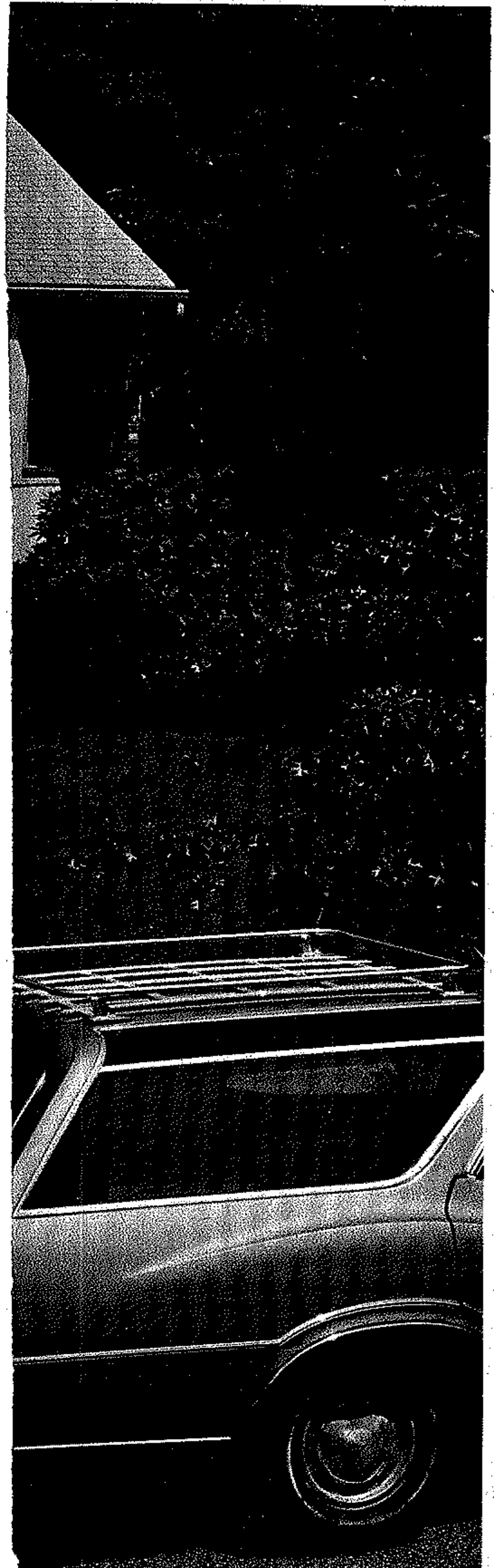
* **3rd Software Conference and Workshop** (NSIA) Feb. 13-15, 1979. Buena Park, Calif. Contact: (609) 234-1100, ext. 2584

6th Energy Technology Conference and EXPO '79, Feb. 26-28, 1979. Sheraton Park Hotel, Washington, D.C. Contact: Martin Heavner, Energy Technology Conference, 4733 Bethesda Ave., N.W., Washington, D.C. 20014 (301) 656-10190

* **International Conference on Fast Breeder Reactor Fuel Performance** (ANS) Mar. 5-8, 1979. Hilton Inn, Monterey, Calif. Contact: E. C. Norman, Fuel Systems Branch, Div. of Res. & Tech., DOE, Washington, D.C. 20545 (301) 353-4471

* **1979 Conference on Information Sciences and Systems.** Mar. 28-30, 1979. Johns Hopkins University, Baltimore, Md. Contact: G. G. L. Meyer, Dept. of EE, Johns Hopkins University, Baltimore, Md. 21218

* **IFAC Workshop on High Level Systems Control in and by Man** (IFAC Comm. on Biomedical Engineering) Apr. 5-6, 1979. Karlsruhe, F.R. Germany. Contact: VDI/VDE—Gesellschaft Mess- und Regelungstechnik, Postfach 1139, D-4000 Duesseldorf 1/F.R. Germany



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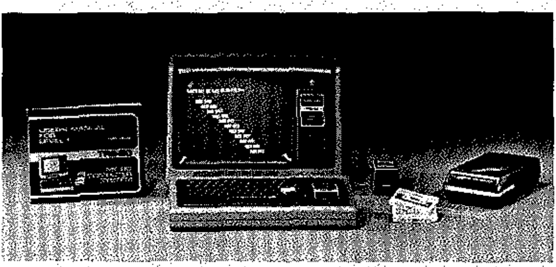

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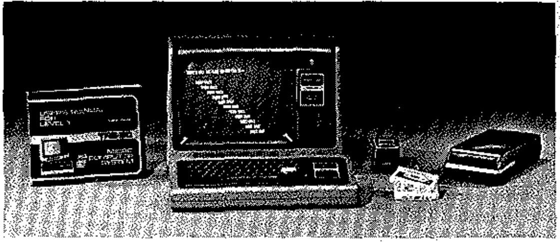

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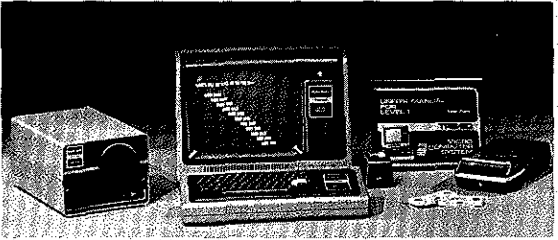

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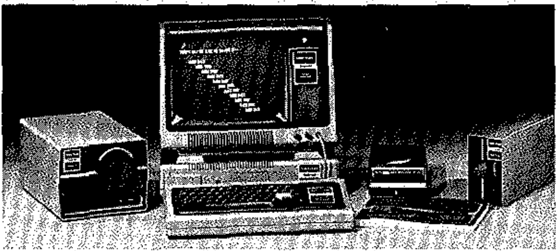

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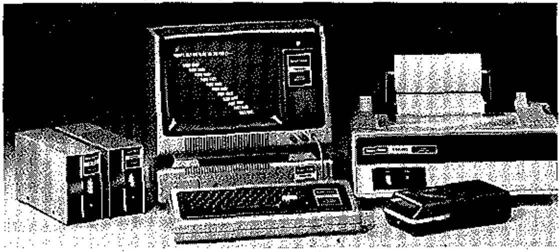

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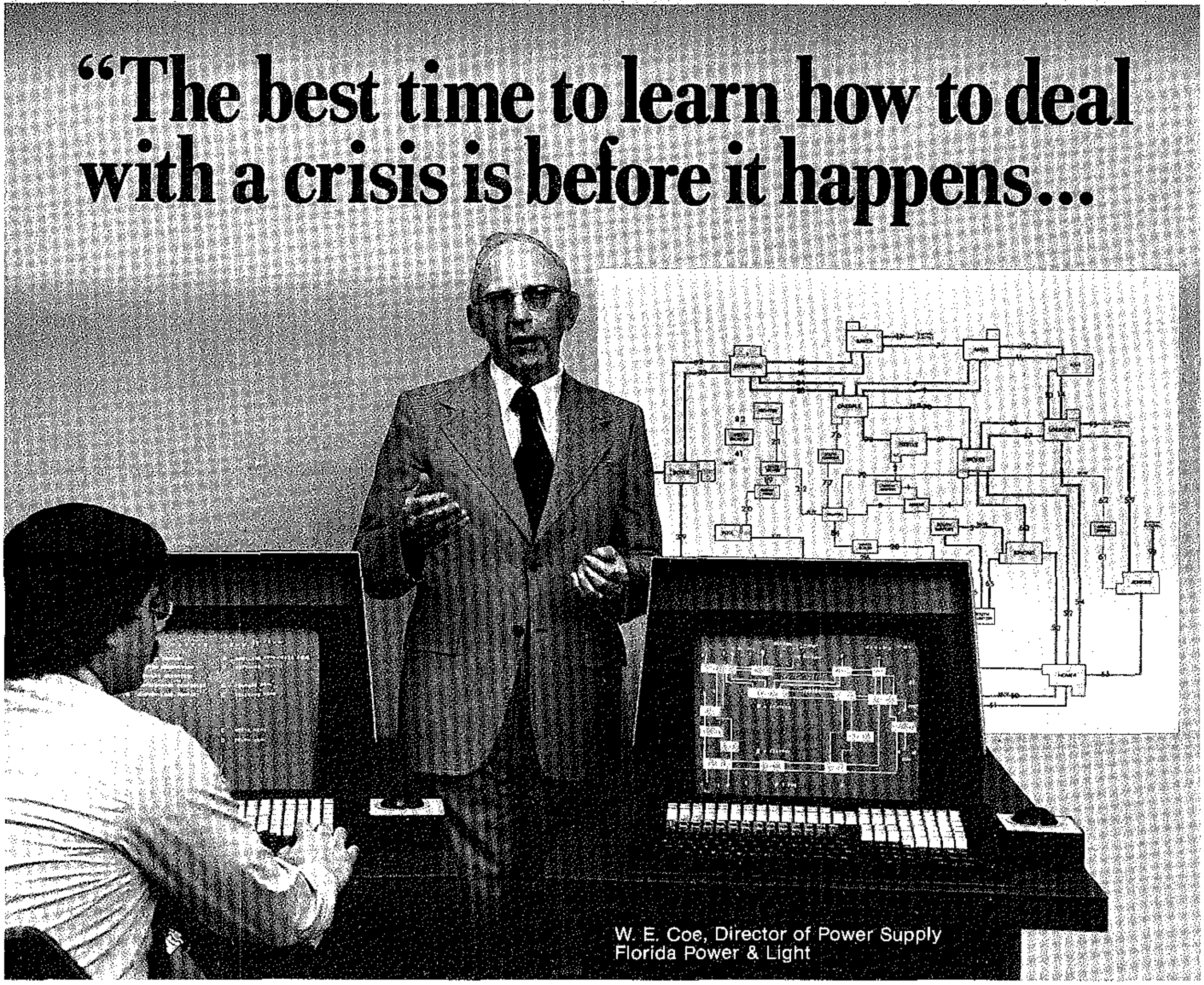

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for this survey is not a measure of job performance. Many job activities of engineers do not result in papers, presentations, patents, or awards, and the achievement index *per se* has not, to the best of our knowledge, been studied in relation to job performance. However, certain of the factors that make up the index have been so related. For example, D. C. Pelz and F. M. Andrews (*Scientists in Organizations*, University of Michigan, 1966) found a positive relationship between job performance and the production of papers and reports. T. J. Allen (*Managing the Flow of Technology*, M.I.T., 1977) found a positive relationship between technical performance and "gatekeeping"—a concept similar to effectiveness as an information source as used in the index. A. Grasberg (*IRE Trans. Engineering Management*, Mar. 1959) concluded that, in industrial research organizations, the average merit rating of a researcher correlates fairly well with the rate at which that researcher produces internal reports, papers, and patents. Thus, although we make no claim of a relationship between the achievement index and job performance, sufficient evidence exists to suggest further study."

Finally, readers of the article will note that the illustration on page 67, which shows the distribution of respondents to the survey, was mislabeled. The "low group" should have been at the left and the "high group" at the right.—*Ed.*

TVA interview

Author of the *Spectrum* interview (Sept., p. 64) with new Tennessee Valley Authority Chairman S. David Freeman was *Spectrum* Contributing Editor Judith Michal.

Prior to her assignment for *Spectrum*, Ms. Michal was an associate engineer for applied mechanics with Gibbs and Hill, Inc., New York, N.Y. Before that, she had been an assistant engineer in the Applied Physics Department of Ebasco Services; a professor of physics at the University of Northern Colorado, Greeley; and a physicist with Esso Research and Engineering, Linden, N.J. She holds the B.S. and M.S. degrees in physics from Upsala College and Stevens Institute of Technology respectively. At the latter school, she has completed her course work toward a Ph.D. degree.—*Ed.*

Corrections

The following corrections should be made in P. N. Ewart's article, "Whys and wherefores of power system blackouts" (Apr., pp. 36–41). On page 36, column 2: In the first paragraph, delete reference to Fig. 1. In the second paragraph, Fig. 1 should read Fig. 3. In the first statement of the first listing, 2900 MW should be corrected to 650 MW, and in the first statement of the second group, the time refered to is 20 minutes (not one hour). Finally, on page 38 in the caption for Fig. 3 and on page 41, column 2, last paragraph, 1 Hz should be 1 Hz/s.

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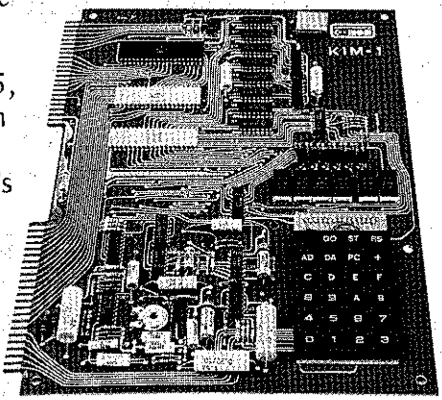

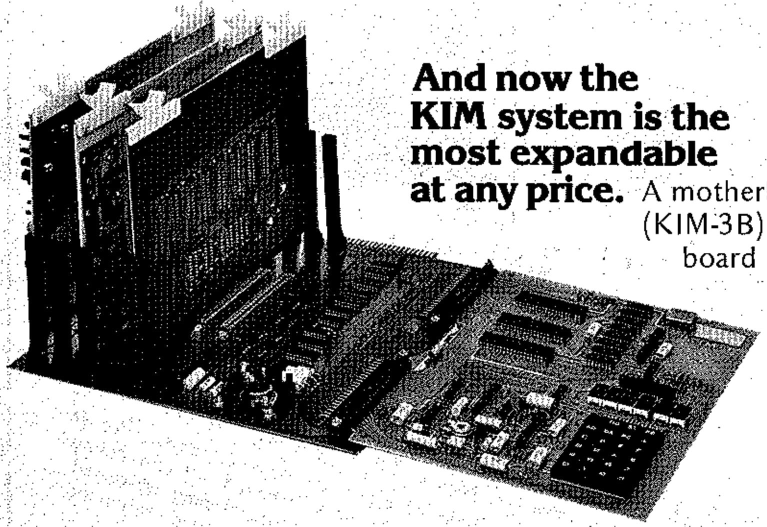

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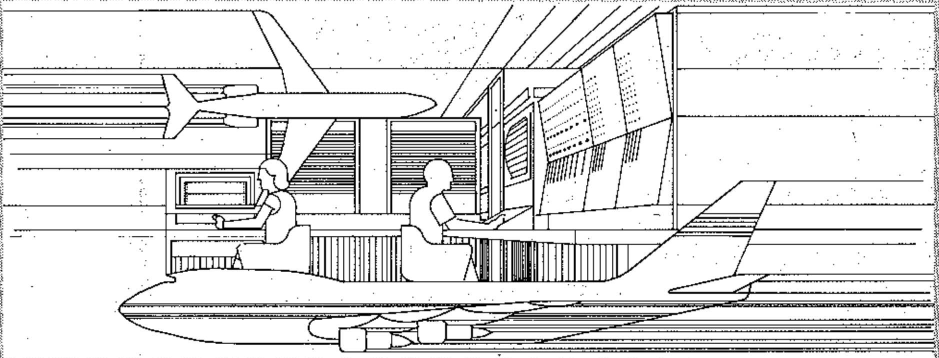

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To learn more about why MITRE people are excited about Monday morning please contact M. P. Cavaiola, The MITRE Corporation, Metrek Division, 1820 Dolley Madison Blvd., McLean, VA 22102.

Of course, MITRE people look forward to Friday afternoon. Being located in dynamic Fairfax County, a suburb of Washington, D.C., all the historical, social, and cultural attractions of the national capital area are only minutes away.

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" Who's worried and why?"—has been contributed by the most knowledgeable people our editors could find. Some are well known—such as inventor Jacob Rabinow and Texas Instruments president J. Fred Bucy. Others, perhaps not as well known, have made detailed studies of productivity matters for years. The latter experts include Edgar Weinberg, who has written countless reports on productivity for the Government's now-defunct National Center for Productivity and Quality of Working Life, and Ernst R. Berndt and Dale W. Jorgensen, economists at the University of British Columbia and Harvard University, respectively.

Just because *Spectrum*'s authors in this issue's first section are long-time students of productivity does not mean their conclusions are correct, however. To ensure a balanced presentation of views for our readers, *Spectrum* Contributing Editor Tom Collins has assembled a variety of "counterviews" into a single package (page 40), ranging from an attack on some of the conventional measures of productivity to questions regarding such assumptions as "Productivity must continue to rise for the common good."

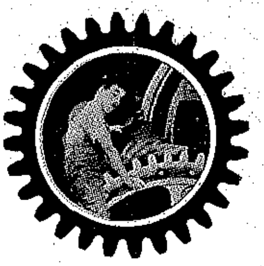
The authors include the president-elect of the American Association for the Advancement of Science, staffers of the National Science Foundation and IEEE Fellow and M.I.T. Professor Jay Forrester. The balance of the issue is devoted to explorations of possible means to improve productivity growth. Both staff and expert authors have contributed articles on how technology can play a role.

Associate Editor Robert Sugarman (page 53) looks at computers and controls in the continuous-process industries, especially in the currently limping United States steel industry, and, at the uniquely skyrocketing productivity of the semiconductor industry. Associate Editor Roger Allan (page 60) has assembled articles on computer-aided manufacturing and robotics, and *Spectrum* power expert Gadi Kaplan (page 70) investigates state-of-the-art hardware and approaches to curtail peak power demand on the utilities.

Senior Associate Editor Edward Torrero then takes up the topic of how corporate management can improve productivity. Articles beginning on page 74 deal with enhancing product innovation and motivating the production worker—the latter topic is addressed by Associate Editor Don Mennie.

On page 85, Editorial Director Ronald Jurgen leads off a section on what government can do. Included among the expert authors in this section is IEEE Fellow, and Assistant Secretary of Commerce for Science and Technology, Jordan Baruch.

We know we will not solve today's problems here, but if we are to deal with them intelligently, we must begin with a greater understanding of the factors involved. *Spectrum* hopes to have contributed in some measure to that understanding. ◆



ductivity increase during the current expansion has already tailed off markedly—only 2.4 percent in 1977 compared with a 4.2-percent increase in 1976.

Admittedly, it is difficult to project productivity in view of the multiplicity of factors that influence the trend—changes in production techniques, the volume of capital investment, the education and experience of the work force, the quality of management, the rate of capacity utilization, the scale of operations, the state of labor-management relations, and the impact of government regulation. The productivity of the economy is also affected by changes in the industrial composition of employment, such as the shift from the farm to the nonfarm sector. These factors are interdependent and the interaction among them is of considerable importance in the overall picture.

Still, as the experts point out, the long-term outlook for U.S. productivity is disquieting. The BLS, for example, projects a rate of 2.4 percent for 1980-85—higher than in the 1968-79 decade, but still significantly below the postwar, 20-year 3.2-percent trend. Other experts project an even lower productivity rate of 2.0 percent per year.

The productivity climate in Europe and Japan is not all rosy either, but while growth there has slowed of late, its pace is still faster than in the United States. Output per employee-hour in Japan, for example, is projected to grow at a rate of 6 percent a year, and worldwide communication and transportation, investment capital, advanced technology, and skillful management are so transferrable across borders that higher productivity is a realistic national goal throughout the industrial world.

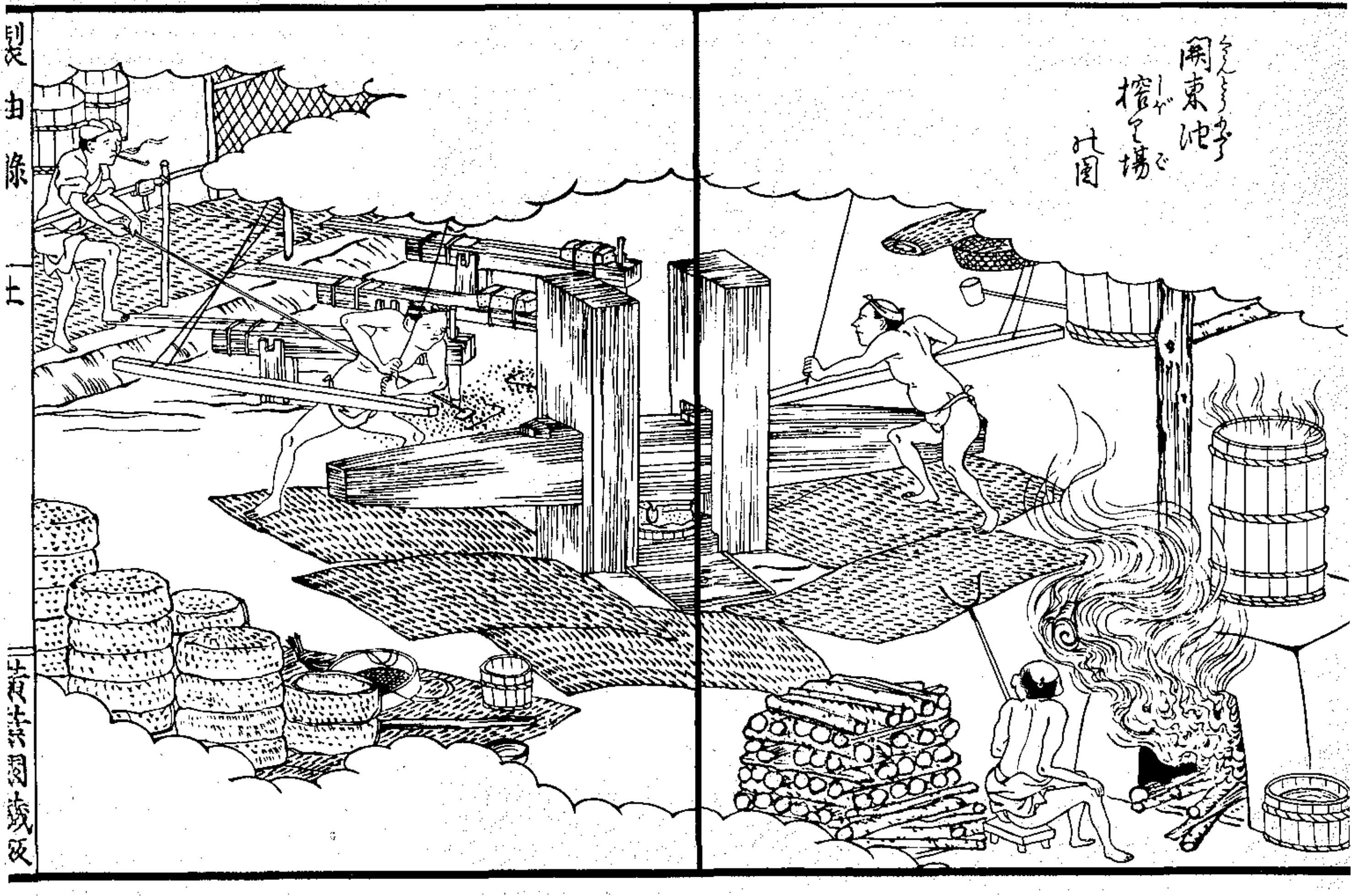
The measurable factors that contribute to the low U.S. growth rate in the past decade have been delineated by economists in great detail. They include the end of the shift from farm to nonfarm employment; the influx of a substantial number of inexperienced young people and women into the labor market; and the slowdown in the growth of the capital/labor ratio. The shift to business and personal services was *not* a major source of the slowdown. (Because adequate measures of government output are not available, the impact of the growth of this major service sector on the economy's performance cannot be fully assessed.)

On the other hand, the intangible influences of the economic and social setting on productivity are too often overlooked. The past decade was characterized by an unusual accumulation of disturbances. Not only were there exceptionally sharp fluctuations in output and employment, but shocks were produced by sharp rises in the price of energy, materials, and food. And the expansion of government regulation resulted in business uneasiness that, in turn, may have resulted in conservative management practices not conducive to continued high productivity.

Why productivity matters

One cause of the lack of concern over U.S. productivity performance is the failure of policy makers to appreciate fully the relationship of productivity to major national economic and social goals. Improved productive efficiency means better control of inflation, conservation of jobs, higher living standards, and a better quality of life in general.

The Japanese oil industry in 1836—not the petroleum industry; the extraction of oil from rapeseed. The productivity-spurring technology shown is from a book, *Seiyu Roku*, lent by Bern Dibner, director of the Burndy Library.



work; for someone born in 1970, that period should increase to 27 years.

How to improve productivity

From the point of view of the National Center for Productivity and the Quality of Life (described in the box, p. 38), there are four broad areas for improving productivity: accelerating technological innovation; enlarging capital investment; enhancing human resources; and improving government-business relationships. In developing a perspective on major opportunities in these complex areas, the Center convened panels of experts from business, labor, and government, and commissioned studies to supplement existing research. The following highlights of this experience are presented not as a final consensus but rather as a summary of preliminary findings in a continuing search for possibilities for productivity improvement.

Productivity improvements come about through changes in production, methods, materials, and machinery, which, in turn, stem from the accumulation of scientific and technological knowledge. The technology factor is credited with at least 40 percent of the growth in productivity over the past 50 years.

Technological change has an impact on productivity at the time when a new technology is put into place and efficiencies are achieved. Before this can happen, an innovation must be conceived, information regarding it must be diffused to potential users, and the innovation must be implemented. Therefore, the entire process must be considered before productivity improvements can be realized.

We have no definitive indicators on whether the process of new developments has slowed recently, except in terms of one final result—the slowdown in productivity growth. In the opinion of the National Science Board and other authorities, the environment for innovation seems to be less favorable and the momentum of technological progress is waning. It would be useful to have comprehensive data on the speed of adoption of new technology, the time period between stages, and the comparative status of U.S. technology in relation to other countries in order to be able to gauge the pace of change. In the absence of such data, we must be willing to draw conclusions from a number of more indirect indicators.

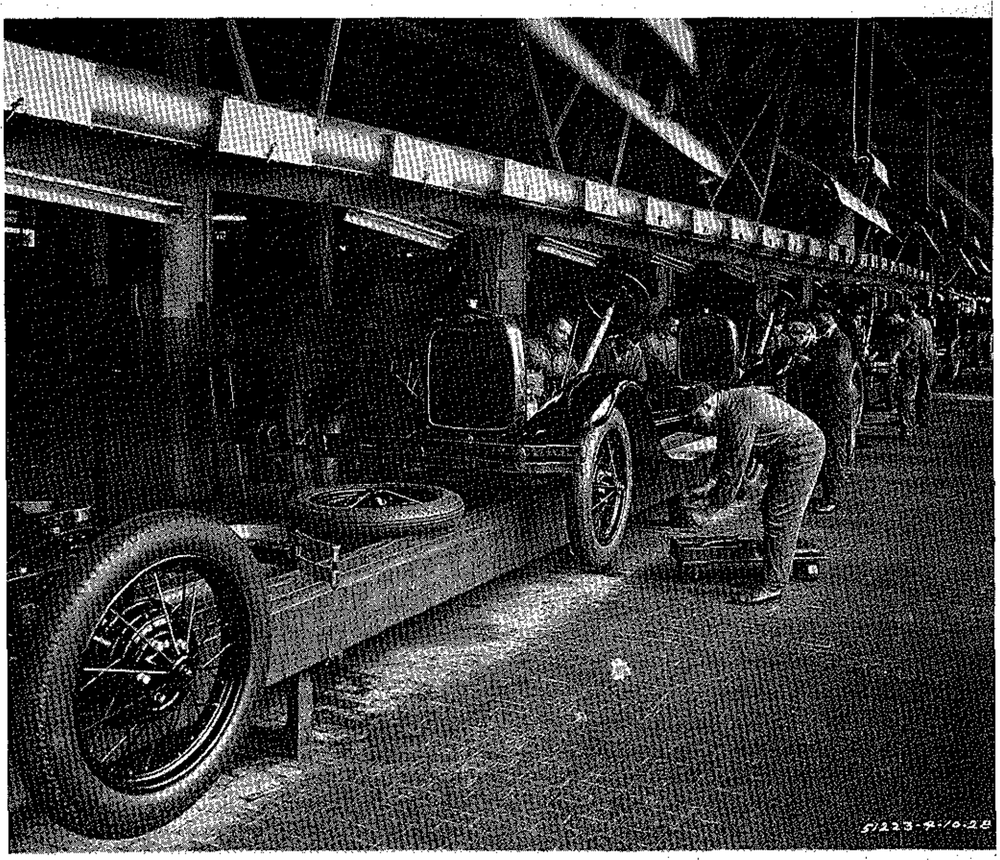
One unfavorable trend is declining support by the U.S. Government and industry for research and development. Despite evidence of large private and social return from R&D, total spending for R&D by industry, government, and universities dropped from 3.0 percent of GNP in 1964 to 2.2 in 1977. The National Science Foundation expects the ratio to decline to 2.0 percent by 1985. Total R&D dollars spent increase each year, but when adjusted for inflation, the real volume of R&D spending has been declining.

Comparative data for major industrial nations show a slippage in the U.S. position since the mid-1960s, relative to Japan and the U.S.S.R. These nations are devoting an increasing proportion of GNP to R&D. Patent activity by non-U.S. inventors is also rising; for example, 37 percent of all U.S. patents went to "foreigners" in 1976, compared with 17 percent in 1961. This increase in "foreign" patents is disquieting not because it is a reflection of a loss of creativity of U.S. scientists or the quality of their inventions or discoveries (which it is not), but rather because R&D outlays tend to have a positive correlation with productivity growth and a decline in the U.S. proportion of patents could foreshadow a slowdown in the flow of new products and processes.

The lack of adequate support for research and development of manufacturing technologies is especially disturbing. For example, experts have reported that the U.S. trails West Germany in R&D in metalworking (an area that is vital to productivity improvement). The Japanese Government is giving full support to R&D on automation (flexible manufacturing systems). The only reasonable conclusion from all this is that the U.S. no longer has sole control of technical leadership in manufacturing technology developments.

The reasons for this slowdown are difficult to determine. Economists often treat technological innovation as exogenous and subject to its own laws of development. At a recent conference on the future of productivity, Simon Ramo stated, "The bottleneck is not science and technology *per se*, but lies instead in the arrangement-making process among government, private enterprise, and science and technology." Thus, the pace of innovation is affected by many nontechnical factors, including the state of the economy; the profitability of investment; the patent, tax, antitrust, and regulatory policies; the structure of industry; the skill and knowledge of management and the work force; and the pressures of organized interests.

Resolving the bottleneck involves closer cooperation among the different groups in the process—scientists, engineers, inventors, manufacturers, distributors, users, consultants, and others. The groups in this complex chain pursue different and sometimes conflicting goals, are motivated by



The assembly line—that famous productivity innovation—is shown here as it existed in 1928 in the Ford motor works. Photo from the Henry Ford Museum, Dearborn, Mich.

1970s, the rate of gain was only 2 percent annually. The recovery in investment since 1975 has been weaker than in the typical postwar cyclical upswing. To a great extent, this lag in expenditures on plant and equipment contributed to the slowness of U.S. industry in installing automated technology that could boost productivity growth.

Third, the composition of capital expenditures has shifted markedly. Of the dollars invested, larger amounts are earmarked for meeting environmental and occupational health and safety regulation requirements. Investment in capital equipment for environmental goals now accounts for about 9 percent of investment outlays in the manufacturing sector. If these mandated capital expenditures are excluded, investment, as a share of value added, has actually declined in the manufacturing sector since 1966.

Fourth, and finally, lagging investment seems to be the result of a deterioration in profitability. There are many ways to measure profitability, but all tend to show similar trends. In 1977, after-tax rates of return on capital averaged 5-9 percent, compared with an average of 8 percent during the mid-1960s. These rates are considered particularly low in view of the greater risks and uncertainties of investment today. A factor in this low rate of return may be the continued low rate of capacity utilization, which depresses productivity and discourages investment.

We must keep in perspective the contribution of capital investment relative to other sources of productivity growth. Depending on the concept used, about 15 percent of the postwar increase in productivity came from growth of tangible capital (including structures, equipment, and inventories). This about equalled in importance the contribution of advances in education and training of the work force, a form of intangible investment in human skill and knowledge, which complements physical capital. However, since capital investment is intertwined with the technology it carries, it is difficult to estimate the effect that an increase in capital investment by itself would have on productivity growth.

Many economists believe that a faster rate of economic recovery would stimulate significant savings and investment to expand productive capacity and update aging facilities in the private and public sectors. Others feel that additional incentives will be necessary to encourage productivity-enhancing capital, particularly investment in capital-intensive energy production. Whatever the mix of monetary and fiscal policies to increase tangible capital investments for productivity improvement, they will have to be balanced against the requirements for investments in R&D and intangible human capital, including the education, training, and health of the work force.

When engineers and scientists address the topic of productivity, their tendency is to concentrate on innovation and capital investment. Too often, the management/worker interface is overlooked. However, there is increasing recognition that better management of today's work force is vital to productivity improvement. By 1985, nearly two fifths of the work force will have at least one year of college education and one fifth will have four or more years. Efforts to meet the expectations of workers for better working conditions and to make more effective use of their ingenuity and creativity represent one of the significant economic changes taking place today.

Surveys of job expectations reveal, in addition to traditional concerns about pay and working conditions, a variety of other interests. For example, the Labor Department's Quality of Employment survey, taken in 1969 and 1972, ranked pay high, but also found that workers want many other opportunities—to obtain training; to use their talents more fully; to have greater flexibility in work patterns, education, leisure, and retirement; to have health and safety protection on the job; and to exercise greater control over performance of work. Only a small minority—not over 20 percent—express dissatisfaction with their jobs; however, these are concentrated among young, educated workers whose views may dominate in the future.

To achieve the twin objectives of greater productivity and worker satisfaction, a variety of human resource programs are being tested. New techniques, such as group incentive systems, flexible work schedules, autonomous work teams, job design, and goal-setting approaches, have had varying degrees of success. According to a Work In America Institute study of 103 experiments, techniques that identify effective work behavior, furnish feedback on results, and reward effective performance have significant potential for reducing absenteeism and turnover and improving the performance of the organization. The programs that show the most promise in improving both productivity and job satisfaction seem to be sociotechnical systems that take into account various aspects of the workplace, including recognition for performance, training, a voice in plans and decisions about how work is done, safety and health protection, and appropriate equipment to do the job.

So far, we have discussed ways of affecting productivity that are largely in the control of private industry, but government actions can affect the private sector in several important ways—including establishing the environment (legal, economic, and social) within which private enterprise operates; affecting levels and priorities of R&D; and, of course, by regulating the private sector. Because of the significance of the governmental affect on productivity, a special section has been set aside in this issue (p.85) to express diverse viewpoints on government's current and potential role in the productivity question. ◆

What is productivity?

There are two basic measures of gross output. The gross national product (GNP) is the value of everything that is produced by the citizens of a country, including goods and services produced overseas. Gross domestic product (GDP) is the total produced within a national boundary, whether the producers are citizens or not.

Since productivity is defined as output per unit of input, the outputs just described need to be divided by some measure of input—labor (man-hours), for example, or labor plus available plant and equipment, or labor as measured by number of persons in the labor force. They also need to be corrected for inflation, seasonal changes, and statistical error.

The productivity statistics used by authors thoughout this issue are those prepared by the U.S. Department of Labor's Bureau of Labor Statistics referring to what BLS calls the "private business" sector of the U.S. economy. They have been derived by subtracting from the GNP all output produced (1) outside the U.S., (2) by government, (3) by nonprofit institutions, and (4) in private homes. The resulting output total is then divided by labor as measured in total man-hours.

Other key BLS productivity statistics (*not* referred to elsewhere in this issue) measure the "non farm" portion of the U.S. private business sector of the economy and the manufacturing portion of the nonfarm segment. Services are included in both the private business and nonfarm breakdowns—not in the manufacturing statistics.—*E.R.*

productivity with environmental damage, the time lost in urban traffic congestion, and other "bads" that reduce that productivity.

One of the simplest and most interesting measures available is the PQLI, which tells what happens to people. . . .

Vast resources have been devoted to economic development since 1950. In general, development policies of poor countries and support from abroad were designed to increase their total GNPs as quickly as possible. Rapid growth would increase per capita income and this, according to the theory, would quickly "trickle down" to improve human well-being. While total output in many previously stagnant economies has grown much faster in the past 25 years than ever before, the results of that development strategy have been disappointing.

In many developing countries, including several of the most populous, per capita GNP has grown so slowly that few benefits have been reaped by any segment of their societies. In some, per capita GNP has risen rapidly, but the gains have tended to flow to the few who were already better off, with few appreciable gains for the poorest billion people in the world. In still others, GNP has risen only slowly, but the physical quality of life of the poor majority has improved substantially. To date, only a very small number of countries have been able to combine rapid rises in GNP with rapid rises in physical well-being.

For many reasons, the traditional GNP indicator of national economic progress—whether recorded as a national total or on a per capita basis—does not tell us much about the quality-of-life results achieved. It cannot satisfactorily measure the extent to which the human needs of individuals are being met. Nor should it be expected to do so, since there is no automatic relationship between any particular level or rate of growth of GNP and improvement in life expectancy, death rates, infant mortality, or literacy.

Moreover, even if rising incomes are shared with the poorest groups, there is no guarantee that these increases in income will improve physical well-being. In some societies rising income has been accompanied by adverse dietary changes or the pollution of uncontrolled urbanization; for example, in some poor countries the shift to breast-milk substitutes that often accompanies rising income seems to have led to higher infant mortality rates.

Finally, a considerable proportion of any society's activity never gets incorporated into GNP; for example, household work performed by family members is not included, although this type of work is included if someone from the outside is paid to do it. GNP understates the output of developing countries in particular, because so much larger a proportion of their total activity is performed at home.

I. GNP and PQLI as indicators of progress

	Per Capita GNP, $	PQLI
Low-income countries: (under $300 per capita GNP)	**152**	**39**
Afghanistan	110	19
Egypt	280	46
Ethiopia	100	16
India	140	41
Kerala State	110	69
Indonesia	170	50
Mali	80	15
Nigeria	290	25
Sri Lanka	130	83
Lower-middle-income countries: ($300-$699 per capita GNP)	**338**	**59**
Albania	530	76
Cuba	640	86
Ghana	430	31
Guyana	500	84
Honduras	340	50
Korea, Republic of	480	80
Morocco	430	40
Thailand	310	70
Tunisia	650	44
Upper-middle-income countries: ($700-$1 999 per capita GNP)	**1 091**	**67**
Algeria	710	42
Argentina	1 520	84
Brazil	920	68
Gabon	1 960	21
Iran	1 250	38
Iraq	1 160	46
Mexico	1 090	63
South Africa	1 210	48
Taiwan	810	88
Yugoslavia	1 310	85
High-income countries: ($2 000 or more per capita GNP)	**4 361**	**95**
Kuwait	11 770	76
Libya	4 640	42
Sweden	7 240	100
United Kingdom	3 590	97
United States	6 670	96

NOTE: The PQLI ratings (as well as life expectancy, infant mortality, and literacy figures) of all countries are provided in *The United States and World Development: Agenda 1977*, by John W. Sewell and the staff of the Overseas Development Council, pp. 160-71. Boldface numbers above are averages for all countries in each income group.

Morris David Morris,
Florizelle B. Liser
Overseas Development Council

When compared with the GNP, the PQLI can reveal some very interesting things. Generally, there is a direct relationship between the two figures, but Cuba, Guyana, Korea, Sri Lanka, and the Indian state of Kerala all have PQLIs above average for countries with much higher incomes. In fact, they are far above Gabon, Iran, Kuwait, and Libya, all of which have high GNPs (see Table I).

Also, when the changing figures are looked at over time, it becomes clear that at least these minimum human requirements can be provided much more quickly than we can realistically expect the GNP to rise, even under the best circumstances. After all, there are those who insist the bottom line on all productivity is human value. . . .

There are many productivity concepts—a whole spectrum of them. They all involve a ratio of some kind of output to some kind of input. Productivity increases when output per unit of input rises. Productivity, therefore, is closely related to the efficiency concept; indeed they are virtually the same thing. There are as many such concepts as there are processes that transform inputs into outputs. For example, there are particular productivity concepts in which one output of a process is related to one input, like output of wheat per acre of land.

There are also general productivity concepts in which some measure of total output of a process is related to some measure of total input. These are more difficult, as virtually all processes have many inputs and outputs, so that to measure general productivity we must have a set of "shadow prices" or valuation coefficients by which these various inputs and outputs can be reduced to a common measure. Of course, by far the commonest measure, though not always the most significant, is the monetary unit, where the valuation coefficients consist of the relative price structure.

From the human point of view, all other measures of productivity or efficiency are subordinate to the fundamental concept of human value productivity. Human life is a constant process of transforming inputs of various kinds into outputs of various kinds and the valuations placed on these inputs and outputs and the efficiencies or productivities they represent are a most essential measure of the quality of human life. A high quality of life is one where the ratio of outputs to inputs is high in terms of some process of human valuation.

The human being is unique in the biosphere because of the enormous capacity to receive, process, generate, and transmit information. This has made the human race an enormous producer of artifacts: material, like an automobile; organizational, like a church or a corporation or a state; and personal, in the form of human beings with complex knowledge and skills, tastes, and personalities. Production, whether of a chicken from the egg or an automobile from the ideas and the blueprints and the human knowledge that produces it, originates with "know-how," that is, knowledge of the human being.

The processes of production are limited also by the nature of the genetic informa-

II. Ratio of R&D expenditures to value added in manufacturing, in percent

	Enterprise-Funded					Total				
	1963-64	1967	1969	1971	1973	1963-64	1967	1969	1971	1973
Belgium	2.3	2.1	n/a	2.1	2.4	2.4	2.3	n/a	2.4	2.6
Canada	1.1	1.4	1.3	1.2	1.2	1.3	1.7	1.6	1.5	1.6
Denmark	n/a	n/a	n/a	1.9	1.9	n/a	1.4	n/a	2.0	2.0
France	1.4	n/a	1.6	1.8	1.9	2.2	3.3	2.8	2.7	2.8
Germany	2.0	2.2	2.3	2.6	2.3	2.1	2.6	2.6	3.0	2.9
Italy	1.3	1.5	1.5	1.9	1.3	1.3	1.6	1.6	2.1	1.5
Japan	2.2	2.2	2.5	2.8	3.6	2.2	2.2	2.6	2.8	3.7
Netherlands	n/a	n/a	4.1	n/a	n/a	n/a	4.7	4.3	4.3	n/a
Norway	0.9	1.3	1.3	1.4	1.8	1.0	1.5	1.5	1.7	2.1
Sweden	2.4	2.6	2.4	2.8	2.8	3.3	3.3	2.8	3.3	3.3
United Kingdom	n/a	n/a	n/a	n/a	2.0	n/a	n/a	n/a	n/a	3.5
United States	2.7	2.7	3.2	3.3	3.1	6.3	5.8	5.9	5.6	5.0

Sources: OECD, *Survey of the Resources Devoted to R&D by OECD Member Countries*, International Statistical years, 1963-64, 1967, 1969, 1971, 1973; United Nations, *The Growth of World Industry*, 1967, 1971, and 1974 editions.

ing of industrial R&D.

For the period covered and the countries inspected, several conclusions emerge from these data:

- U.S. R&D funded privately exceeded that of all other nations in its intensity, with the single exception of the Netherlands, and also exceeded the total R&D intensity of most other nations.
- The U.S. was surpassed by Japan in 1973 in the ratio of R&D to value added.
- The increase in U.S. R&D intensity compared favorably with that of other nations.
- The U.S. maintained its relative position in the rate of enterprise-funded R&D activity, except in regard to Japan.
- Government funding had an important influence on R&D intensity only for three of the 12 nations.
- A nation's size did not seem to be a factor in the rate of enterprise funding of R&D.

Our second step was to estimate the distribution of enterprise-funded R&D expenditures across industry groupings, in order to see the extent to which the dispersion or concentration of enterprise-funded R&D differed from country to country. The percentage distribution, averaged for the period 1963–1973, of enterprise-funded R&D, was estimated for the eight industrial groups.

In terms of views frequently expressed, the data indicate three findings about enterprise-funded R&D:

- It was more widely dispersed among industry groupings in the U.S. than in other industrial nations.
- For nearly all industrial nations 40–60 percent was accounted for by two industries—chemicals and electric machinery.
- Available data indicate that aircraft accounted for a relatively modest proportion of it.

The detailed data for the eight industrial groups, when studied for alternate years, indicated most industrial nations had an increase in enterprise-funded R&D in transportation manufacturing (largely automobiles). In the three countries where government funding was an important part of the R&D in manufacturing, 50 to 60 percent of these funds went to the aircraft industry and 30 to 40 percent was dispersed to the electric machinery and equipment industry. Declines in government-funded R&D in the U.S. mostly affected the aircraft industry and left the electric machinery and equipment industry more or less untouched.

Next we tested by industry across the 12 industrial OECD nations for possible relationships between enterprise-funded R&D and economic performance. For the four industries for which sufficient data were available (chemicals, metals, electrical machinery, nonelectrical machinery and instruments), we examined output growth (expressed as output per unit labor) in relation to the average R&D intensity for the 1963–73 period. We also examined the total manufacturing sector for such relationships. Our correlation analyses came up with only a single statistically significant relationship out of the ten cases examined—between total output and R&D intensity for chemical industries.

Our findings indicate that international comparison of R&D intensity and industrial composition and the influence of R&D on output growth do not support a case for Federal actions to stimulate industrial R&D. Taking enterprise-funded R&D in the manufacturing sector, our results show that, in terms of both levels and trends, the U.S. industrial R&D experience in the recent past compares favorably with nearly all other Western industrial nations. In addition, we could not find in international comparisons of individual industries a clear relationship between differences in R&D effort and output growth or productivity improvement.

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One conclusion that can certainly be drawn from all of the data in this issue, is that there is no certainty to be found. There is no fundamental agreement on how to measure productivity or whether it is declining. But there is also no agreement that even if it is declining, the situation is a bad one. In fact, some of the experts think it is right and proper, possibly even a very good thing. . . .

Mature industrial countries are now facing an inevitable transition from maximizing of production, consumption, and waste based on nonrenewable resources to the capitalization of newly designed production systems based on renewable resources and managed for sustained-yield productivity over the long term. Farmers understand sustained-yield management and now we're going to have to teach it to economists.

Currently we exist on a technological plateau that I call the "entropy state"—a society where the technological innovation process has generated such scale and complexity and interlinkage that it has become unmodelable and therefore unmanageable. The soaring, unanticipated social impacts and costs that, illogically, we add to the GNP as if they were real production begin to exceed the real productivity of our economy. In fact, these mature industrial societies may eventually reach a point of "maximum entropy" where they are generating social and transaction costs (i.e., information requirements) that exceed real productivity. Such costs include unanticipated social consequences, social and environmental disruptions and depletion, and the proliferation of bureaucratic attempts to coordinate and regulate the situation.

Since the social costs are added to the GNP instead of subtracted, the GNP goes up and inflation begins to mask the declining economy. The only fraction of the GNP that is growing at that point is the "social cost fraction." I think one of the most persuasive pieces of evidence of this entropy state is cited in the monthly review of the crease productivity and does not pay for itself. The answer to more than adequate capital plant is not still more capital investment, as much of the business press would have one believe. The challenge now is to find ways to relocate people out of the capital-producing sectors and into consumer-product and food sectors where they can fully use the capital plant that has already been brought into existence.

Furthermore, one needs to distinguish productivity per person on the assembly line and per person in the agricultural field from productivity per person in the total population. Total productivity for the economy has been declining because of the rapid increase in overhead activities. Government employment is part of that overhead. About 30 percent of the population is now being supported by tax payments; that is about as high a percentage of the economy devoted to Government overhead as is possible. We also have a very high overhead in corporations. In manufacturing corporations, overhead on direct labor often runs above 300 percent—that means three times as many people around the fringes of the production process as directly making products. About another third of the economy is in the service sectors—much of which is not serving. When one runs through the entire society, one finds that we are operating with about 90 percent overhead. The underlying base of people making products and food has dwindled alarmingly.

One part of the service sector that seems to be moving toward marginal service is electronics and communications. We suffer today from information pollution. I am skeptical about the idea that our problems will be alleviated by more satellites, more telephone lines, and more computer terminals. I feel we are now in the last marginal thrust of the present expansion into communications devices.

I went to a computer trade show a couple of years ago and found that about two thirds of the exhibits were devoted to almost identical keyboard terminals. It made me think of the automobile industry when there were 200 to 300 U. S. car manufacturers. There was not enough product differentiation to support the different entries. The remaining third of the display arena was devoted to electronic fun and games, which suggests that we are at the stage where it is aims and not utility that is the last frontier of the field.

I think in the future we will shift our attention away from technology as the great frontier challenge and toward developing an understanding of social and economic processes. We have very little understanding of people and social systems. There is not much more understanding of social systems than there was in the days of the ancient Greeks. There is, however, every reason to be hopeful, if we are willing to set our minds to understanding social problems with the same vigor that has been devoted to technological problems.

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Exploding a few myths about productivity and presenting a formula for the future

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There is ample evidence that in the past 17 years annual gains in productivity in the United States have lagged behind those of other advanced industrialized countries. Between 1960 and 1977, the U.S. could boast productivity increases of only 2.8 percent per year, compared with 5.7 percent for West Germany and 8.4 percent for Japan (Fig. 1). However, it should also be emphasized that the absolute productivity level in the U.S. is still high compared with other countries, even though the rate of improvement may be lower.

To assess the relative impact of various factors on the deceleration of U.S. productivity, one must analyze the relative importance of sources of productivity growth in the U.S. economy.

Robert Solow, at the Massachusetts Institute of Technology, utilizing his own methods of analysis and corroborating the independent findings of numerous scholars at the National Bureau of Economic Research, has reached the conclusion that "more than half of the increase in productivity is a residual that seems to be attributable to technical change—to scientific and engineering advance, to industrial improvement, and to know-how of management methods."

Similarly, Edward F. Denison, at the Brookings Institution, finds that almost one half of the U.S. increases in productivity can be attributed to technological innovation (Fig. 2). By contrast, only 16 percent is attributable to capital formation (automation). The remainder is apportioned among scale economies (16 percent), education (12 percent), and better resource allocation (12 percent).

The message is clear. In order to obtain step-function increases in productivity, the accumulation of capital must be joined by more R&D and technology to increase the effectiveness of the capital investment.

Based on these findings, we can reach the following conclusions: Although important factors in the deceleration of U.S. productivity gains have included reduced capital formation, environmental requirements, a shift of the labor force to the service sector, a deterioration of the "work ethic," and the orientation of our educational system (too often, young people leave school either uneducated or educated in the wrong things), the most important element appears to have been a deterioration of technological innovation.

Productivity myths

One of the most pervasive myths regarding productivity is that increases in output per man-hour lead to increases in unemployment. Productivity in the past has been tied closely to the use of capital in labor-intensive industries. Thus, if output per worker were to increase without a corresponding increase in demand, employment would decrease. To some extent this is true, but only in the very short run. History has shown that productivity gains not only increase the living standard but also increase the economy's ability to create jobs.

Contributions of high-technology industries to the U.S. economy have been possible because of a continuous and deliberate effort to increase productivity through technological innovation spawned by research and development. During the past quarter century, productivity in the high-technology industries increased at an annual rate of 4.1 percent, compared with 2.2 percent and 1.6 percent for the low- and mixed-technology sectors respectivey.

Contrary to the prevailing views of some of the more vocal groups in the U.S., productivity gains have not been at the expense of employment. Advanced industries generate innovative products for which there are high-growth markets both at home and overseas. The large demand for these products attracts workers into oc-

1976. This decrease was accompanied by a drop of 77 percent in Federal support for basic research in industry. While we can only speculate as to the effects of this reduction in longer-term, high-risk investment, we do know that some of the most striking and useful innovations often arise from basic work. In one area—solid-state physics—shares of four Nobel Prizes have been awarded to industrial scientists. It is no coincidence that the fruits of this science have led to U.S. dominance in solid-state technology. The transistor, the superconducting magnet, the electroluminescent display, the new magnet materials, the large-scale integrated circuit, and all the rest of a multibillion dollar industry [testify] to the effectiveness of that enterprise."

Removing the obstacles

What can be done to lower or remove these barriers? Mainly, U.S. public policies must be redirected toward the creation of an economic climate that is conducive to innovation. Therefore:

- Government spending at the Federal, state, and local level must be curtailed. Reduced Government spending will lead to lower deficits, a smaller rate of growth of the money supply, and lower rates of inflation. This, in turn, will reduce economic uncertainty, promote longer-range planning, reward savings, make more capital available to private investors, and stimulate capital formation and innovation.
- Government regulation must be curtailed or eliminated. This will go a long way toward restoring the vitality of the U.S. productive system.
- The tax laws must be changed. Few corporations can self-fund an increased rate of growth, given the current tax policies. It follows that, if the U.S. intends to remain competitive and at the same time to avoid a capital shortage, appropriate corporate tax cuts to stimulate investment and R&D expenditures are in order.

In addition, a permanent rather than a temporary increase in the investment-tax credit would allow the business community to formulate optimal long-term investment plans. Finally, a tax credit for research and development expenditures would not only free corporate funds for investment purposes, but would also channel funds to those businesses—the high-technology industries with heavy R&D expenditures—that can make the greatest contribution to economic growth, employment, and reduced inflation. ◆

For a further exploration of this area by Mr. Bucy, see the article beginning on page 78.

On stimulating productivity in the U.S.: The need to encourage innovation is broadly supported, and a program is sought

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Technological innovation is the application of the industrial arts and sciences, along with the human intellect, to change the way society creates its goods and services, or the very nature of those goods and services. Despite the fact that technological innovation can secure large benefits for society, and that small businesses secure those benefits out of all proportion to their size, the rate of creation of small businesses in the United States has fallen dramatically over recent years. From 1964 to 1974, the number of new public issues for small high-technology companies dropped from $349 million to $6 million. Even more tragic is the fact that in the first half of 1975, there was not a single new issue for a small high-technology company.

Even for the larger U.S. firms, the drop in significant new technological advances has been noted by writer after writer, by scholar, businessman, and Government observer alike. Specific data are hard to come by, but the perceptual evidence is clear. Most of the dictating machines in the offices of the U.S. Congress and of the Administration come from Germany or Japan. No home videotape recorders are made in the U.S. Machine tools, nuts and bolts, and even skis have invaded U.S. markets in unprecedented numbers from overseas. The U.S. trade deficit from the importation of machinery recently exceeded that from the importation of oil.

Whether or not one can prove statistically that there has been a decline in U.S. innovation, the need to encourage further innovation is clear. One can demonstrate conclusively that the rate of a country's industrial advancement is intimately linked to its rate of industrial technological innovation. There is little doubt that U.S. industrial development desperately needs invigoration, if it is to meet the demands of society for better goods and services, if it is to generate the national surplus that enables the United States to continue its social programs and redeem its environment from the excesses of the past, and if it is to give the country control of its position in world trade so that it can negotiate with others from a position of strength. That vigor can come only from an ongoing aggressive policy of innovation.

Because that policy is in the public interest, because innovation takes place almost entirely within the private sector, and because there is a clear national imperative for its attainment, the United States faces a new opportunity for developing a rational set of Federal policies that will encourage effective technological innovation in the private sector. Such policies involve almost every aspect of Government. Hence, developing them and integrating them into a consistent strategy is a complex and wide-ranging task. What will encourage innovation in small firms may only generate windfall profits for investors in large firms. What will encourage innovation in high-technology firms may have no impact on more mature ones. Policies that encourage innovation in response to domestic demand may have little impact on international trade position.

Since the problem is so complex, President Carter has directed that the Secretary of Commerce conduct a wide-ranging interdepartmental study to develop the policy options—and their implications—that the Administration can use to encourage industrial innovation in the national interest. The Secretary has asked me, as the chief science and technology policy officer in the Department, to undertake, under her supervision, the design and conduct of that study. The study will focus on what Federal options are available for encouraging innovation at the level of the individual firm—large or small, new or established. It also will concern itself with the individual inventor (for that is where much of innovation starts) whether the inventor is an employee or is self-employed.

The initial input to the study is to come from the private sector—from business, labor, public-interest groups, and academics. The business portion will involve the leaders of some of the most innovative large firms; representatives from less innovative, mature industries; and members of the venture-capital industry, successful small-business leaders, and those who are pass, titanium, shell molding, the zipper, automatic transmission, helicopters, power steering, and color photography.

And in the same category are such inventions as air conditioning, the Polaroid camera, cellophane, tungsten carbide, Bakelite, Velcro fasteners, Hovercraft, magnetic-core memories, catalytic cracking of petroleum, the oxygen steel-making process, shrinkproof knitted wear, the Dacron polyester fiber "Terylene," continuous hot-strip rolling of steel, continuous casting of metals, and foam rubber.

Finally, the third class of inventors includes the vast number of professionals who work for large corporations, Government laboratories, and other institutions that take full rights to the inventions made as part of the job.

However, when discussing inventions made by large corporations, one should not minimize the contributions of the large corporate research staff in reducing an innovation to its final, practical, mass-produced form. And, of course, one should not overlook such tremendous efforts as the invention of the transistor by Bell Laboratories or the final development of television, as we know it, by RCA.

Technological climate

There is no doubt in the minds of many technical people that the technological climate of the U.S. needs to be improved. And there is ample evidence that such improvement could be accomplished best by encouraging the formation of new enterprises, particularly small, new technological companies that have to innovate to stay in business and that cannot depend simply on traditional market strength. Such small companies clearly will have an uncertain future. Many will go bankrupt. A few will become large corporations. Others will be bought by, or otherwise join, large corporations and thus transfer their technology into the mainstream of our economic life.

A great deal has been written and said about why large corporations are unwilling to support radical innovations, preferring instead to spend R&D money on improvement of old technology. Among the usual reasons given are the following:

- High interest rates make it easier to earn money by lending it rather than investing it in risky inventions.
- Government regulations make it necessary for large R&D institutions to spend more time and effort in meeting these regulations than in developing new products.
- Bonuses and other incentive systems for executives of large corporations are based on short-term profit and the best way to make short-term profit is to "play it safe" in technology.
- Large and multinational corporations prefer to do their R&D outside the U.S. both because of lower costs and less stringent regulations and because the R&D will then be done closer to where the product will be produced.
- When business is slow, the profits are low and, under such conditions, the business manager doesn't want to spend money on risky ventures.
- The investing public, particularly as represented by Wall Street, is disillusioned because of the failure of many high-technology ventures after World War II.

All of these arguments are true to a greater or lesser extent, depending on the point of view. But a reason that is not mentioned very often is that many of the large corporations are no longer run by their founders or, for that matter, by the offspring of their founders. Instead, their direction comes from "professional managers" who do not know much about the products the company produces and certainly have no emotional involvement in those products or the technology that surrounds them.

In my view, this situation is much more important and tragic than is commonly believed. An invention is like a child: it has to be nurtured, protected, and defended. Unless the child has the love of its parents, its chance of survival is small. Similarly, a new technology is full of trouble. It has bugs in its basic approach; it has difficulties in production; and it encounters opposition from the sales staff, the service staff, the suppliers, and often the customers.

The larger the corporation, the more traumatic the introduction of a new product. It is relatively easy for a small company to produce a new product and debug, sell, and service it. It is much harder for a corporation with branches all over the world when the product represents an investment of millions of dollars and necessitates retraining of sales, service, and supply personnel. A mistake in this process, or a difficulty in the field, can give a corporation manager nightmares. On the other hand, making gradual improvement in an existing product is safe, the market is predictable, the sales and service people can easily learn about the changes, and the overall risk is small.

Government support of R&D

The U.S. Government spends roughly half the R&D dollars of the U.S., yet the patents that result from Government R&D are no more than about 1/60th the number that result from private R&D. In other words, the Government R&D dollar produces only about 1.5 percent as many patents as the private R&D dollar. This figure is amazing when one considers that the Government supports far-out technologies and the number of inventions in the two areas shouldn't be too different.

What has happened in recent years, in my opinion, is that the motivation and patriotism characteristic of inventors during World War II are not present to the same extent today. If I were running a company doing R&D for the Government, for instance, I would be certain that any really brilliant idea I might have would be developed with my own money. If it were assigned to the Government, it would receive the kiss of death of a "free licensing" policy. Many companies refuse to do Government R&D in fields that are important to them. They prefer to spend their own money and to control their own patents.

Government R&D is often carried out by a "two-platoon" system. The first platoon consists of brilliant designers and inventors who write proposals and convince the Government that the company can do a particular job. After the contract is let, the first platoon does little or none of the work, but it is passed on to a less competent group. Some corporations hire outside firms to write proposals; they know that if they write enough of them, they will get some Government work. This situation is less true with small companies where the boss is the chief engineer, the proposal writer, and the supervisor of the project.

One of the problems with Government support of R&D is that, in most cases, the Government follows a policy of taking title to the invention and only releases it to the company that created it under special circumstances, and then seldom with a simple totally exclusive license. The pressures for using this "title policy" are many. There is the argument that if the Government paid for it, it should own it. If the Government paid for it, why shouldn't everyone get the benefit of the free invention? If the Government paid for it, how can it possibly give all the commercial rights to one company? If the Government paid for it, why should it permit a "monopoly" to be set up? (A patent, however, is not a monopoly; it is a piece of property limited in area and in duration.)

The question should not be, "Who paid for an invention?" What should be asked is: What will happen to it afterward? Will it become a product? Will it contribute to a series of other inventions? Will it create employment? Will it enable U.S. products to be sold overseas?

One should also ask: Does the Government "title policy" give the Government the best rather than the second- or third-best effort? Why is it that governments (city, state, and Federal), which provide free education to citizens, support families of all of which are combined to produce goods and services. For example, fuel, in combination with transportation equipment, can provide motive power. However, to transport goods and people, the fuel and equipment must be combined with labor to operate the equipment.

To link energy use and productivity, we examine the relationship between capital and energy on the one hand and labor and materials on the other.

An unambiguous finding of recent empirical research is that energy and labor are substitutable inputs. This agrees with basic intuition. In the field of transport, for example, energy conservation and labor time are clearly substitutable. Truck drivers have become militant over the 88 km/h speed limit in the United States, since such energy conservation requires more time to travel given distances. On the other hand, the supersonic Concorde jet uses more fuel per passenger km than other similarly sized planes, but it conserves time. In the residential sector, self-defrosting refrigerators or self-cleaning ovens use more energy but save human labor.

Since energy and labor are substitutes, energy prices rises imply a tendency to increase labor input to obtain a given output. This implies further at least a reduction in the rate of increase in labor productivity.

But the impact of higher energy prices on productivity growth depends not only on energy prices but also on wage trends. If future wages increase more rapidly than energy prices—the historical pattern until 1973 in post-World War II America—then both energy and capital spending will continue to be substituted for labor.

Although empirical evidence and simple intuition support the notion of energy-labor substitutability, more careful analysis is required for the energy-capital relationship. The discussion so far suggests that energy conservation is possible, but only by use of more capital input. On the other hand, if an increase in energy prices reduces the de-

Tasks, fuel, and capital

If we denote a task by T, and the input of fuel and "physical" capital equipment by F and K, respectively, we can represent the process of transforming fuel and capital inputs into the task output by a production function, $T = f(F,K)$.

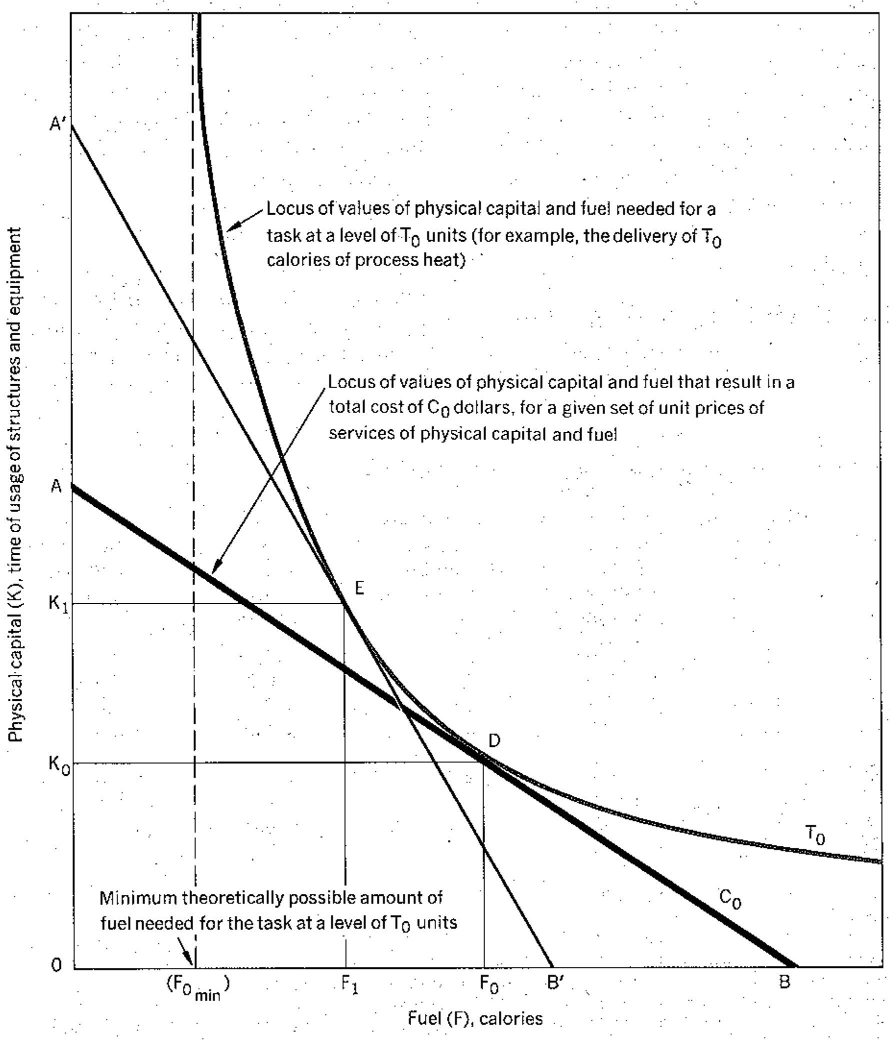
The various fuel-capital combinations capable of performing a specific task at a given level, T_0, are represented as coordinates of a curve called an "isoquant" (see graph). Since fuel and physical capital are substitutable inputs—an increase in the price of one decreases the demand for that input and increases the demand for its counterpart, for a given task. The isoquant is convex to the origin. The larger the task, the farther away from the origin is the isoquant.

To determine which combinations of fuel and capital will be chosen for a given task, we assume that companies choose fuel and capital to minimize total costs. If we now denote the unit prices of capital services and fuels as P_K and P_F, respectively, then the total cost, C, in dollars, is given by the linear equation $C = P_K K + P_F F$ depicting an "isocost" line. (P_K may be the annual cost of a furnace and P_F dollars per ton of coal.) For example, at the isocost line AB in the graph, F_0 units of fuel and K_0 units of physical capital cost C_0 dollars. Isocost lines corresponding to larger total costs but identical prices of capital services and fuels would be parallel to and to the right of line AB. In the illustration, the minimum cost combination of fuel and capital for one set of P_K and P_F is at point D where AB is tangent to the isoquant. At this cost-minimizing point, the derived demand for fuel is much larger than the minimum possible value based on the Second Law of Thermodynamics (F_0^{min}). Indeed, the ratio of line segments OF_0^{min} to OF_0 in the graph represents the actual efficiency of fuel usage; in this case it is considerably smaller than unity.

The effects of recent fuel price increases on fuel efficiency can be seen. Increases in the unit price of fuel will make the negatively sloped isocost line steeper (isocost line $A'B'$, tangent at E), and thus will decrease the economically optimal amount of fuel demanded (F_1), at the expense of higher need for capital (K_1).

Since the new level of fuel utilization is still greater than the thermodynamic optimum F_0^{min} some fuel "waste" remains economically optimal. The economic and thermodynamic optima would coincide at F_0^{min} only as the isocost line became virtually vertical—that is, only as the ratio of unit prices of fuel and capital approached infinity.

A thermodynamic optimum of fuel use is not necessarily the most economical one. Economic considerations show that to accomplish a task with the theroretical minimum amount of fuel would require infinite physical capital.



PRODUCTIVITY II

Electrotechnology to the rescue

Productivity is a complex measure. The factors affecting it involve substitutions and equivalents. For example, Texas Instruments' Patrick Haggerty has postulated that a "unit" of electronics (the "active element group") can replace a given amount of energy that would otherwise be required in specific manufacturing operations. And, as Associate Editor Kaplan states in the introduction to his article, every fluctuation in availability and price of energy affects both the world economy and national productivity.

Productivity can be increased in various ways; the most elegant and promising is through innovative design of product. Of this last method, the integrated circuit is clearly a classic example. The ability to cram more and more electronics (functions) into the same space, and at lower cost, exceeds in its effect on productivity that achieved through "merely" producing IC packages more rapidly. Thus, as Associate Editor Sugarman points out, most of the semiconductor industry, in the assembly of these IC packages, still employs what steel makers would regard as stone-age manufacturing technology.

In another twist of irony, semiconductor products permit the steel industry the luxury of the foregoing sentiment, and semiconductors and computers hold the hope for giving the steel (and other) industries a series of "booster shots" to spur their productivity further. For example, author Munson stresses that electronics makes robots easily programmable with built-in nonobsolescence and long-term cost effectiveness. And author Olling observes that computerized systems for machine tools can minimize in-process inventory, lead time, direct and indirect labor, tool changing, and setups, while maximizing equipment utilization and flexibility.

Computers are making giant strides in automating production—but human decision making is still crucial

Robert Sugarman
Associate Editor

In the 1960s, computers were considered by many as an infallible future way of boosting productivity, since they worked faster and had more memory than humans.

But the then high-cost computers, the need to place them in central locations, and a gross underestimation of the complexity of programs required to outperform humans even at routine tasks doomed many of the early efforts.

By the early '70s, a better understanding of both computers and human operations, plus cheaper computer power, finally made computers legitimate productivity boosters.

Today, with microprocessors and more sophisticated hierarchical programming concepts, (see Fig. 1), it is theoretically possible, though not always cost-effective, to replace or parallel humans in many continuous-flow and batch-flow operations. For industries requiring a lot of assembly steps, like automobile making, however, even theoretical total automation seems a long way off. (See page 60 of this issue.)

Semiconductor and steel makers, whose processing uses a variety of both batch and continuous-flow operations, could not operate today without computers, and both industries are extremely sophisticated about their use. But there are present limits to further automation in both industries.

In the semiconductor field, no one sees the computer replacing the human designer, except to uncover design errors and help to generate the artwork from which semiconductor circuits are made. But if the computer isn't being creative in this process, it is surely being productive. If productivity is measured as the number of functions a month a designer can put on a chip from product definition to final artwork, then computers have boosted this rate a factor of three to seven for random logic circuits like microprocessors and 15 to 35 for memory circuits.

In steel making, complete computer control is at least five years away, according to even the most optimistic process-control experts. And no one is even planning such control for the manufacturing of semiconductor circuits.

In the U.S., no one suggests that all steel plants, particularly those with antiquated production machinery, ever be completely automated. Japanese steel makers, with newer plants than the U.S., seem to be ahead in automation. But some specialists feel that Japan's automation edge may be, to some extent, overkill in that some of it has been installed for prestige value rather than for proven gains.

Fragments of total computer hierarchical control (Fig. 1) are in place in the steel industry for controlling furnaces, rolling mills, and continuous casting, as well as in other industries such as paper and pulp (see July, p. 48) and in such continuous-flow industries as oil. But no one, not even the Japanese steel mills, has completely unassisted computer control from purchase order to final fabrication. So the final assessment of such a program on productivity has yet to be made.

Increased use of computers and microprocessors in both industries even without such control has also brought about better product uniformity and smaller inventory levels and promises to continue to do so in the future.

In some cases, these gains are translated to increased productivity but in others they are hard to quantify.

The gains to be made by future hierarchical computer control in both industries are also difficult to pin down, because they will probably involve new proaching a peak-demand-rate penalty.

Inland Steel's Indiana Harbor Works is to have an energy-data-collecting and -monitoring system operating next year to check out where and how much energy is being consumed in that mill, the largest steel producer in the U.S. The company's analysts expect that as a result of their data studies, they may be able to use more coal and less oil but that the total energy saving in Btu's, even with a master plan for the whole plant, may be only one percent or less. This is simply because the plant is already using energy efficiently without complete computer control. But, again, small percentage points are the name of the game in steel making.

Dr. Williams is a little more optimistic about the energy savings possible with hierarchical computer control. He estimates that a 5- to 6-percent overall saving has been obtained so far, with purely local controls on boilers and furnaces, and that adding more control levels might double the saving. But he cautions about the interpretation of such an estimate. It may be, as with the Indiana Harbor Works, that control systems already installed by the steel makers have already accounted for much of the potential energy saving per ton of finished product.

Investment in automation

With the U.S. steel industry closing down some 3 percent of its raw steel capacity in 1977, one wonders why steel makers bother to invest in such apparently marginal luxuries as computers. But the fact is that steel companies in the U.S. have spent some $30 billion on capital improvements since 1960; not only Inland but Armco, U.S. Steel, and others are also making such investments. Even after replacement of antiquated machinery or other production bottlenecks and the investing of about 20 percent of available capital in computerized pollution-control facilities that contribute nothing to productivity, the steel industry still has some discretionary capital left for productivity automation.

U.S. Steel, for example, is updating the controls of its hot-strip mill at Gary, Ind. By adjusting the furnace heating rate to mill-rolling rate, the controls should save several million dollars in real energy (Btu's) a year. The Inland Steel designers, who are also planning such furnace control in their hot strip mills, estimate spot fuel savings of some 15 to 25 percent a year.

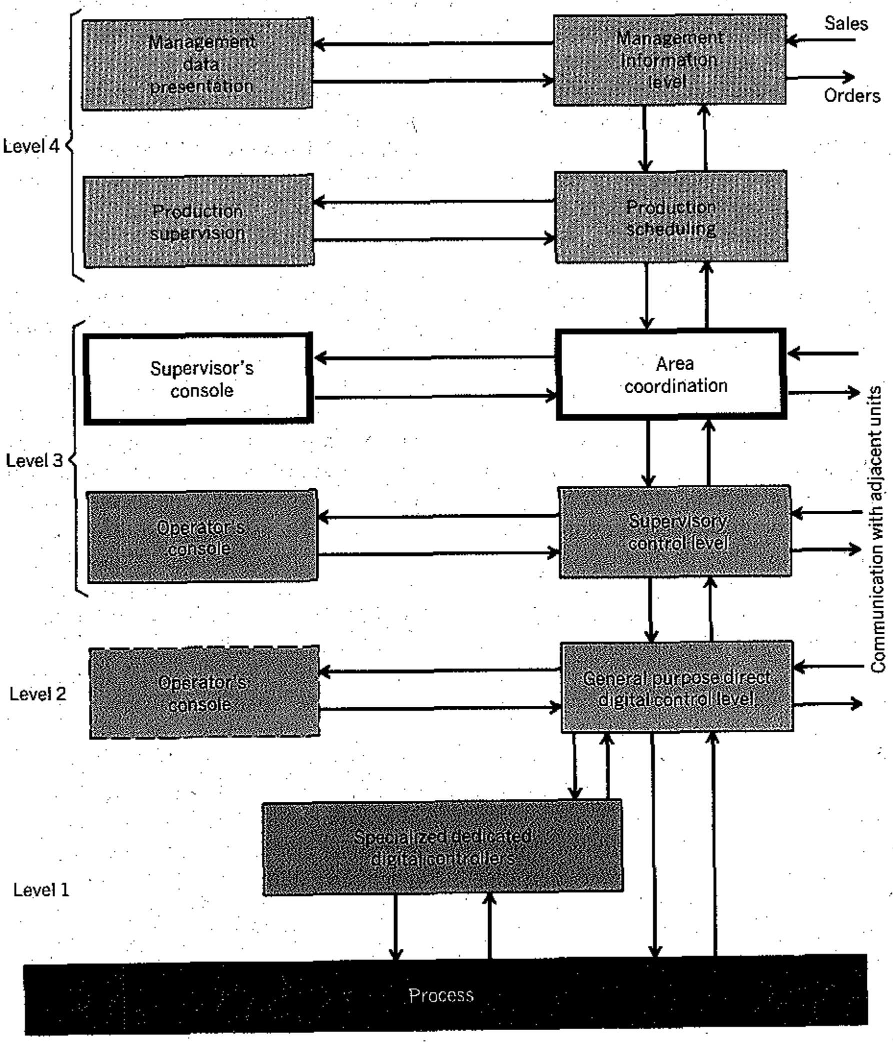
While this is a good example of a layer of hierarchical control linking two processes—the hot strip mill and the preheat furnace—and making substantial fuel and energy savings, it is not a typical illustration, since the hot strip mill operates at high speed and needs faster input changes than almost any other equipment in the yard. The other mill furnaces operate on far slower cycles, such as 20 minutes for a basic oxygen furnace or continuously for a blast furnace. Updating analog controllers with digital computers will hardly make a dent in the efficiency of these furnaces until steel makers can predict the behavior of their furnaces under different operating conditions.

For those readers unfamiliar with steel-making technology, a blast furnace is used to convert iron-bearing raw materials to molten iron. Then a basic oxygen furnace refines a mix of molten iron and scrap steel to make molten steel. The latter is either cut into slabs or poured into ingot molds, reheated, and then rolled into 20-ton slabs. The slabs are the raw material for the hot strip rolling mill. Here, the slabs are squeezed down to a coiled strip about a 1/10 inch thick. The coils then go to a cold strip mill for final shaping, finishing, and annealing.

Continuous casting cuts out some of these intermediate ingot-to-slab operations by pouring steel directly from the basic oxygen furnace or equivalent through an open-bottom mold down a long, right-angle bend, where it is water-cooled precisely and then cut into slabs for hot rolling.

Continuous-casting and electric-scrap furnaces are both popular operations these days because of high return on investment. When the two are combined, as in U.S. Steel's pipe-making operation in Houston, more automation is sure to follow. So the Houston plant in Texas, which is a good place to sell pipe, is being updated with a computerized supervisory system to control its four electric furnaces and the three continuous casters. This should provide more uniform product, with better yield, and cut the big power bills incurred by the electric furnaces. However, the saving will be in dollars, not Btu's, since the

[1] The basic layers of hierarchical control are conceptually the same for any industry.



blowing oxygen through pig iron to cut its carbon content. During the blowing the operator does not know what's happening without a lot of expensive thermocouples shot at the melt and/or a halt in the blow for time-consuming metallurgical analysis.

Dr. Williams estimates that perhaps a 20-percent improvement could be made in basic oxygen furnace throughput if one could obtain by accurate computer modeling the details of what is happening during the blow step. A blast furnace, he feels, could also make a better grade of pig iron more consistently if its dynamics were better understood. Dr. Williams' associates, as well as Inland Steel and the Japanese designers, are developing computer models to further explore the behavior of both furnace types.

The payoff in hot strip rolling mills

While furnace behavior is still enigmatic and continuous casting, at some 60 inches a minute, can survive with local analog controls under digital supervision, the hot strip mill operating at a much higher speed benefits from a direct digital control hierarchy. Steel in these mills is continuously being heated, roller-squeezed, cooled, and coiled, with, typically, ten different roll stands used in sequence. The sheet steel has to run faster as it gets thinner, with maximum speeds up to 1000 meters a minute.

The old Indiana Harbor analog roll-controls at the 80-inch hot-strip mill are now being changed over to direct digital control by a Digital PDP 11 computer connected to existing Westinghouse supervisory computers. The Indiana Harbor plant's computer staff has put in some 20 programming-person-years on the hot strip mills and as part of a continuing computer-updating program.

Rolling temperature and pressure variations outside of preset limits have to be sensed and compensated for within a fraction of a second—more quickly and accurately, the designers believe, than could be done with the old analog system.

The all-digital controls should give greater product uniformity in other ways as well. When, for example, a new set of rolls is installed, with an analog system the rolling parameters will be slightly off for half an hour before the rolls heat up, but not enough off for the system to make accurate on-line changes. With the digital system, knowledge of what variables to change during warmup is prestored in program memory and activated at roll change.

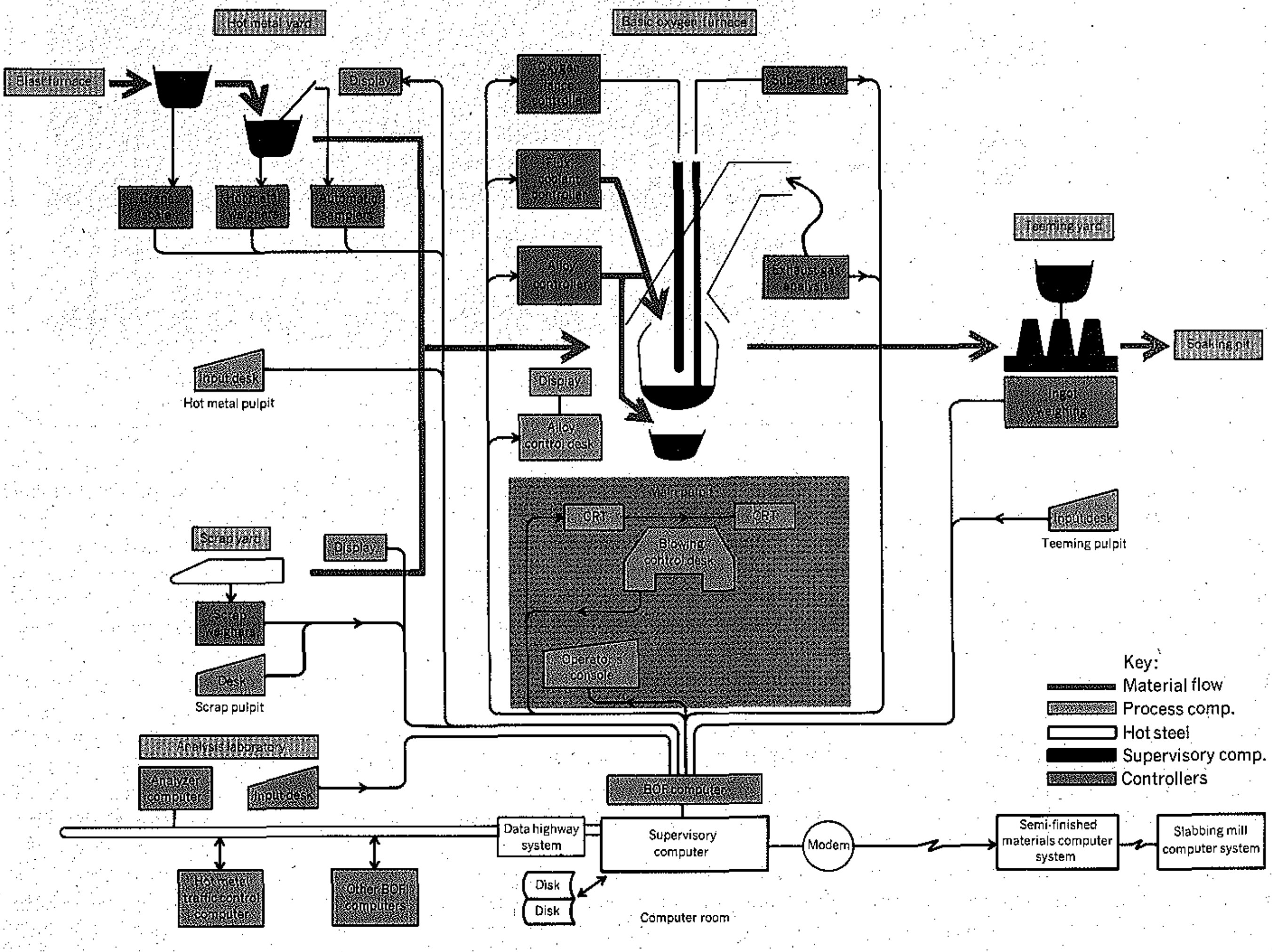
The hardware engineers have also connected two 8-bit microprocessors to the computer hierarchy. These control the crane and walking-beam conveyor system that picks up the finished 20-ton steel coils and passes them along to inspection, annealing, and storage stations.

Will steel automation cost jobs?

While automation in the long run has historically created more jobs, whether in the short run it can safely cut the work force is a continuing argument in the U.S. between steel labor and management.

In Japan, the Sumitomo Company has claimed a 30-percent worker reduc-

[2] Many of the layers of local hierarchical control, shown here in complete form for a basic oxygen furnace, are already installed, even if some of the controllers are still analog – for example, the one lowering the oxygen lance into the melt.



masks that define functionality—and process engineers, who create workable circuits from the masks.

There is nothing routine about either of these tasks because of yield—the ratio of dies that pass inspection to all dies made. Yield is a critical function of circuit size, minimum geometry, and the number of masks needed to make a circuit. The IC designer usually can't pull some standard function designs or cells out of a computer library and then ask the computer to interconnect them without his help, because the computer might waste 20 to 50 percent more space than a human, which is not acceptable except for rush designs or someone who may want small quantities of parts.

Wasted silicon in design means a lower production rate. Going to a bigger die cuts the yield, because it increases the chance of an impurity defect in the silicon or in the mask. Trying to raise productivity by scaling down an inefficient mask to fit a smaller die can ruin a die, because if the process isn't set up to work with the finer line widths, there will be no yield at all.

The mask design is turned into an active semiconductor by repeated mask photoexposure and etching followed by various combinations of silicon impurity doping, growth, and deposition.

After the process is complete, computer-controlled sorters, assisted by computer-driven testers, separate the good dies from the bad ones. The yield at this point might horrify a steel-processing expert, who expects to rework a slab now and then but not to have to destroy 70 to 95 percent or more of a run—typical figures in the semiconductor industry.

Stone-age assembly

At present, the bulk of the semiconductor industry still resorts to what steel people would regard as stone-age technology. The good dies are shipped to Hong Kong, Korea, Malaysia, and Indonesia for attaching to lead frames, for bonding electrical wire connections from the die pads to the frame leads, and for encapsulating and checkout on computer-driven testers.

The dies travel around the world to take advantage of cheap assembly labor, because the wire attach process is still largely done by hand. The semiconductor managers are frankly canvassing the world for low-priced human labor.

"The impact of computers on our industry's assembly lines is still very low," says Pierre Lammond, chief technical officer at National Semiconductor. Federico Faggin, president of the Zilog Company, feels it will be another five years before the semiconductor assembly process becomes automated. Mr. Lammond notes that the recent use of microprocessors for automating assembly has potentially improved worker productivity tenfold. National is experimenting overseas with such automation, as are other companies for "jelly bean" consumer products, but the price of such machines at some $20k to $50k per station is not a fast write-off when the yearly wages of the operators are taken into account. The automated die-attachers come in various states of sophistication. In most common setups the operator sequentially lines up two preselected points of each die with a microscope. With the die position then embedded in the microprocessor memory, the machine proceeds to bond wires at the rate of two or so per second.

In a more elaborate and more expensive version made by Kulicke and Soffa, the model 1414, a television scanner fed to a pattern-recognizer microprocessor, performs the initial alignment automatically, without operator assistance. The company, which makes the wire bonders in all grades of automation, says one operator can handle two of the human-aided versions. The latter take some ½ to 1 seconds to attach a wire to each die bond, and an operator can, in some cases, run four to six of the machines with a special optional console. The pattern-recognizer lead bonder is a less fatiguing operation; it requires only loading and spot-checking, with perhaps six to seven machines per operator. All of the automatic K&S bonders are user programmable, in the sense that the operator does a manual bond cycle for each new production run. The wiring sequence is then stored in memory.

Although, like the steel companies, all the semiconductor companies have sophisticated computer order-entry and management information systems, few semiconductor companies are thinking about physically connecting computers to the production machinery, for the very good reason that there are no hierarchical computer layers linking the production-line machines yet in place, although a few are planned. With the whole production process changing every two years, such a linkage is premature, many feel, at the present state of the computer art.

The designer/computer interaction

If one argues that the semiconductor industry's great productive edge is its ability to come up with increased product functionality each year, then decreasing design time must be assessed as a true productivity gain.

The computer interacts with the semiconductor designer at many levels, increasing its usefulness almost exponentially toward the end of the design process. At the beginning the designer, as architect, struggles with alternate strategies and, of course, the usual conflicting goals of customer needs, yield, and cost. Few on-line computer aids other than a pocket calculator are yet available to help in the designer's creative compromises.

The next step after a design is created is either building a working model from a collection of discrete logic and/or memory elements or simulating the model. The trouble with building a model, says Dr. Faggin, who was a designer before founding the Zilog Company, is that such complete simulation of high-density logic may require 1000 discrete packages. Just the problem of debugging the physical connections to get anything working would be so time-consuming that today's designers have responded by going to logic simulations with commercially available computer programs.

If the logic is correct, the next step for the designer is to computer model the transient analysis to ensure correct electrical behavior. Modeling by mode analysis of a complete LSI or VLSI circuit with thousands or tens of thousands of active circuits would require a staggering amount of matrix inversion calculation time on a computer. Designers at Intel, for example, claim even the part-time loan of the world's fastest computer, the Cray-I, wouldn't suffice. Dr. Faggin says designers will reluctantly settle instead for analysis of critical paths within the circuits, which can lead to some surprises later, he adds, if the wrong paths are chosen.

The next step is to draw the basic functional logic elements, or cells, usually with a "hand-draw" approach but sometimes with computer aids. The hand-draw (even with a pen at a CRT console and the ability to recall often-used routines) is better, many feel, than any computer at minimizing die area allocated to each cell.

If the basic cells and the interconnect listing are both in the computer, it can then direct a plotter to draw a greatly enlarged replica of the mask on a layout table about 6 by 12 feet.

After the designers study the layout and make topology corrections for best yield, the circuit is ready for masking. At is used only to load and unload workpieces in a centralized area, and to handle tool replacements. The system is adaptable to a wide range of machinable parts, and its control strategy is such that maximum utilization is achieved.

Batch-type manufacturing

Job-lot manufacturers in the United States need production equipment that is as cost effective as the highly automated transfer lines employed by high-volume producers. The advent of NC and the subsequent development of NC machining centers have improved the situation somewhat for the low-volume producers of many parts. Nevertheless, most midvolume manufacturers continue to search for production systems that can reduce per-piece part costs significantly below those of the job-shop level that use traditional technologies.

Computerized manufacturing systems (CMS), flexible manufacturing systems, higher-level direct numerical control (DNC) systems, and variable mission manufacturing (VMM) systems are some of the more promising answers offered by builders of machine tools to the midvolume manufacturers. Although the approach varies with each machine-tool builder, all stress the same objectives: (1) minimize in-process inventory; (2) minimize lead time; (3) minimize direct labor; (4) minimize indirect labor; (5) minimize tool changing and setups; (6) maximize equipment utilization; and (7) maximize flexibility.

Midvolume processing

The first integrated or computerized system in the U.S. was the Sundstrand Omniline installed at the Ingersoll Rand Company in Roanoke, Va., in 1970. This DNC system employs two five-axis OM-3 machining centers, two four-axis Omnimils, three four-axis OD-3 drilling machines, and a powered roller conveyor. It shuttles palletized parts to the correct tool, automatically loads them onto the machine tool, and returns them to the materials-handling conveyor system after they have been processed.

The system handles up to 150 different part numbers, in scheduled lots of two to ten pieces, with three operators doing all tool setting and pallet loading and unloading. Compared with stand-alone machines, its output reportedly matches that of 30 machines plus 30 operators in a conventional machine shop, and has reduced parts costs by an average of 45 percent. Two more of these systems have since been installed, at Sundstrand and at the Caterpillar Tractor Company in East Peoria, Ill.

Caterpillar's need was for transmission cases for the company's articulated motor grader being built at the Decatur, Ill., facility. Since this was a new product with no existing production process, several approaches for making the transmission cases were considered: conventional machining, utilization of transfer-equipment, and utilization of a computerized manufacturing system for machining the transmission cases from rough castings.

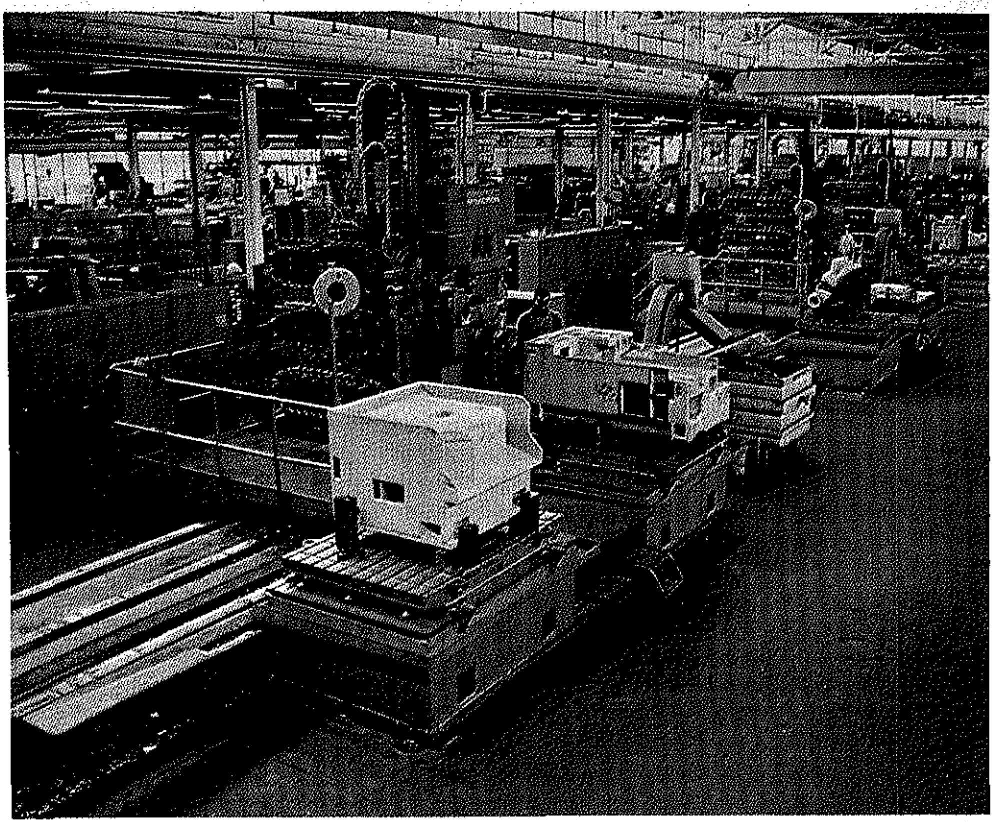
Conventional machining was not a solution since it would have required 13 machine tools and ten men per shift. A transfer system was also ruled out since it was felt that it would have been too rigid, particularly when considering the dynamic nature of the transmission design. The computerized manufacturing system (a Sundstrand Omnicontrol DNC line), was selected primarily because of its flexibility and the reduced need for machine tools and manpower, and because of Caterpillar's interest in gaining more experience with DNC systems at that technological level.

The system was purchased by the company in 1971 as a turnkey installation. In this case, turnkey refers to the entire system, including machine tools, material-handling equipment, computer and peripherals, the system software, and the parts programs. Caterpillar personnel participated in the initial software design and parts programming to some degree, and experience indicated that their greater involvement in the design of the system would be beneficial to both companies.

The line consists of nine machines fully integrated with a material-handling system and a Digital Electronic Automation (DEA) coordinate-inspection machine. A remotely located Digital Equipment Corporation PDP 11/20 minicomputer with 48k of core-type memory and four RKO 3 (Rotating Kartridge Zero) disk-type drives (1.2 million words of storage each), a Centronics Company line printer, a paper-type reader/punch, and one 800-b/in tape drive control the entire system in real time.

Metal-cutting machines in the line (Fig. 1) include four OM-3 Omnimils, five-axis machining centers with 60-tool capacity for precision boring and milling; three OD-3 Omnidrills, four-axis machining centers with 60-tool capacity for drilling, boring, and tapping; and two Gidding and Lewis vertical turret lathes for boring and turning. The machines are arranged on opposite sides of a center rail, on which are two automatically controlled CONCO

[1] A turn-key Sundstrand DNC system used by the Caterpillar Tractor Company to mass produce transmission cases comprises four OM-3 Omnimils, three OD-3 Omnidrills, two vertical turret lathes, and an inspection machine.



CAM-I

In 1972, Computer Aided Manufacturing-International, Inc. (CAM-I), was formed in Arlington, Tex. It grew out of the co-operative development of machine-tool and control companies that found mutual benefit in working together to find solutions for their NC problems. These companies, from the United States, Europe, and Japan, were encouraged by their efforts in working together and decided to broaden their scope to other areas of manufacturing and design, not only in the application of computers, but also in system organization.

Except for a small technical and administrative staff, all CAM-I work is done through its members. They set up long-range plans and specify projects, which are then contracted out to competent organizations throughout the world.

The CAM-I general manager and staff are responsible to a board of directors, who are elected from the member companies. As a result, corporate members can consolidate and coordinate their efforts, thereby reducing duplication. The CAM-I objective is to bring together the various technical and managerial abilities to work as a community, solving problems associated with the development of a viable computer-integrated manufacturing system. CAM-I's development program is structured to include the following:

- **Long-range planning.** Through planning committees and interest-group formation, CAM-I members prepare their specifications for project work. Project development is then contracted out in accordance with the needs and requirements of supporting companies. The most important group is the Advanced Technical Planning Committee, which is responsible for long-range planning. This committee is divided into three regions—the United States, Europe, and Japan—each with its individual chairperson. The committee has produced a long-range development plan covering the durable goods industry for the next ten years.
- **Process planning.** The process planning development, like most CAM-I projects, is split into two major areas: short- and long-term development. The long-term development aims at evolving a framework or model of manufacturing, and introducing methods for automatically generating process plans. In the short term, a system has been developed to utilize existing technology and to create new process plans that are variants of existing standard plans.

The short-term project is the CAPP (computer-aided process planning) system development, which is available for use by manufacturing managers. It is designed to bring order out of confusion to the process planning engineer, and is based on the principles of group technology. Standard plans are developed for part families, and are stored under a coded part description. New parts are coded, and with this information, CAPP's variants system enables the process planner to retrieve standard operating plans developed for a part family, if a similar part has been previously planned. This creates more uniform manufacturing plans in a structured format. The operational details of these plans call for the development of a series of application programs to cover all technology aspects of process planning—including machine-tool selection, tool and fixture selection, feeds and speeds, time study, and numerically controlled interfaces.

Finally, and most important, the project is responsible for the development of a long-range total architecture for process planning. This system attempts to utilize information on machine tools, tooling, and other resources of material data, component description, and planning know-how to generate process plans using the planner in an interactive role.

- **Geometric modeling.** This major project aims at developing technology by which users will be able to create a three-dimensional model and part description that can be stored in the computer, and used for a whole host of manufacturing subsystems.

Because the information would be initially captured at the design stage, the capability would immeasurably improve the accuracy of communication through the entire manufacturing environment. The model will contain not only the geometric description, but other information required by the manufacturing subsystems. It is envisioned that this computer-stored master-part description of a component or assembly could replace the traditional engineering drawing.

However, if necessary, drawings can be produced from the model. Because a full three-dimensional description can be stored, any views or sections can be produced at will. For example, in process planning, sketches of operational setups could be produced; or if it were required to view the component through a particular section, then a call would be made for that particular section to be displayed. The framework of information storage and communication, from product design to manufacturing, will be developed, initially. The framework will be designed to allow common interfaces with geometric modeling systems that are either being developed, or that will be developed. Computer graphics are expected to be the key communication tool.

- **Numerical control.** When CAM-I was formed in 1972, it took over custodianship of the APT-Long Range Program, providing a continuous updating of the APT computer language for universal acceptance. Whereas most large computer houses furnish APT coded in their particular language, the basic APT system comes from the cooperative developments of CAM-I members. Initial NC development was in three special projects—CAM-I APT, ARLELEM, and sculptured surfaces. Today, all these projects are altering their objectives to meet added demands for computer-aided manufacturing.

Of particular interest is a new CAM-I development called Advanced NC. Systems such as the Geometric Modeling Project aim to create and store geometric information at the design stage in what is termed "bounded form." NC programmers and process planners will not need to respecify the geometry, as is now done in APT-like systems. Although this permits the description of any geometry, it does not describe the part; the programmer's definition of the tool-motion statement (which defines the path of the tool going around the component) describes the geometry of the shape.

In APT, the bounded-component geometry is not defined. Using bounded geometry for the shape definition, the computation of the tool path is less difficult. Advanced NC will capitalize on bounded geometry definition developments in the CAD field, and will provide an NC processing capability to the geometric modeling project.

- **Job-shop control.** Another important area is in shop-floor management. Although many companies have production scheduling, they lack effective shop-floor management systems. CAM-I member companies have decided to examine this area to develop a system that will attack the problems encountered in meeting production schedules. Many major companies already have software systems operating for this purpose, albeit with unsatisfactory results.

CAM-I's aim is to develop computer-aided control systems so that planned procedures can be followed to insure work schedules and quality. Further, modules will be developed within the project covering the coordination of material flow relating to machine availability, supply of tools, fixtures, and NC programs, inspection, machine maintenance, etc.

- **Standards for CAM.** CAM-I's Standards Committee works with various standards organizations around the world, since consensus standards are required in future manufacturing systems to preserve user freedom of choice and equipment. Standards promote simplicity and economic advantage. Standards allow varied industries to cooperate in solving universal manufacturing problems.
- **Industry/education.** CAD/CAM system development is bringing about a change in the educational requirements for engineers interested in entering manufacturing. It will slowly change the nature of current tasks and require retraining of existing employees.

The objective of the Education Industry Committee is to stimulate interaction and cooperation between industrial and education member groups, as well with other professional organizations, in terms of information exchange, common research areas, faculty and student exchange, and the development of CAD/CAM educational programs.

ing a solution to the deficiency by a process of creative innovation within the framework of new technology.

4. Attempt to develop a new manufacturing philosophy that would overcome many of the deficiencies present in today's solution.

5. Subject the new philosophy to rigorous technical and economic feasibility analyses.

The concept of VMM emerged from this broad-scope developmental study. In the original VMM approach, a system consisted of a group of work stations serviced by a material-handling system, all operating under the control of a central data source. A prototype of such a system operated for many months in the early 1970s, to identify product goals, and to further research and development tasks essential to bringing such a high-level system to maturity. Cincinnati Milacron reports that it has learned much from the early stages of that development program, which peaked in a prototype "automatic factory" that was terminated after extensive testing and evaluation.

The VMM prototype included not only general characteristics of computer-managed parts manufacturing, but also provided better processing for low-volume parts at higher production rates than possible with more conventional NC machining centers. It also allowed the processing of entirely different parts in random order, the use of process-specialized work-station modules, and the complete handling of workpieces from above—thus permitting efficient handling of coolants and chips, and easy access for inspection and servicing of machines and tooling. One central computer was in total command of all machine units and materials handling, and provided other management and processing services.

In addition to contributing directly to the development of other lower-level but very advanced, multiunit manufacturing systems, experience with the prototype has had numerous spinoffs that have reached economic viability.

Carl J. Rogan, manager of Advanced Systems for the Machine Tool Group, Cincinnati, Ohio, notes that two varieties of work stations can be employed in a VMM system. One type, such as machining centers, emphasizes versatility, and the ability to perform a wide variety of operations. The other type emphasizes specialization, and includes stations dedicated to special operations, such as special drill heads. The number and mix of versatile and specialized machines ultimately determine the efficiency of a VMM system.

Today, there are perhaps no more than a dozen or so such systems operating in the United States. Of these, about ten are as complex as the Sundstrand Omniline at the Caterpillar Tractor Co. and the Kearney and Trecker system at Allis-Chalmers. This number is expected to increase substantially within the next five years. Most progressive manufacturing companies are now planning toward an eventual computer-integrated plant. As multiunit manufacturing systems take on greater significance, communications and transport within each system will present new demands for more efficient, reactive, and reliable tooling and parts storage, retrieval, and delivery to and from the machining systems, with precise timing. The computer—or probably a hierarchical system of computers—will integrate all operations, aided by interactive computer graphics, and eventually will provide instant, real-time, two-way communication between many aspects of a plant.

Integrating CAD and CAM

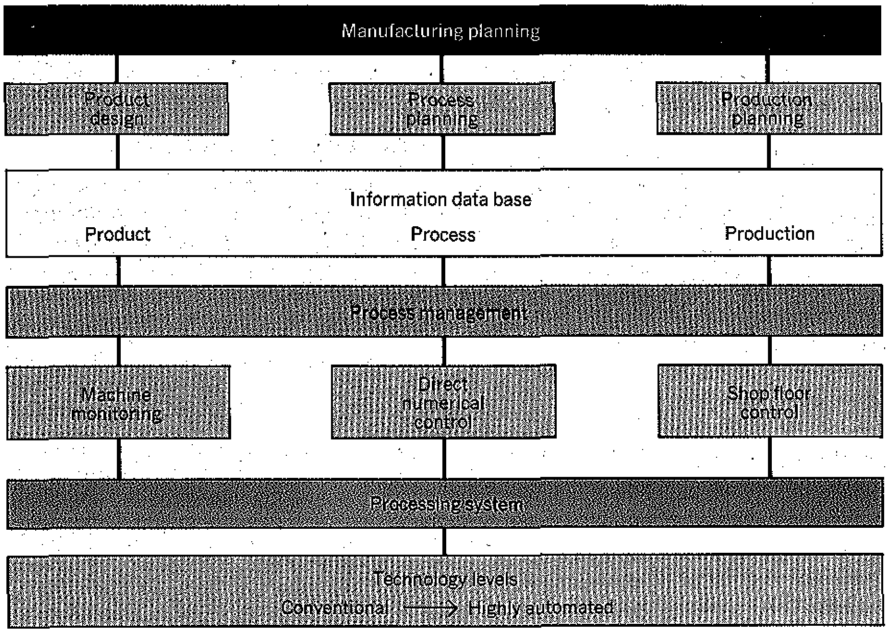
The manufacturing system centers around process selection—which must be a joint effort of the design and manufacturing sectors. Process changes to reduce cost and/or improve quality require economic analysis and a thorough understanding of the relationship between cost, design intent, processes, and materials. At present, CAM experience suggests that only when all of the design-to-manufacturing processes are integrated into a single coherent process will computers be used economically and on a wide scale for both CAM and computer-aided design (CAD).

Professionals on both sides of the design/manufacturing interface have felt there is no reason why engineering data generated by design people should be recreated to satisfy manufacturing needs. Many believe that a single technical data base, if properly constructed, would be sufficient. Hence, the so-called CAD/CAM interface is envisioned as a computerized data base that can be accessed and enriched by either design or manufacturing professionals during various stages of the product development and production cycle. Most important, the computer is the first sophisticated management tool that enables managers to make scientific decisions based on fact, rather than on previous experience and intuition.

CAD and CAM mean different things to different people in different industries. The automobile industry, for example, may identify CAM with the mathematical definition of body surfaces for use in producing body dies by NC, whereas some aerospace industries associate CAD combined with DNC as synonymous with CAM. The term CAM should thus represent a total systems concept—a system that relies on the integral use of a computer to assist in the operation and management of manufacturing processes, with applications extending from raw materials to the delivery of a completed product.

Crucial to the effectiveness of a CAM

The objective of long-range manufacturing planning is to create an orderly interactive network of system functions, with a common data base, to insure accuracy of communication among the functions.



puter can be interfaced with an external one, as in the case of computer-aided manufacturing systems. This can be done through already available channels to accomplish the following: synchronization of the robot with other machinery in real time; external computer control of robot memory address, so that robot actions can be a function of external data and commands; and mass storage of programs in the external computer.

Contemporary applications

The suitability of robotics to a range of industrial production is illustrated by some outstanding current applications. Figure 2 shows some of the gripping devices for handling workpieces or tools.

Since 1970 spot welding of automobile bodies has become a major area of robot use, both in the U.S. and elsewhere. In 1970, the first breakthrough in robot industrial applications came with the installation of 26 Unimate robots for spot welding car bodies at the General Motors Vega plant at Lordstown, Ohio. Three facts stand out about the historic event: The robots were a production item, not designed expressly for GM. The Lordstown situation was tailored for the robot approach (as opposed to earlier islands of robots in industrial plants). And the installation was a "first" in the automotive industry. This last gave rise to a mixed blessing, for it tended to identify robots with large-scale continuous production and to disqualify them for low-volume "batch" production, an error that took a while to dispel.

Today GM uses robots at its Tarrytown, N.Y., assembly plant for spot welding automobile floorpans on a highly mechanized shuttle conveyor. Each spot-welding head weighs 225 pounds. The extra-large memory allows for weld-pattern variations according to car model. A similar installation has been put in at a GM plant in Wilmington, Del., and the costs are reported to be lower than those for any other spot-weld setup at GM. The company is also using robots to load machine tools, assemble small parts, and paint underbodies. Coming soon at GM is robotic painting of car bodies, a job that has always been difficult and unhealthy for the workers assigned to it.

At Chrysler, "respotting," the final spot welding of body parts already tacked together, is done with some 80 robots at four of its assembly plants.

Ford employs robotics extensively. Throughout its plants about 200 robots are used for spot welding, die casting, painting, materials handling, and assembly operations. Ford engineers prefer to call them "universal transfer devices" rather than robots, but, by any name, they constitute an increasing share of production equipment at that company.

In Europe and Japan, robotics is taking over in automotive production at a pace even faster than that in the U.S. Fiat doubled its production of auto bodies in Italy with the installation of robot welders and estimated an overall 25-percent production increase from their use. Volvo in Sweden installed over 50 respot welders with significant increases in productivity. Peugeot and Renault in France also use robots for respot assembly operations, as do Damler-Benz and Volkswagen in West Germany and Saab in Sweden. At Toyota, Mitsubishi, and Nissan in Japan, robots are in use not only for spot welding but also in a variety of other processes, including forging, painting, die casting, heat treatment, machine-tool loading and unloading, and palletizing. In many instances, the robots are suspended from overhead trolleys to conserve floor space and introduce mobility.

Many other applications in the automotive, chemical, basic-metals, and plastics industries, as well as in materials-handling functions throughout industry in general, could be cited. But the area that typifies the truly unique role of robots in improving productivity is machine-tool loading and unloading. Here robots are intrinsically flexible automation, in contrast with the "hard," or fixed, automation of single-purpose machines. The latter are generally high-capital-investment machines useful for one purpose or one product and seldom flexible enough for changeover to others as business climate dictates.

Most U.S. manufacturers employ batch production. It is this fact that motivated a statement in a recent National Science Foundation report on productivity improvement to the effect that industry should emphasize more flexible approaches to automation. Robots fill that need. They are easily programmable and therefore adaptable not only to model changes but also to fundamental product changes, and their growing sophistication invests them with built-in nonobsolescence and long-term cost effectiveness.

Many examples can be given of how robotic machine-tool loading and unloading is increasing productivity. At Xerox in Rochester, N.Y., for instance, three robots load and unload six machine tools, including a pair of CNC lathes. The two-handed robots insert the workpieces in less than 2 seconds. At a GM diesel plant in Detroit, a line of machines is fed connecting rods and caps by a robot that has increased productivity 25 percent and freed the human operator to handle tooling, check automated gauging, and make adjustments. It is clear that in the automated plant of the future, robots will link standard machines and tools, all under computer control.

Certain axioms of robotics

What kinds of production lend themselves to robotics? Perhaps the most prudent answer is to cite certain ax-

A typical robot, in this case manufactured by Cincinnati Milacron.

and did simple materials-handling jobs. The installations had certain common traits: Workpieces were already oriented or easily oriented; robots served discontinuous processes; no extreme positioning accuracy was demanded; equipment interfacing was simple. But the paramount aspect was the attractive payout of robots when used on a two-shift-a-day basis, a fact of industrial production economics that has become more attractive every year.

As shown in Fig. 3, in the early 1950s the annual cost to employers of the pay and fringe benefits of a semi skilled factory worker was about $3 an hour. By 1974 this had climbed to $10 an hour, and at present it is as high as $20 an hour. Current bookkeeping shows that an industrial robot costs about $4.50 an hour to operate on a single-shift basis, or $3.50 when operated on two shifts. These figures will vary somewhat, based on types of applications and the type of robot employed. Obviously, robots are not cheaper to use than humans in all industrial jobs. But where they can be used—and their potential applications are growing—they yield increased productivity, reduced scrap and higher-quality of product. And these benefits often outweigh the cost of the replaced labor.

Throughout the 1960s Unimation Inc. was the major source of commercially available robots. Since then close to 200 different industrial robots have been introduced worldwide. Most of these efforts have aborted through lack of staying power, but about a dozen manufacturers hang on in the conviction that robotics is an idea whose time has come.

Robotics of the future

What of robots of the future? In general, they will have increased speed and precision. Though they can now exceed human speeds for large loads and motions, they do not yet excel in critical timing areas, such as load/unload manipulations. Unloading, reloading, or reorienting of a workpiece, for example, needs to be done in less than 5 seconds to optimize machine-tool-cutting operations. One approach is to equip the robot with a dual hand, with one gripper to unload and the other ready to reload a new workpiece.

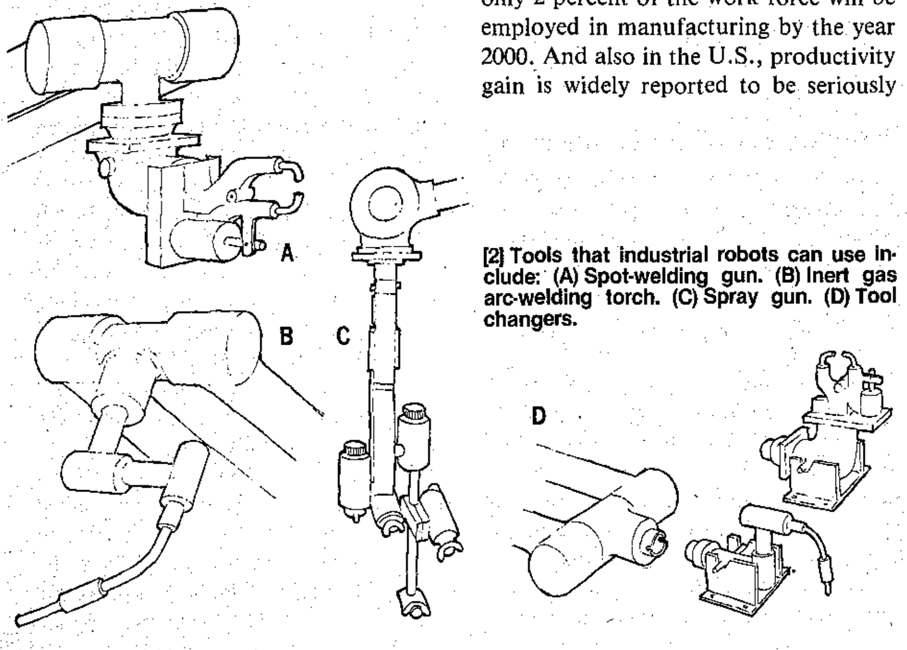
Certain major improvements are already available or in the immediate offing:

- Conveyor-synchronization robots that work on assemblies as they travel along a conveyor line,
- Two-armed (and even multiarmed) robots with arm-to-arm coordination, computer-generated trajectories, resolution of 10 mils, and very high speed,
- Small, precise, lightweight robots for detailed assembly work under microcomputer control,
- Robots with sensory perception, including visual and tactile faculties. Several developmental models of robots with sensory perception have already been demonstrated. And computer-generated robot trajectories, which are more time- and energy-efficient, are rapidly coming into use.

Robotics and society

The impact of robotics on industrialized nations needs to be viewed in the light of facts that appear indisputable because they are reinforced by studies and new evidence each year. For one thing, the world is entering what has been called the post-industrial society. In the United States, for example, a Rand Corporation study indicates that only 2 percent of the work force will be employed in manufacturing by the year 2000. And also in the U.S., productivity gain is widely reported to be seriously lagging that of other advanced nations—thus fueling inflationary forces and contributing to the U.S. unfavorable balance of trade.

In addition, the economic pressure to convert from human labor to robots is strong and getting stronger. In terms of return on investment, payback period analysis is particularly telling. The payback period is the cost of the machine divided by the annual labor savings, minus the annual robot upkeep cost. Typically robots pay back their investment in far less time than the maximum allowable period of three years. And in terms of return-on-investment, robots offer handsome returns, even in some industries with single-shift daily operations. And, indeed, these economic justifications lead to conservative market



[2] Tools that industrial robots can use include: (A) Spot-welding gun. (B) Inert gas arc-welding torch. (C) Spray gun. (D) Tool changers.

The leading manufacturers

Though robot development in the United States traces its roots to the 1950s, there are still relatively few manufacturers of these machines. The Robot Institute of America, headquartered in Detroit and managed by the Society of Manufacturing Engineers, lists the following as the ten leading manufacturers of robots in the United States:

AMF Electrical Products
Development Division
Herndon, Va. 22070

ASEA Inc.
4 New King Street
White Plains, N.Y. 10604

Auto Place Inc.
1401 East 14 Mile Road
Troy, Mich. 48084

Cincinnati Milacron Inc.
4701 Marburg Avenue
Cincinnati, Ohio 44001

DeVilbiss Company
Division of Champion Spark
Plug Company
300 Phillips Avenue
Toledo, Ohio 43692

General Electric Company
3198 Chestnut Street
Philadelphia, Pa. 19101

Nordson Corporation
555 Jackson Street
Amherst, Ohio 44001

Prab Conveyors Inc.
5944 East Kilgore Road
Kalamazoo, Mich. 49003

Pratt & Whitney Machine Tool
Charter Oak Boulevard
West Hartford, Conn. 06101

Unimation Inc.
Shelter Rock lane
Danbury, Conn. 06810

average load on power-generating equipment over a designated period of time to the peak load occurring in that period. Load factor is one of several measures of the extent to which utilities use their investment in equipment. Increasing that figure up to a point is beneficial. This can also be construed as one indication of the "productivity" of the electricity generation process.

Implementation of so-called "time of day" rates is expected to improve the load factor—that is, to even out the valleys and the peaks in a typical utility's daily demand curve. How will this be achieved? The rates are structured to encourage the use of electricity during off-peak hours (roughly weekends and nighttime) through a substantially lower power-demand charge for those periods, compared with the charge for daytime use during the week.

A number of utilities are testing this approach. One pioneer is the Long Island Lighting Company (LILCO) of Hicksville, N.Y., whose time-of-day rates for commercial customers with a power demand higher than 750 kW have been in effect since February 1977. In the LILCO experiment—which involves some 200 customers, mostly big stores and other commercial facilities—the utility employs magnetic-tape recorders that are attached to the power and energy meter of each customer. Using a technique that translates the rotation of the disk into pulses, LILCO employs mostly two-track magnetic-tape cartridges. One track is used for recording time signals generated within the recorder; the other contains the pulse data for the meter. Each cartridge can record up to 36 days' worth of information of this type.

"Translating" equipment converts the data from the cartridges into a computer-compatible format on a larger magnetic tape. This information is subsequently processed for billing.

Residential rate tests

LILCO is planning to expand its application of time-of-day rates to include residential customers who consume more than 45 000 kWh in a year. That phase of the testing, which will involve some 1200 customers, is to be based on a different type of rate. It will include, in addition to regular daily on-peak and off-peak periods in the commercial experiment, a premium rate period (Fig. 1). This rate is to be determined by the outside temperature at a predetermined point on Long Island. Whenever this temperature reaches 28.33 °C on a summer day, the premium rate period will begin, and it will remain in effect until the end of the on-peak period. The aforementioned temperature was statistically correlated to a massive turning on of air conditioners, the biggest drain on LILCO's power supply.

To indicate the onset of the premium rate period, a radio signal will be sent from a central location to all participating customers, whose meters will be equipped with small receivers. An additional component, a prototype of which has recently been developed, is a device with an indicator lamp, which will be plugged into a regular power outlet in the customer's residence to alert the customer to the onset of the premium-rate period.

For the time being, however, this residential time-of-day rate program has been somewhat slowed. The reason: a pending court case related to the commercial experiment. Some customers are alleging that the mandatory nature of the rate discriminates against some of those customers who qualify. The lower court decided that there was some basis to this argument. The Public Service Commission of the State of New York is appealing that court's decision with LILCO's support. In the meantime, the commercial time-of-day rates go on.

The success of the time-of-day rates at LILCO and elsewhere depends not only on the resolution of the legal question, but also on a number of other unknowns, primarily of technical and economic nature. For example, a bottleneck in the commercial experiment at LILCO is the high cost of processing the data from the field tapes. This makes the cost–benefit of large-scale use of tape recorders questionable. Another question facing the industry is the reliability of new components that the utilities must add to conventional customer meters to implement time-of-day billing.

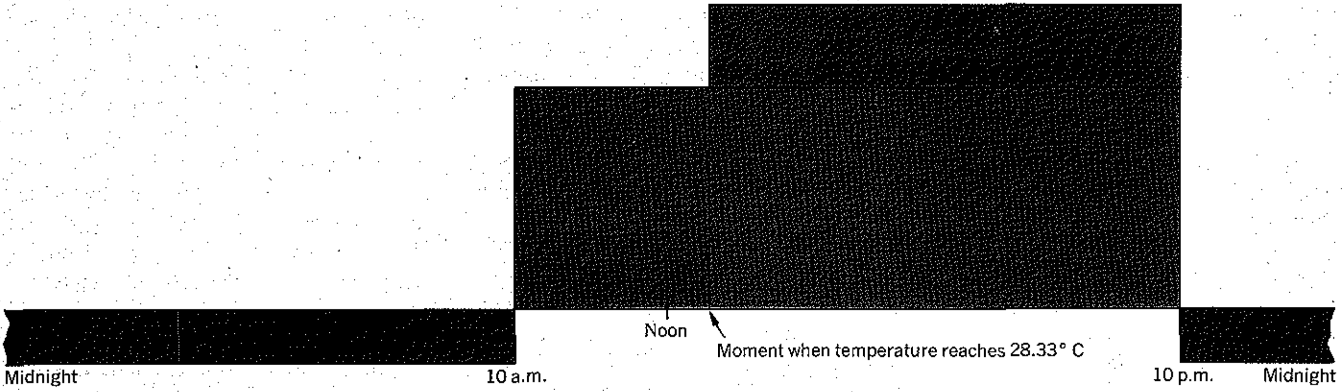
Time-of-day billing is costly

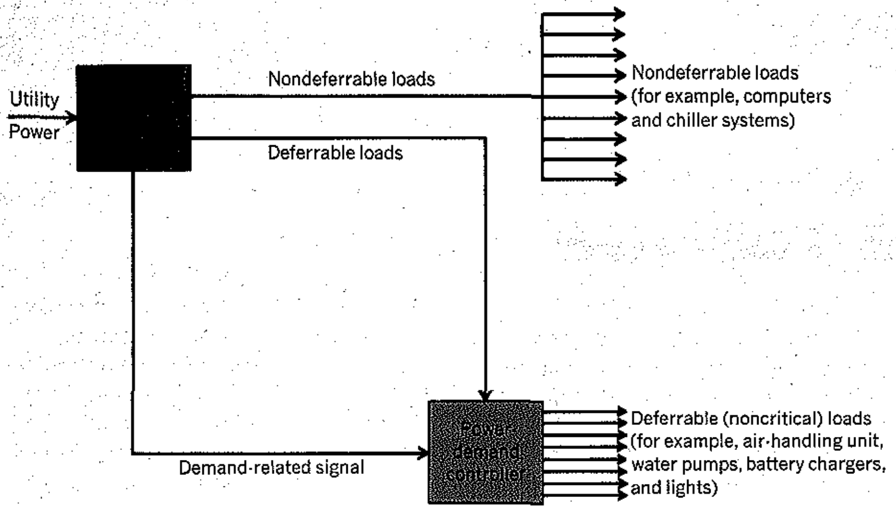
The cost of the components, as well as the processing of data, are no small items for utilities. While a conventional residential meter costs about $25, one of the new meters, along with its receiver, is costing LILCO about $450 in quantities of 1200 in the residential time-of-day experiment. The tape recorder and additional equipment for LILCO's commercial experiment cost about $750 for each unit, and the yearly data-processing cost associated with each is $250. Thus, before there is any large-scale implementation of time-of-day metering, these costs must come down by at least an order of magnitude. (With its 870 000 customers, LILCO's total costs for new equipment would be in the neighborhood of half a billion dollars!)

For the data-processing aspect, one solution contemplated at LILCO and elsewhere is automatic meter reading, with use of two-way communication between the utility and the individual customer's meters. For economic reasons, however, such systems must also serve other purposes, such as control functions.

Several techniques for communicating between customers' meters, or devices for controlling equipment of power

[1] Periods for the "time-of-day" rate for electric-power demand by residential customers, as proposed in an experiment planned by the Long Island Lighting Company, Hicksville, N.Y. The rate involves on- and off-peak periods, as well as premium rate, to be initiated automatically by sensing an outside temperature at a specified site. This temperature (28.33°C) was correlated to a massive turning on of air conditioners by customers.





[3] One possibility for curtailing the demand on an electric power system is to use demand controllers—devices with logic and memory. In a simple example, these are set to disconnect "deferrable" loads according to a predetermined sequence whenever the total power at the load site exceeds an allowed value.

some energy-conserving techniques are very promising. A large man-made fiber plant in South Carolina, for example, has been advised by a consultant to reduce the pressure in a number of water-pump systems with a total potential demand for electricity of more than 4 MW. The equipment includes vertical turbine pumps with power requirements ranging from about 75 to 225 kW (100 to 300 horsepower).

It is anticipated that by trimming the size or reducing the number of impellers for each pump, the company can reduce the excessive pressure caused by "overdesign" at no sacrifice in required flow of water. The price tag for a one-time investment in equipment and instrumentation to carry out the modifications, which are now under way, has been estimated at $120 000, and that is expected to result in a yearly saving on the energy bill of $100 000.

Power utilities distinguish between industrial users—factories, refineries, and the like—and commercial and residential customers. The commercial category includes schools, department stores, and other moderate users of energy.

A large consulting firm, Flack & Kurtz Energy Management Corp. of New York City, has been helping a number of facilities in the aforementioned categories. The firm has broken down energy-conservation techniques into three successive levels that have proved to be successful (Table I).

The first level involves no capital cost for material or labor, yet it is designed to reduce the "energy fat" on the premises. It mostly involves changes in the schedules of equipment, such as heating and cooling systems; the adjustment of temperatures, pressures, and control settings; the modification of design criteria; the reduction of ventilation rates; and the general "fine tuning" of mechanical and electrical systems.

The second level calls for minor fixing and refitting measures at minimal costs ($8000 at one university). Generally, these measures involve modification of controls and minor component additions to mechanical and electrical systems to improve operating efficiency (for example, the use of time switches to reduce the use of unnecessary lighting).

The third level involves more significant retrofit measures and other steps, such as the introduction of heat-recovery hardware (Dec. '77, pp. 27-28), "duty cyclers" (devices that shut off equipment on a cycling basis), and even computer-based, central supervisory control systems. The costs can be substantial. Third-level investments may not always be economically feasible for energy users.

Commenting on the use of electrical hardware, generally associated with the third level, Jack Caloz, a consultant with Flack & Kurtz, has provided a valuable insight into the economics of such use. For example, he indicates that, in some cases, equipment for handling air for ventilation of a building can be turned on for 15 minutes and off for three minutes without a noticeable effect on the building's environment. This can be done by using anything from hard-wired relay systems to programmable controllers and dedicated microprocessor-based systems.

Programmable controllers are relatively cheap—about $1000 to $3000 for a controller of about eight to 100 points—and they are flexible. But they require expertise to program in "relay ladder" logic format. Plug-in, dedicated microprocessor-based systems, on the other hand, are preprogrammed for a specific task, and thus require no programming expertise. But their costs may run up to $40 000 apiece for control of eight to 100 points.

Mr. Caloz says that at the onset of the energy-conservation trend a few years ago, there was a tendency toward overkill. Users would employ large computers at enormous cost for just turning equipment on and off—a task that much less sophisticated equipment would do at a fraction of the cost. Even today, he indicates, psychology is an important factor in selecting equipment. Many energy users would prefer a sophisticated, computer-based system costing $100 000, even if a simple $3000 machine could do the job—the cheaper equipment isn't impressive enough.

Electronics: power challenges

Part of the aforementioned discussion may well be crystalized into a key question—can electronics be used to improve the efficiency with which we use energy in our society? Patrick E. Haggerty, general director and honorary chairman of the board of Texas Instruments, expressed his ideas on this subject in a speech delivered in May 1977 in San Francisco. The question is not so easily answered, unless we establish some quantitative measures of the "amount" of electronics in a given application and the value of its energy "equivalent." According to Mr. Haggerty, with a few assumptions, electronics can indeed be quantified. And, at least based on experience gained in the manufacturing and service areas at Texas Instruments, the "quantity" of electronics installed per capita can be correlated to an amount of energy saving.

To an extent, this conclusion can be cautiously applied even to fuel savings in automobiles and homes. Data on the use of electronics in these two areas, though limited, seem to indicate a measurable amount of energy saving.

To the power engineer, the challenge of improving the productivity of delivery of electric energy means more than just improving the load factor; it also involves the reduction in system reserve margins, while, at least, maintaining the overall system reliability. Another factor is the reduction of "heat rate" of delivered energy—the amount of Btu's of input fuel for each kWh delivered to the customer. Not the least challenging is the recycling of valuable resources, such as cooling water, for such uses as growing agricultural crops. ◆

level of product technology is appropriate to that market. In such a case, the product design might be a technical success, in a sense, but it might be unacceptable in the marketplace.

The C-3 block implies maximum risk in both dimensions. Any product innovation in this classification would not be pursued intelligently unless there was a potential for high reward relative to investment. But a number of spectacular successes can be identified as C-3 products; e.g., the original Polaroid instant camera, the Xerox electrostatic copier, and the original hand-held calculator developed by Bowmar Instruments. The C-3 failures can be equally spectacular but tend to be less well known. Among these: Du Pont's long and costly development of Corfam, a synthetic leather, that proved to be insufficiently acceptable to the shoe industry.

The matrix chart and its accompanying propositions can be seen as a rather simple distillation of common wisdom. Yet it is evident from the high mortality rate of new products and the low batting average of product innovations that the product-planning process in most companies does not include adequate analysis of these primary-risk factors.

On the other hand, the growth pattern of a number of successful "innovation" companies appears to consist primarily of a large number of small moves from their base technology and market positions. It has been observed, for example, that 95 percent of the 3M Company's products can be traced to its basic technologies—and its markets—in coatings and adhesives. This type of growth pattern will be discussed in some detail later.

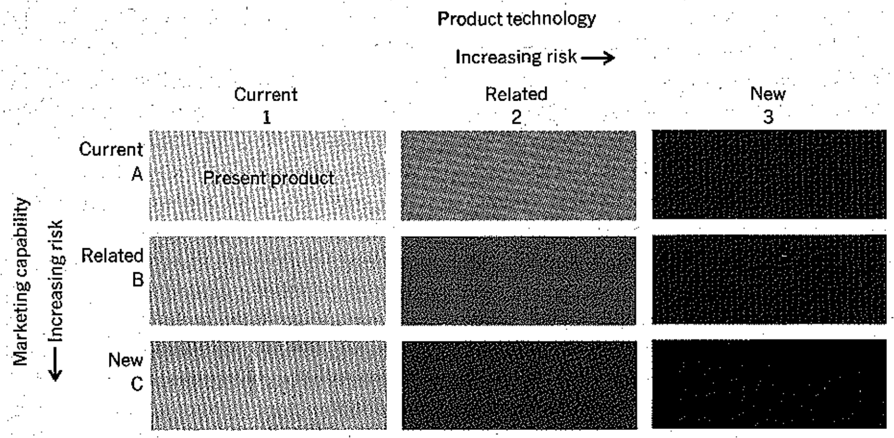
Opportunities in innovation

The matrix concept, in addition to providing a framework for systematic risk analysis, can also be an educational tool for encouraging the innovation of product ideas relatively close to areas of existing success and capability. Or the matrix can discourage the expenditure of time and creative energy on "far out" product ideas, unless they have potential benefits to the company commensurate with the levels of investment and risk indicated.

The use of the matrix concept can lead to provocative and creativity-stimulating questions:

- If each currently successful product does, in fact, represent a set of technical and marketing capabilities, what exactly are these capabilities and how can they be exploited?
- If products are sold successfully to an identifiable set of customers, what else can be developed for these customers? Should not their needs be explored intensively to develop "need-driven" product ideas with reasonable chances of success? This kind of curiosity and thinking may have sparked the introduction in 1956 of Raid dual-purpose insecticide by S. C. Johnson and Son, Inc. From a strong market position in household cleaners and polishes, Johnson moved successfully to household insecticides, a field in which it had no previous technical background.
- Conversely, do existing products incorporate unique technical ideas or indicate some unusual technical capability that might be exploited in another market area? If so, what has to be done to develop a marketing capability in this area? Is the new market understood well enough to penetrate it successfully? If not, how can this knowledge be obtained? This area of "technology-driven" innovation is one in which the primary stimulus is the desire to find an application and a market to exploit a new technical opportunity. A technical opportunity is not only a technical advance, which is new in a global sense, but also a technical capability that is new to the company. An example is a new or improved corporate capability to integrate electronic, optical, and mechanical technologies in order to create new and better process-control systems.

[1] Product technology/marketing capability matrix for two degrees of departure from existing products.



In general, more successful products come out of need-driven innovation than out of technology-driven innovation. Studies indicate that about 70 percent of innovations are stimulated by knowledge of market, mission, or production needs, whereas only about 30 percent are generated by technical opportunities. Still, the many successful technology-driven innovations indicate that this area should not be neglected.

For many years after its invention almost two decades ago, the laser was referred to as a solution in search of a problem. Now lasers are applied in a variety of markets with a level of business estimated at $200 million, and with no apparent limit to further growth. And it is reported that the stimulus behind Bowmar's development of the hand-held calculator in the late 1960s was the need to find a market for a light-emitting-diode (LED) display capability that the company had developed and to exploit low-power, large-scale integrated-circuit technology.

Defensive technology

In the area of technology-driven innovation, companies should consider not only exploitive innovations but also defensive innovations—innovations to protect the viability of existing products and markets from new technologies being exploited by others.

A classical case of the lack of defensive innovation involved a number of companies firmly entrenched in the desk calculator field. When electronic technology suddenly began to replace electromechanical systems, at least three major companies—SCM, Remington-Rand, and Singer—were unable to convert to the new technology and compete with new electronically oriented suppliers, and so dropped out of the business entirely.

The practice of defensive innovation implies that companies should actively assess new technology and projections of technical progress as they relate to existing products, and consciously develop the capabilities needed to cope with technological change. Lewis Branscomb, chief scientist for IBM, describes IBM's defensive innovation this way: "At IBM, for instance, management invests money in central research out of the profits of the company, and there is no return-on-investment test applied to our central research organization. We are measured not by what products and businesses come from the research department's one with limited technological background, can have in markets with which it is not familiar are illustrated by the Gillette Company's three attempts to compete in consumer electronics. In 1974, Gillette began test marketing pocket calculators but found itself unable to cope with the rapidly falling market prices for these products. In early 1977, it pulled out of digital watches after trying for only three months to sell them in 13 major cities. Here, the big marketer of razors and toiletries was hurt not only by declining prices, but by the shift in the market from push-button LED models to continuous-indication watches using LCDs. Gillette executives indicated that one problem was that marketing these products was not the same as selling razors, and that lack of technological background and dependence on outside sources of supply were also major factors in the failures.

In April 1978, Gillette decided to withdraw from smoke detectors after extensive nationwide marketing efforts. Again, Gillette was caught in a situation in which prices dropped rapidly as many companies were attracted to a large and growing market. As was the case with its other electronic products, Gillette did not manufacture its own smoke detectors. As a result, it could not move quickly to low-cost mass production using a substantial degree of vertical integration and process-oriented manufacture.

Developing capabilities too

Companies seeking to grow through new-product innovation will not necessarily succeed by confining themselves to their existing markets and technologies. Risks must be taken, and growth in capability in both dimensions may be required, if long-term progress is to be achieved. Here, the matrix concept has further implications that seem to be of value in analyzing the strategies that have been followed—either consciously or intuitively—by several successful technology- and innovation-oriented companies. These strategies should be considered in developing a new-product strategy.

The principal proposition is that each successful new product that penetrates a new market area or incorporates technology new to the company creates a new and demonstrable set of marketing and technical capabilities (a new A-1 product) that can be further exploited. The potential values of these capabilities should be considered in product planning.

This proposition also implies that if a new product is perceived to have value in capability development—if it represents, for example, a company's first effort to establish itself in a new market area or with a specific new customer—its development, testing, and marketing should be pushed with particular vigor and should receive increased management attention. If success has the potential to breed more success, every resource needed to achieve the initial success should be applied. A first-time failure in a new product area usually discourages any further effort. The Gillette experience indicates that this may be a wise decision.

The remarkable history of success of the 3M Company in bringing to fruition a continuous stream of innovative products is largely a case of continued exploitation of the market-technology bases of existing products, and the expansion of these bases by the success of new products. The company appears to have achieved its steady rate of growth by many successful moves into 'A-2' and 'B-1' products with relatively few high-risk product adventures. To what extent this pattern has been a conscious strategy or merely happenstance as a result of the creation of a highly innovative organization and product-development environment is an interesting question. It should not be overlooked that 3M does not stint on product-development funds. Its rate of R&D expenditure at 4.4 percent of total revenue is probably the highest of all U.S. companies of comparable size and nature.

How HP got into computers

Another case history relevant to the proposition of capability growth by product success is the set of initial steps that led to the emergence of the Hewlett-Packard Company as a significant factor in the computer industry.

The company initiated its efforts in digital computation in 1966 in order to add computational capability to its line of scientific instruments to provide immediate data analysis and to facilitate the use of the instruments in real-time control systems. Capabilities in this area led to the introduction in 1968 of HP's first calculator/computer product as such, the model 9100 desk-model programmable scientific calculator. This product could be classified as "A-3." Its technology was new to the company, but its market consisted of the scientists and engineers who had been using HP scientific instruments and electronic test equipment for many years.

The success of the 9100 calculator led to another A-3 product, the HP-35 hand-held scientific calculator. It performs many of the same functions as the model 9100, but incorporates integrated circuits and miniature LED display technologies. Sold to the same customers, its initial price was $395. Owning one became a status symbol among engineers and scientists.

At this point, someone at HP must have asked, "Who other than engineers and scientists have to make a lot of calculations that could be programmed into an LSI calculator chip?" The answer apparently was that it might be people in the financial area, who had to depend on compound-interest tables and laborious calculations to obtain the numbers needed for analysis of mortgages and other investments. Then, when some innovative financial people at HP, recognizing the usefulness of the HP-35 to HP's own technical personnel, suggested that a calculator be made for them, the result was the model 80 hand-held financial calculator. This can be classified as a "C-1.5" product, since it was essentially a modified and reprogrammed HP-35 that sold very successfully in a market not previously addressed by the company.

HP now markets a wide variety of calculator and computer products for both technical and business purposes, but it must be acknowledged that it has had its fair share of problems in programming and in the development and production of advanced ICs. The company expresses its general product-planning strategy with the analogy that if more than one leg of the three-legged stool of technical, marketing, and manufacturing capability is missing, the product idea will probably not be considered. It is evident that HP expends quite a bit of effort in making new legs for its stools.

The value of capability enhancements resulting from product success depends, of course, on the desire and ability of the company to exploit them. If no further use for them can be foreseen, their value is probably negligible. But in many product areas, getting an initial toehold in the market seems essential to future success, probably because at least some experiential knowledge is needed to prevent the kind of management and marketing judgment failures described in the Denver study.

In dealing with sophisticated customers, demonstrable technical capability is often essential in making the sale. In defense procurement, successful technical experience relevant to a new procurement is an important factor in the formal source-selection process. A company without a solid and well-documented technical background has little chance of being awarded a significant development contract. It is also generally recognized that performing successfully on a small project for a specific agency is often a key factor in being awarded larger projects by that agency.

It is difficult, if not impossible, to put meaningful numbers on the value of technical or marketing capabilities that will result from the success of a new product. An innovator attempting to sell a new-product idea on the basis of its capability-enhancement value in a company run by a thinking about the nature of the company's business and how to improve it instead of concentrating exclusively on current administrative duties. Thinking about innovations is thinking about strategy. Thus, as a manager one would develop the self-discipline needed to divide one's time wisely between today's demands and tomorrow's needs.

Successful execution of strategy benefits everyone in the company. Though the private benefits to a manager may be low, the corporate benefits are by no means small. Therefore, innovation must be a corporate undertaking, initiated and condoned by the corporation as a whole. The discipline of looking ahead must be strong at the very top. The importance of long-term objectives must be communicated to all employees, thus calling their collective wisdom and social values into play.

Impact of market factors

Marketing management is risk management. It must be approached as a process of risk reduction through planning and control.

In the United States, manufacturers have always enjoyed the advantage of selling to the largest national market. Thus, most companies became inward looking. New domestic ventures could enjoy long periods of growth without tapping overseas markets. However, the increase in the speed of the flow of information and the improvement in transportation technologies have forced domestic producers to compete vigorously against overseas firms. Innovation alone no longer affords long-term protection. A firm must move fast to commercialize new ideas if it is to become the dominant force in the new market. Therefore, it must learn to export and develop world markets simultaneously with the development of domestic markets.

Often the need for capital, coupled with the high cost and unavailability of funds, significantly erodes the advantage of being first in the field. Sometimes it is cheaper to utilize the existing sales force and distribution channel to promote new products. However, if the innovation is significant, it should not be coupled to existing departments. It should be given sufficient individual attention to encourage it to flourish on its own.

To match manufacturing capabilities to market need, we need to develop a better understanding of end-use markets and how they are affected by the economy.

Salespeople can confidently forecast demand for the short run and a trend line is sufficient for the long run, but the demand in between (two to five years) is highly uncertain. One who guesses wrong will either be saddled with unused capacity or will miss major market opportunities. In addition, new markets are maturing faster and product life cycles are shorter. One can only reduce the uncertainty by investing resources in intelligent forecasting, planning, and review.

Assessing needs is a learning process. When the market is dominated by few buyers, understanding their needs can be relatively simple. This process requires cooperation between the seller and user, and short communication channels.

A different approach is needed when marketing to millions of consumers. Here, a company can minimize the probability of failure by test marketing the product, and reevaluating its potential at each decision point.

Government-industry links

Government-industry relationships have deteriorated because of poor management on the part of both—but these relations can be improved if industry takes a more active role in policy formulation. This means making the public and regulators aware of the cost of nonsensical decisions and offering ingenious solutions to problems that arise.

Our present problems of low productivity and high inflation are symptoms that the U.S. may be heading down the road to socialism that has already been traveled by Great Britain. To change the course of its development as a nation, the United States must establish a set of national goals that are solid enough to stand for a decade, or perhaps for a generation.

How can this be accomplished? One approach could be through the establishment of a Board for National Goals. Its members, who would be appointed for terms extending beyond normal political tenures, would include ex-members of the U.S. Congress, ex-Presidents of the United States, and representatives from labor, business, and the general public. The charter of the board would be to formulate—through studies, public debate, and the evolution of a national consensus—a set of national goals, with the highest priority initially in the economic area.

One danger in a Board for National Goals involves the question of how to limit its power. A way in which this could be done would be to give the board only the right of recommendation—with legislating reserved to the Congress and the execution to the Administration, in the traditional way.

A vital part of establishing a consensus on national goals is an intensive educational thrust. Knowledge concerning the free enterprise system and the many issues to be resolved is at such a level that the public is simply not equipped to make the difficult choices. And many educators don't understand the system either, since they generally don't become involved in it.

The people of the United States certainly have the ability to cope with the key issues and the courage to make difficult, intelligent decisions—but they must be aware of the facts underlying these decisions.

In addition, industry should take a preventive approach; i.e., provide intelligent inputs to the decision-making process before the damage is done. To implement that approach, industry should: (1) organize and take the issues to the public; (2) remain constantly on the lookout for regulations that may appear in the near future; (3) concentrate on the issues that really matter; and (4) supply the agencies with information about the costs of pending regulation and alternatives to the problem.

One would expect the climate most conducive to innovation to be competition. And from an industry point of view, this is true. However, from the social viewpoint, this free-market solution would be suboptimal. In a 1958 McGraw-Hill survey of manufacturers, 41 percent of the respondents gave as the main purpose of their research programs improvement in present products, 48 percent gave new products, and only 11 percent gave new processes. This is not a surprising result. Since patents on methods or processes are more easily infringed than product patents, new-product investments are more profitable. In a pure free-market framework, a nation is more likely to devote most of its research effort to applied technology and too little to either basic research or research in management techniques.

Would a shift of emphasis from the private to the public sector solve the problem? Of course not. Without the profit motive, a public approach to R&D would probably be random. Since there is no mechanism to order the priorities, and with the public agencies' tendency to serve themselves, the allocation picture would be even worse.

What is needed, therefore, is an allocative system that combines the best features of the two extreme cases. Since the private sector will respond to profit incentives, it is in industry where need assessment, commercialization, and cost reduction should be initiated. The public sector to repay the loan taken out to exercise the option.

One may argue that long-range R&D investment is clearly of benefit to the stockholders, particularly those who are investing rather than speculating, and that their interests will prevail—either because of the dedication of the top executives or because the stockholders will insist that their interests be served. The first part of this argument is certainly valid, but the sequel is dubious.

Stockholders are generally not very well equipped, by background as well as by knowledge, to appreciate a company's R&D effort. In fact, for competitive reasons the details of the company's R&D objectives are usually kept from the public, and hence from the stockholders. Since the annual report that explains poor performance as due to large investment in R&D for future profits is generally distrusted and often suspected, why should the chief executive take the risk?

Although there is no quantitative measure of the impact of this motivational phenomenon on corporate R&D policies, one could believe that it is quite significant. But there is no valid reason why retirement annuities of top corporate executives could not be tied to future corporate profits instead of being fixed dollar amounts as they generally are now in the United States. A company might combine a smaller fixed-dollar portion with a participation in a fixed portion of corporate profits earned during the retired life of the executive. Thus,, the future welfare of the executive would be coupled closely to the long-term welfare of the company.

A key question, of course, is how one can implement this concept. What mechanism and leverage can be employed to encourage the boards of directors of large corporations to modify their pension plans in this way? Actually, this may not be difficult. Most stockholders are investors rather than speculators and, as such, their primary interest is in the company's long-term performance. Clearly, it is to their benefit to identify the top executives' financial welfare with their primary interest. And the company's current balance sheet would improve because of the reduced fixed pension costs.

Furthermore, aside from problems of pension erosion by future inflation, a company, through its board of directors, is likely to be more generous if the payments come from future earnings rather than from current contributions to a retirement plan.

What is needed is public discussion of the concept, thus leading, perhaps, to endorsement by influential groups or, alternatively, to the exposure of the concept's flaws. The IEEE Task Force on U.S. Innovation in Electrotechnology has already begun to do carry on such a discussion. Reader comments are welcomed. ◆

Most are hardened skeptics, yet production workers may be guided to higher productivity and greater job satisfaction

What makes workers want to do a good job? The answer, if indeed one relatively straightforward explanation can be found, has thus far proved most elusive. However, elaborate theories, often extrapolated from seemingly successful case histories, abound. Money, promotions, status symbols, working conditions, peer-group pressure, pride, teamwork, enrichment programs...all have been thought to provide the key, yet each is but a single dimension of an intriguing social and political landscape that shapes attitudes and thereby individual actions.

Blue-collar workers are not stupid, and they are generally suspicious of any new scheme to boost productivity. It is pretty obvious that their own short-term interests are not well served by speed-ups, automation, and restructured job assignments that result in layoffs ...regardless of "positive" benefits to the corporate profit margin or the national economy.

On the other hand, management must somehow cope with the rising costs of materials, capital goods, labor, taxes, energy, and interest rates. Often these costs can only be partially offset by charging more for the finished product. Some form of increased productivity must be successfully implemented to make up the difference. And if corporate growth is to occur, increased productivity is absolutely mandatory.

Don Mennie Associate Editor

The Hawthorne studies

From 1924 to 1933 the Western Electric Company conducted at its Hawthorne works a series of experiments on those factors thought to affect the morale and productive efficiency of workers (e.g., lighting conditions, rest periods, group size, shorter and longer work days and work weeks, methods of compensation, and incentives). Today's ongoing efforts to stem worker dissatisfaction and rebelliousness have their roots in the data collected 50 years ago by Western Electric.

A synopsis of the original work and its major conclusions is provided by Eugene L. Cass and Frederick G. Zimmer in their book *Man and Work in Society*, published by the Van Nostrand Reinhold Company, 1975. Cass and Zimmer report that observers were assigned to the Hawthorne test areas to note all activities engaged in by the workers. From these data it was discovered that workers quickly develop their own unwritten code about what constitutes acceptable behavior and work output. These groups brought immediate pressure on individuals to control deviant conduct. They ostracized persons whose behavior was against their interests.

Hawthorne also provided some insight as to why workers resist supervision and work rule changes that management introduced to promote efficiency. Technical specialists—engineers, cost accountants, rate setters—look at the worker with a critical eye, thinking of ways his job can be improved. To the worker, however, his job, the way he does it, and his relation with other workers, are not objective matters. They are full of social significance. Changes in them affect his status, and may upset his feelings of self-importance.

Another important observation derived from Hawthorne illustrates the difficulty of isolating variables for study among groups of working people. The illumination experiments are a case in point. To quote Cass and Zimmer, "In these experiments the intensity of illumination was increased and decreased and the effect on output was observed. The effect was puzzling. Output bobbed up and down in some groups or increased and stayed level in still others. But in no case was the increase or decrease in proportion to the increase or decrease in illumination. Where a parallel control group was set up for comparison with the test group undergoing changes in lighting, the production pay nearly equal to earned wages. Extra "holidays" can be taken at virtually no risk to the worker's pocketbook.

Community effort

Productivity need not be considered the sole concern of industry and labor. When serious problems develop, they can effect the economy of a whole region because expansion ceases and new businesses stay away. Then local merchants begin to close up shop and the whole area becomes economically depressed.

This is what had been happening to Jamestown, N.Y. In late 1971, Jamestown, with a population of 40 000, was experiencing its most severe economic downturn since the depression. One of the largest local firms had gone bankrupt two years earlier, and unemployment had reached 10 percent. In this near-crisis atmosphere, Jamestown Mayor Stanley N. Lundine encouraged local company managers and union leaders to talk out problems, leading to the formation of the Jamestown Labor-Management Committee early in 1972. However, communications alone wasn't enough.

In 1973, members of the Management and Behavioral Science Center (MBSC) of the Wharton School, University of Pennsylvania, studying the area found that Jamestown industry was characterized by old buildings, old work forces, and a lack of systematic training programs. Most firms had fewer than 300 employees, and all were job shops of small-batch production operations. They shared common problems in scheduling and materials handling. But MBSC's recommendations were dismissed by managers as "some sort of job enrichment." Jamestown companies, barely breaking even, considered these suggestions irrelevant when their primary concern was staying afloat.

However, between 1975 and 1977, many of the recommendations, including training programs and profit-sharing programs wherein workers could benefit financially, did take root. Jamestown's success is probably based in part on the communications network set up by its mayor, in part on a restructuring of the labor-management environment, and, no doubt, in part on Federal monies that sent productivity experts like Robert W. Keidel to Jamestown as one of two MBSC consultants—in-residence. While none of the ideas introduced at Jamestown were new phenomena, they had never been tried there. What brought about the economic turnabout?Says Mr. Keidel, "With the exception of skills development, a gestation period was necessary during which 'interesting ideas' could mature into 'meaningful alternatives.' "

Time off instead of money

But most productivity problems will never be resolved by building a new multimillion dollar factory (Volvo) or employing the diplomatic skills of a socially conscious local politician (Jamestown). Can an ordinary company, struggling to stay in business, afford to engage in anything except the usual squabbles when resolving labor-management differences? The answer is a resounding "yes" according to social psychologist Michael Maccoby, who points to the example of Harman International Industries, Bolivar, Tenn. This experiment in industrial democracy was initiated by Sidney Harman, chief executive of the company (now Under Secretary of Commerce for the Carter Administration) and Irving Bluestone, vice-president of the United Auto Workers.

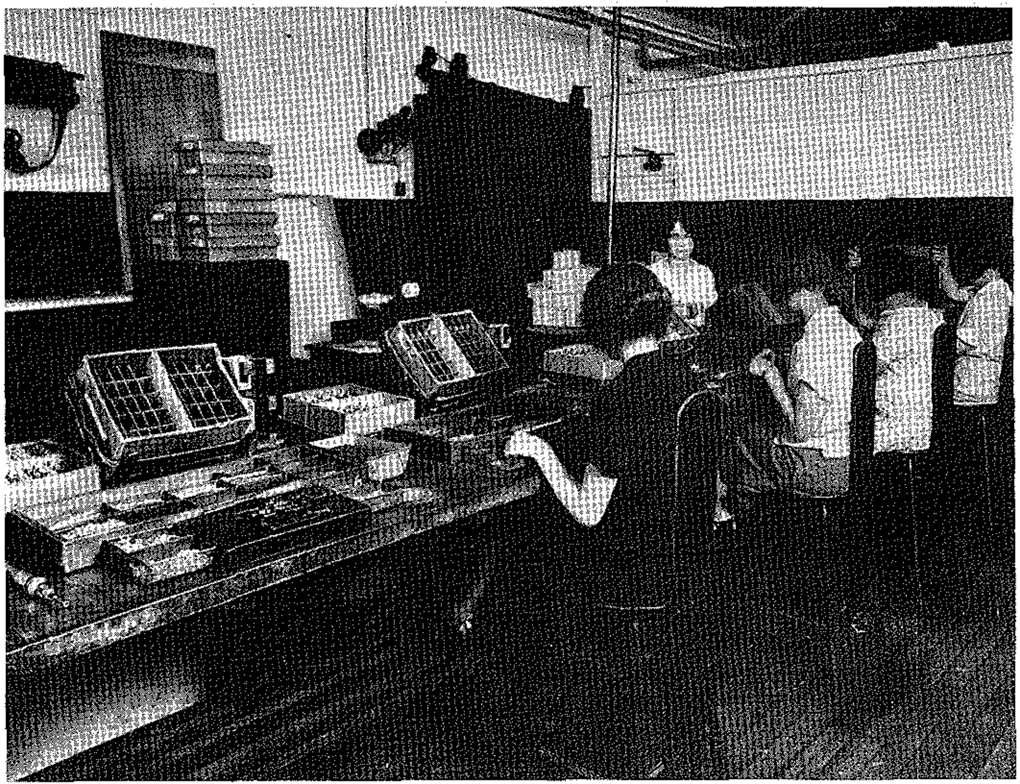
Before he describes the details of the Bolivar experiment, Maccoby cautions that management efforts to "enrich" jobs are often seen by workers as attempts to manipulate or pacify them, and to undermine unions. He says, "If management merely wants to increase production, it would be better advised to refrain from humanistic language and to adopt less pretentious methods, such as better pay incentives." Otherwise, "a sense of bad faith and distrust is inevitable."

The Harman plant was never a showcase for labor-management cooperation prior to the experimental period. Maccoby explains "the Harman auto mirror factory in Bolivar is in the highly competitive auto parts industry where many companies hover on the edge of survival. At the start of the project, the spirit was one of distrust, resignation, and some hostility. There was little open conflict, other than grievances, but workers did not expect much from management.

"Unlike experiments that have combined work redesign with a new plant and carefully selected workers, the Bolivar project took on an existing plant competing in a tough market. From the start, the project included all the 600 employees (managers and workers) rather than a limited, experimental group. The plant population was 50 percent black, 50 percent white, and divided equally between men and women. And there was a history of management-union struggle.

"The agreement worked out between management and union stated that the aim of the project was not to increase productivity, but rather to make work

From 1927 to 1932, six volunteer relay assemblers at Western Electric's Hawthorne works were subjected to various changes in their work environment. Observers attempted to correlate these changes with measurable variations in relay production.



PRODUCTIVITY IV

What can Government do?

Government clout, when used wisely, can have an extremely positive effect on productivity. The problem is that there is no clear-cut path to efficacy of government influence for that purpose. What looks wise in retrospect may have been, at the time of decision, no more or less brilliant than other comparable decisions that proved to be ineffective, or even adverse. In fact, as author Nash points out in the following article, government influence is frequently ignored because major technological innovation—and the attendant productivity improvement—do look so simple in retrospect.

Historical examples of governments influencing productivity in a positive way tend to be significant and dramatic. Mr. Nash, for example, cites the cases in the U.S. of the telegraph and rural electrification. Today, however, the examples tend to be less dramatic, though not necessarily less significant in the long run. One present-day example is given by author Tibbetts. The U.S. Government program he describes is still too new to be rated in any meaningful way. But it does show promise. As he phrases it, the program may prove to be one of the fastest and most capital-efficient ways to bring new technological ideas to commercial attention and to the marketplace. And, as is stressed throughout this *Spectrum* special issue, increased innovation, in turn, tends to enhance the opportunity for improved productivity.

What seems to be needed, and is already in operation in some countries, are means for getting government and business to work together toward the common goal of increasing productivity. Too often, particularly in the U.S., government and business are at loggerheads over issues that ought not to be disputable. Any mechanism for bringing the factions together to work for improved productivity deserves serious consideration.

Classic examples show how the Government can influence, directly or indirectly, innovation and productivity

Robert Nash
Vanderbilt University

Because the technological innovation process is so complex, ranging from basic research to the retirement of old technology, it is influenced by a broad spectrum of public policies. At times, this influence is intentional; in other cases, it happens indirectly—when intentional, technological opportunity, societal (market) needs, and timing have combined in such a way that public policy initiatives have contributed significantly to ultimate success.

The U.S. Government has influenced technological innovation for over 150 years. This influence has been exercised directly in three areas of innovation: creation, diffusion, and implementation. And, in addition, various areas are affected indirectly.

One of the earliest, if not the first, examples of its direct influence was the U.S. Government's retention of the Franklin Institute during the 1820s to determine the reason for the widespread bursting of boilers on steamboats plying the western rivers. The lively discussions that ensued in the *Journal of the Franklin Institute* attest to the considerable impact of the investigations. In contrast to the Franklin Institute's retrospective evaluation of the sloppy practice of a technology, the U.S. Congress actively supported the development of the first practical application of electric energy with its grant of $30 000 to Samuel F. B. Morse in 1843 to construct a telegraph line from Baltimore to Washington. This grant led to private commercial development—Congress had no interest in establishing a public system when offered the opportunity by Morse. Within 20 years, no developed area in the U.S. was without telegraphic service and submarine cables were in regular operation under the Atlantic Ocean. Thus, evaluation of operating boilers on steamboats led to the diffusion of information concerning the best practices; and the grant to Morse aided directly in the development of a pilot system.

In certain instances, inadequate rates of return on capital preclude the implementation of primary innovations. By 1925, for example, 47 million horsepower was in use on farms—twice that in manufacturing—but only 4 percent of that horsepower was electrical. In 1935, no more than 10 percent of the farmers in the U.S. had access to central station electric power, whereas in Holland no farmer was without it. The Rural Electrification Authority (REA), created in the 1930s, stimulated the diffusion of electric power to nearly 90 percent of U.S. farmers. Another benefit to technology through the REA was reduction of the cost of installing rural power lines from $1500–$2000 per mile to $841 per mile by 1939. The social rate of return from this innovation is incalculable for it led to vast increases in productivity that created first-order changes in rural life during the next generation.

The indirect influences of military procurement had a major effect on the development of the semiconductor industry during the 1950s and 1960s. Aerospace procurement contributed significantly to markets for the semiconductor manufacturers during this period. And this demand spurred increases in output, cost reduction, and the rapid diffusion of the technology into the commercial sector.

The most readily identifiable Federal influence on technological innovation today is the U.S. Government's support of research and development. Direct Federal support accounts for more than half of all R&D expenditures. Also, the expensing of private expenditures provides a subsidy to the developer.

Although the support of R&D can

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The U.S. Activities Board of IEEE recommends actions Congress could take on behalf of the U.S. technologist and businessman

What can Congress do to spur U.S. productivity? The question was addressed in the writer's May 16 statement to the U.S. Senate Subcommittees on International Finance and on Science, Technology, and Space, in testimony on behalf of the Task Force on U.S. Innovation in Electrotechnology of the Institute's U.S. Activities Board (USAB). The following is an excerpt from that statement.

IEEE has developed a set of initial recommendations for consideration by the U.S. Congress. The first group of recommendations, which call for direct Congressional action, include the following items:

1. A committee of the U.S. Congress should examine the desirability and feasibility of specific legislation requiring evaluation and approval of the transfer of high technology to overseas industrial production facilities. On a more general level, monitoring and/or controls should be considered in connection with the transfer offshore of any high technology. An appropriate component of the monitoring process would be the requirement for filing a "technology impact statement" in advance of any potential technology transfer offshore.

2. A committee of the U.S. Congress should examine the charter and experience of the National Research Development Corporation in Great Britain. This organization funds the development of innovations and provides some mechanisms for the transfer of these innovations into industry. The establishment of a similar body in the U.S. could be useful in view of current needs. Its members might include: one each from the National Academy of Sciences and the National Academy of Engineering, from the appropriate discipline; one from the President's Economic Advisory Council; one from the relevant technical society (e.g., IEEE or the American Chemical Society); and one from the appropriate industry association (e.g., the Electronic Industries Association or the Pharmaceutical Manufacturers Association).

3. The Small Business Administration could play a significant role in supporting high-technology ventures in small organizations. The Commerce Department could be redirected so that it not only would provide advice to industry concerning overseas and domestic market potential but could also assume the leadership role in a manner somewhat similar to that of Japan's Ministry of International Technology and Industry (MITI), which has been very successful in that country.

4. A committee of the U.S. Congress should reexamine the current antitrust policy and statutes. The competitive status of the U.S. could benefit from appropriately monitored cooperative ventures involving industry leaders and from the encouragement of internationally recognized centers of excellence.

5. A committee of the U.S. Congress should explore methods of allowing rapid write-off for capital investments that are required for environmental protection or occupational safety; this would effectively increase the amount of venture capital available for industrial research.

6. A committee of the U.S. Congress should examine the problem of establishing equitable methods of depreciating high replacement-equipment costs due to inflation and, at the same time, consider more favorable approaches to depreciating capital expenditures required for R&D.

7. A committee of the U.S. Congress should explore the feasibility of extending the concept and coverage provided by U.S. patent laws to such new arts as the development of computer software and semiconductor device masks.

General recommendations

The remaining recommendations are less well focused but also merit serious consideration. They include:

1. Methods of encouraging and facilitating Government-industry-academic cooperation should be examined. One such mechanism could be a series of Governmental/industrial committees, similar to the ones assisting MITI in Japan, to offset the adversary relationships that frequently exist between Government and industry.

2. Efforts should be made to strengthen Government laboratories and to increase the expertise needed to facilitate the commercialization of the results of mission-oriented R&D. The National Aeronautics and Space Administration has instituted various programs of this type, but more are needed.

3. Organizations such as the National Bureau of Standards, and similar centers of excellence, should be funded on a long-term basis and permitted to perform non-mission-oriented research to provide the scientific foundation for future innovations and their diffusion throughout U.S. industry.

4. A means should be found to permit the exchange of personnel between Government laboratories, industry, and the universities so that interpersonal expertise and information can flow more readily through the "technology system."

5. The U.S. Government should support graduate engineering and science students in their initial attempts to adapt to, and be employed by, industry. A program could be established to fund a portion of the salaries of graduate students willing to work, during summer vacations, in both small and large R&D-oriented corporations throughout the U.S.

6. Methods should be examined whereby merged or combined cooperative research can be performed in the U.S. in such vital areas as very-large-scale integration, taking into account the current antitrust laws.

7. An urgent need exists for the proper definition and description of the dynamic system we call technology. The effort must be undertaken not by just one organization, but by several groups whose results can be merged. In time, possibly five to ten years, a better understanding of the complete interactions between the developing technology, its industrial application, and the economics involved in funding the industry and in the return on investment can be obtained. The initial stimulus for such an undertaking should come from the Congress.

8. There is a need to identify future technologies that are likely to become important to the national interest. The identification of these technologies and their nurturing over a long period of time should be the responsibility of several organizations.

In summary, USAB is in favor of a policy designed to increase the supply of technology and thus the amount that may be safely exported at a reasonable price. The Government can significantly foster and encourage the process of technological innovation and sharpen the U.S. competitive edge in the world economy. And the Congress can act as a spearhead not only in investigating and providing the legal foundations for some of the actions required, but in stimulating universities, industrial organizations, and the Federal government to undertake and carry to fruition those activities necessary to maintain a vital and dynamic United States of America in the third century of its existence. ◆

Bruno O. Weinschel
IEEE Vice President,
Professional Activities

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Requires MS or PhD. in Engineering with 5-10 years' experience in the analysis of navigation systems, real-time software implementation and a thorough knowledge of optimal (Kalman) estimation and smoothing.

INERTIAL NAVIGATION SYSTEM ANALYST (32K)

Design and evaluate techniques of aligning, calibrating and updating (resetting) inertial navigation/guidance systems. Model inertial component errors and other sources of error, and design reduced state Kalman filters for multi-sensor systems. Design test procedures and evaluate test results. Advanced degree in EE, ME or AE with a working knowledge of modern estimation and control theory.

SR. ENGINEER—WEAPONS SYSTEMS (TO 37K)

Prepare technical program plans for study contracts and then operate in accordance with budget and schedule; manage an engineering staff with responsibility for technical quality and customer satisfaction; maintain customer contact; prepare technical reports; prepare and deliver technical presentations.

MS in Engineering with 10 years' related experience in current military program management procedures employed during acquisition and operational phases of a weapon system's life cycle; conceptual multi-discipline design of large-scale systems; maintenance and training operations.

SR. ELECTRONIC DESIGN ENGINEER (TO 30K)

Design, develop, test and maintain electronic test equipment for inertial systems test laboratory. Provide design support to other departments and divisions in the evaluation of advanced electronic systems.

BSEE with a minimum of 5 years' experience in design/development/maintenance of electronic test equipment. Specific experience in one or more of the following logic designs using TTL, CMOS, etc. Technologies, linear circuit design, design of inertial component test equipment-servo amplifiers or encoding electronics.

We'll talk about the compensation and benefits packages after we've established an area of mutual technical interest. They will be an additional inducement in considering my client. In the meantime, send me your resume or information on how to contact you and let's begin to discuss these openings. All qualified replies will be acknowledged forthwith. If you prefer to be contacted by me before sending your resume, call toll free anytime, 1-800-327-0173 Ext. 36.

Timothy D. Crowe, Jr.
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CHALLENGING CAREER OPPORTUNITIES IN LASER FUSION TARGET FABRICATION

LOS ALAMOS SCIENTIFIC LABORATORY

Our Laboratory, a multi-faceted national R&D facility, is seeking experienced scientists, engineers, and technicians to work in the Laser Fusion Target Fabrication Program. Opportunities include:

—Development of ultrasonic, electrostatic, and other techniques to levitate small particles and to fabricate complex multilayer, multishell laser fusion targets. Requires Ph.D. or equivalent experience in experimental physics or electronics with a minimum of 5 years' experience in applied physics/electronics/ultrasonics R&D and demonstrated ability to solve pragmatic, goal-directed problems.

—Development and bringing on line of automated image analysis techniques used with X-ray microradiography to measure and quality-characterize microballoons. Will also aid in the development of new, higher-resolution measurement and characterization techniques and help in the design, development, and fabrication of other microprocessor-controlled instruments and devices used in target fabrication. Requires B.S. or advanced degree in computer science or electrical engineering with several years' experience in generating software for mini- and microprocessors and in designing and fabricating interfaces and/or instruments using microprocessors or minicomputers.

—Development and application of techniques to deposit high-quality metal and/or dielectric coatings to microsphere and microballoon substrates. Requires Ph.D. or equivalent experience in materials science, metallurgy, physical chemistry, or experimental solid state physics, with demonstrated ability to apply metal and/or dielectric coatings via physical vapor deposition, sputtering, and/or ion plating.

SENIOR TECHNICAL SUPPORT POSITION ALSO AVAILABLE IN ABOVE AREA

—Senior technical support in the development of techniques to prepare high-quality targets containing cryogenic solid deuterium/tritium as the fuel. Will design, assemble, and use apparatus to generate these cryogenic targets and evaluate their quality, positional stability, and lifetime. Requires skill in high-resolution optical imaging of submillimeter objects and experience in fabrication and assembly of precision mechanical and optical systems.

Operated by the University of California for the Department of Energy, the Laboratory provides excellent working conditions and benefits, such as a variety of professional growth opportunities and 24 days' annual vacation. Our setting in the mountains of northern New Mexico offers a pleasing lifestyle in a setting of great natural beauty: a pollution-free environment; abundant recreational activities; casual, uncrowded living; a superior school system; and low taxes.

Send complete resume, in confidence, to:

R. B. Brown
DIV—78-AV
Los Alamos Scientific Laboratory
P. O. Box 1663
Los Alamos, New Mexico 87545

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large complicated tools for research, the authors give a short history of the founding of CERN—in itself, no easy task. It involved 13 countries and their governing bodies, and the long-range commitment of funds, but these obstacles were overcome and the European physics community was provided with three fine accelerators: a synchrocyclotron, an intersecting storage ring accelerator (ISR), and the 28.5-GeV proton synchrotron (PS). The PS became operational in 1959 and is still doing productive physics as well as serving as the injector for the ISR and SPS.

In the 1960s, the need for an accelerator with an energy of 200 GeV or greater was becoming more evident. The difficulties of dealing with the intricacies of site selection and the problems of nationalism were even more pronounced than when CERN was originally created. The chapters dealing with these aspects are among the most interesting in the book because of the similar problems of siting facilities of this size in the United States.

A key figure in all the machinations was John Adams, who worked extensively on the PS, returned to England, and then answered a call to come back to CERN to lead the SPS program. He was instrumental in getting the project going and in making key technical decisions. It was his leadership that put an end to site-selection bickering, and resulted in the SPS being located at CERN.

The final chapters of the book treat the major technical systems of the SPS, the site and tunneling, acceleration, magnets, facilties, etc. It is a tribute to all the individuals involved that the SPS was built on schedule and within the budget originally projected and at an energy of 400 GeV, twice that originally conceived.

The book concludes with a short description of the uses of accelerators and an appendix on their history.

The only criticisms of the book are minor. Many of the illustrations in the opening chapter are superfluous. It is not necessary to devote three quarters of a page to show people watching a television set or a half page to show a crowd of people. In their technical descriptions, the authors pay little attention to work done outside of CERN, implying that CERN originated most accelerator ideas. Although the CERN contributions are extensive, the worldwide accelerator community works together rather closely and ideas are transmitted from one laboratory to another quite rapidly. Also, although the most prominent figure at the SPS was John Adams, many other people were heavily involved and made significant contributions. They are given very little mention in the book.

The book should be read by anyone with an interest in accelerators and in the problems of converting an idea for a large research tool to a finished project. It is interesting, readable, and well illustrated.

Martin Plotkin
Brookhaven National Laboratory
Upton, N.Y.

Recent books

Applied Electricity and Electronics for Technology. Faber, R. B.—John Wiley & Sons, Inc., New York, 1978, 359 pp., figs., $15.95.

Large-Scale Dynamic Systems: Stability and Structure. Siljak, D. D.—Elsevier North-Holland, Inc., New York/Amsterdam, 1978, 432 pp., $25.00.

Analysis and Design of Sequential Digital Systems. Lind, L. F., and Nelson, J. C. C.—Halsted Press/John Wiley & Sons, Inc., New York, 1977, 154 pp., figs., $17.00.

Electroluminescence (Topics in Applied Physics, Vol. 17). Ed. by Pankove, J. I.—Springer-Verlag, Berlin/Heidelberg/New York, 1977, 210 pp., figs., DM 66/$29.10.

The Hamilton-Jacobi Equation: A Global Approach (Mathematics in Science and Engineering, Vol. 131). Benton, S. H., Jr.—Academic Press, Inc., New York/London, 1977, 158 pp., $13.50/£ 9.60.

Proceedings of the International Conference on Magnetooptics (Zurich, Sept. 1976). Ed. by Wachter, P.—Elsevier North-Holland, Inc., New York/Amsterdam, 1977, 311 pp., figs., $38.95/Dlf. 95.

The Solid-Vacuum Interface IV (Proceedings of the Fourth International Symposium on Surface Physics, Eindhoven, The Netherlands, June 1976). Ed. by Oostrom. A. V., and Sparnaay, M. J.—Elsevier North-Holland, Inc., Amsterdam/New York, 1977, 563 pp., illus., Dfl. 185.00/$75.50.

Information Mechanics. Kantor, F. W.—Wiley-Interscience/John Wiley & Sons, Inc., New York, 1977, 410 pp., $21.95.

Analog and Digital Communication: Concepts, Systems, Applications and Services. Gregg, W. D.—John Wiley & Sons, Inc., New York, 1977, 622 pp., figs., $21.95.

IC Timer Cookbook. Jung, W. G.—Howard W. Sams & Co., Inc., Indianapolis, Ind., 1977, 287 pp., figs., $9.95.

Reliability in Engineering Design. Kapur, K. C., and Lamberson, L. R.—John Wiley & Sons, Inc., New York, 1977, 586 pp., $21.00.

Earthquake Resistant Design: A Manual for Engineers and Architects. Dowrick, D. J.—Wiley-Interscience/John Wiley & Sons, Inc., New York, 1977, 381 pp., figs., $27.50.

Low-Energy Ion Beams, 1977 (Conference Series No. 38). Ed. by Stephens, K. G., Wilson, I. H., and Moruzzi, J. L.—The Institute of Physics, Bristol/London, North American distr. American Institute of Physics, New York, 1978, 332 pp., illus., £ 22.00/$44.00

Multiphoton Processes (International Conference Proceedings, Rochester, N.Y., June 1977). Eberly, J. H., and Lambropoulos, P.—Wiley-Interscience, New York, 1978, 439 pp., 124.95.

Computer Techniques for Image Processing in Electron Microscopy (Advances in Electronics and Electron Physics, Suppl. 10). Saxton, W. O.—Academic Press, Inc., London/New York, 1978, 301 pp., illus., £17.55/$27.00.

New Trends in Systems Analysis: International Symposium, Versailles 1976 (Lecture Notes in Control and Information Sciences, Vol. 2). Ed. by Bensoussan, A., and Lions, J. L.—Springer-Verlag, Berlin/Heidelberg/New York, 1977, 766 pp., figs., $22.60.

Clinical Laboratory Testing; and Computers in Office Patient Care.

Details are available from Ms. Glenda L. Snow, Department of Continuing Medical Education, Medical College of Virginia VCU, Box 91, Richmond, Va. 23298; telephone (804) 786-0494.

Papers are invited

- Workshop on Computer Analysis of Time-Varying Imagery (CompSoc), Philadelphia, Pa., April 5–6, 1979. Topics: two-dimensional and three-dimensional movement analysis, change detection and description, hardware for real-time image processing, low-level operators for dynamic imagery, high-level representations, search and control strategies in dynamic environments, biomedical imagery applications, interactive techniques in motion data acquisition. A 300–500-word abstract to: Dr. J. K. Aggarwal, Department of Electrical Engineering, University of Texas, Austin, Texas 78712; telephone (512) 471-1369. Deadline: December 1, 1978.
- Tenth Annual Pittsburgh Conference on Modeling and Simulation (Pittsburgh Sect. *et al.*), Pittsburgh, Pa., April 25–27, 1979. Two copies of summary and 50-word abstract (identify one author as contact) to: William G. Vogt or Marlin H. Mickle, Modeling and Simulation Conference, 348 Benedum Engineering Mall, University of Pittsburgh, Pittsburgh, Pa. 15261. Deadline: January 31, 1979.
- Second IEEE International Pulsed Power Conference, Lubbock, Tex., June 12–14, 1979. A 150-word (or less) abstract to either: Dr. M. Kristiansen (Conference Chairman), Department of Electrical Engineering, Texas Tech University, P.O. Box 4439, Lubbock, Tex. 79409; or Dr. A. H. Guenther (Technical Program Chairman), Chief Scientist, Air Force Weapons Laboratory/CA, Kirtland AFB, N.Mex. 87117. Deadline: March 15, 1979.
- 29th Electronic Components Conference (S-CHMT; EIA), Cherry Hill, N.J., May 14–16, 1979. Topics: manufacturing technology; materials; hybrid microcircuits; discrete components; interconnection and packaging; reliability, evaluation, and failure analysis. Ten copies of a 500-word abstract and extended outline (including author's telephone number) to: Professor W. A. Porter, Electrical Engineering Department, Texas A.&M. University, College Station, Texas 77845. Deadline: November 3, 1978.
- Optimization Days 1979 (S-CS; SIAM) (jointly with the Canadian Conference on Automatic Control), Montreal, Que., Canada, May 23–25, 1979. Topics include: mathematical programming, optimal control, numerical methods of optimization, systems theory, stability theory, identification methods, applications. Two copies of a 200–700-word summary (in English or French) to: Optimization Days, c/o Professor Bruce Francis, Department of Electrical Engineering, 3480 University Street, Montreal, Que. H3A 2A7, Canada. Deadline: January 31, 1979.

COMPUTER AIDED DESIGN ENGINEER

The Los Alamos Scientific Laboratory is seeking a staff member to assume responsibilities for the computer-aided design activities in the Electronics Division.

These activities include, but are not limited to, the development and maintenance of design automation and computer-aided manufacturing systems for wire wrap, printed circuit card layout, and schematic drafting. Responsibilities also include interacting with the using manufacturing group to insure proper personnel training and utilization of the system.

Individual must have a B.S. or M.S. in engineering or a related technical field. Computer-aided design background and experience preferred but as a minimum must have experience in FORTRAN code development and maintenance of large codes dealing with large quantities of input/output. Experience with digital circuit design preferred.

The University of California's Los Alamos Scientific Laboratory is located high in the mountains of northern New Mexico. The living is uncrowded, casual; the environment is pollution free; the climate is superb—cool summers and mild winters; school system is excellent. The laboratory sponsors a variety of degree-level courses. Recreational opportunities include skiing, golf, backpacking, hunting, fishing, tennis, etc.; fringe benefits provide for 24 days annual vacation.

Send a complete resume, in confidence, to:

Leo Gonzales, Employment Representative
Division -78-AJ
Los Alamos Scientific Laboratory
P.O. Box 1663
Los Alamos, New Mexico 87545

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Fast fault detector has 99-wire capability

This portable test instrument is designed to identify faults in wire and cable assemblies with up to 99 wires. Suitable for either production testing or field troubleshooting, the instrument indicates the precise nature of each fault within 1 second—fault, open, or miswire—and displays its pin number.

A "from-to" button permits the display of the pin number at the destination end of a short circuit or miswire defect.

Offered in two standard models—99- or 49-wire capacities—the instrument is self-contained and uses LED displays. Each model includes a standard probe and a set of mating connectors.

An optional five-column printer is available to print out on paper tape the nature and identity of any fault discovered.

Unit prices are $1825 (99-wire capacity) and $1550 (49-wire capacity).

Addison Div., Muirhead Group, 1101 Bristol Rd., Mountainside, N.J. 07092.

Circle No. 42

Single-chip microcomputers have 11-MHz internal clock

With an 11-MHz internal clock, the 8049 and 8039 are the fastest single-chip microcomputers offered by this manufacturer. The two provide 128 bytes of read/write memory. The 8049 contains 2048 bytes, or twice the program memory of the rest of the MCS-48 microcomputer family.

The 8049/8039 is a fully programmable system designed to perform I/O control and processing tasks at rates to 720 000 operations per second. It contains a basic processing and control subsystem: an 8-bit general-purpose central processor, the 128-byte read/write memory, three programmable 8-bit I/O ports and eight other control and timing lines, a programmable interval timer/event counter, priority interrupt controls, a system clock generator, and a full set of system controls and utilities.

Within the 8049 is an 8-bit central processor with a 1.36-µs instruction cycle time. The microprocessor executes over 90 different instructions, with no instruction requiring more than two cycles for execution.

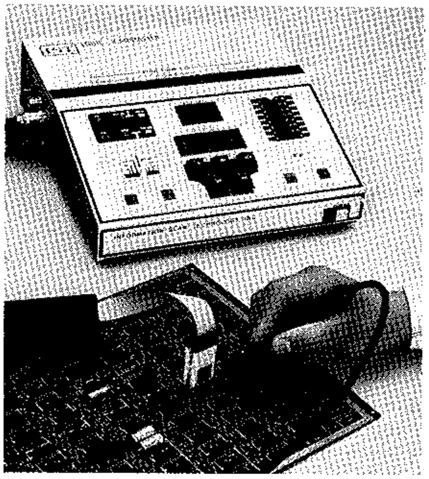
Intel Corp., 3065 Bowers Ave., Santa Clara, Calif. 95051. **Circle No. 43**

High-accuracy frequency receiver priced at $99.50

This low-cost standard-frequency receiver features an accuracy of better than one part in 100 billion. It is fixed tuned to 60 kHz to receive WWVB, the official NBS primary-time and frequency-standard broadcast station at Fort Collins, Colo. It functions as a phase-lock receiver and provides a time-code source.

Three BNC output connectors provide the user with the 60-kHz carrier signal, a 100-kHz phase-locked to the WWVB carrier, and the demodulated WWVB time code. All output signal levels are 9 volts logic thresholds for testing any of the following logic families: CMOS, TTL, HTL, RTL, and DTL.

The instrument includes a built-in, dual-threshold, high-speed logic state analyzer that provides the logic information and stores the static or dynamic failure. At the same time, the instrument stores the number of the IC pin being probed.



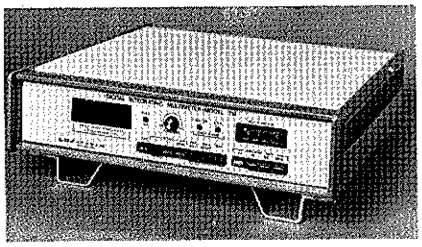
The instrument combines a pulser, logic-analyzing circuitry, a scanning system, a memory, and a 3½-digit multirange dc voltmeter.

The unit is priced at $1295.

Information Scan Technology, 1725 Rogers Ave., San Jose, Calif. 95112.
Circle No. 53

Fluxmeter/integrator has 0.01-percent resolution

The model 710 digital integrating multimeter is a precision voltage integrator that can be used to measure magnetic flux, magnetic flux density, magnetic permeability, or the voltage integral of an input voltage.



A 4½-digit display provides a resolution of 0.01 percent or 1 maxwell (10^4 webers). A combination scale factor and amplifier gain allow full-scale readings of 19 999 to 19 999 × 10^7 maxwells.

The instrument has four modes of operation; it will integrate positive signals only, negative signals only, the absolute sum of positive and negative signals for an absolute value, and the arithmetic sums of positive and negative signals for an arithmetic sum or bipolar integration.

Price is $2675, with delivery from stock to two weeks.

LDJ Electronics, Inc., 1064 Naughton, Troy, Mich. 48084. **Circle No. 54**

AIR FORCE ARMAMENT LABORATORY
GUIDED WEAPONS DIVISION
TECHNICAL DIRECTOR

The Air Force Armament Laborafory, Eglin Air Force Base, Florida, invites nominations and applications for the position of Technical Director of the Laboratory's Guided Weapons Division. The Air Force Armament Laboratory serves as the Armament Development and Test Center agency responsible for research, exploratory development and preliminary advanced development of air-delivered conventional weapons.

The Technical Director serves as the principal technical advisor to the Chief of the Guided Weapons Division and is directly responsible for the technical content of the R&D program which is currently funded annually in the twenty to twenty-five million dollar range.

Candidates should have a record of distinguished achievement in guided weapons research and development. Qualifications include appropriate academic degrees in engineering or physical sciences, experience in systems development, administrative experience and dynamic technical leadership abilities. In addition the successful candidate should have demonstrated outstanding technical competence in the development of aircraft-delivered missile systems and sub-systems.

This position is classified under Federal Civil Service as a GS-15, salary $36,171 per annum.

Federal employees should file SF-171, Personal Qualification Statement, directly to this agency and should include appraisal of current and potential performance, as well as career development appraisals.

Other interested applicants must apply under US Civil Service Commission Announcement 424, Engineering, Physical, Mathematical and related professions. In order to make this application, contact any Federal Job Information Center located near you. These Information Centers are listed under US Government in the telephone directory. If you are unable to obtain the proper forms or cannot locate a proper Center under US CSC 424, contact this agency and we will furnish you the necessary requirements. In addition to applying under US CSC 424, please forward this agency a copy of the forms submitted for consideration. Closing date for this announcement is 30 November 1978.

The agency address for all correspondence is:

USAF, Armament Development and Test Center
3201 Air Base Group/DPCM
ATTN: Mrs. Jeanine Williams
Eglin Air Force Base, Florida 32542
Telephone: Commercial-AC 904, 882-2941
Alternate 882-2251—Autovon-872-2941/2551

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$200 12-bit A/D converts in 5 μs

The MN5240 12-bit A/D converter provides throughput rates over 200 kHz, yet is priced under $200. Extended temperature ranges and processing to MIL-STD-883 are available for military and aerospace applications.

Other specifications include a 5-μs conversion time, no missing codes guaranteed over the full operating temperature range, and five user-selectable input ranges.

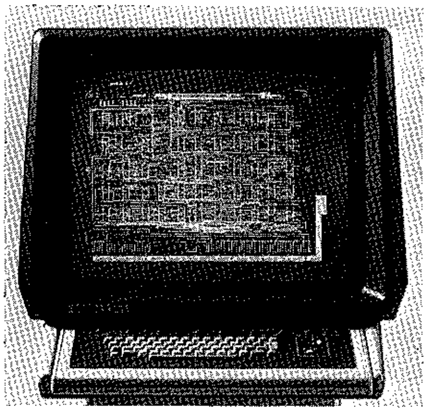
The device is pin compatible with the ADC84 and ADC85 series converters and can be used to upgrade system performance and improve throughput in existing designs employing these A/D converters.

Price is $193 each in unit quantities and $151 each in quantities of 100 or more.

Micro Networks Corp., 324 Clark St., Worcester, Mass. 01606. **Circle No. 59**

Display system plotter is for design and mapping

With a 63.5-cm diagonal screen, a resolution of 4096 by 3120, and 10-mil wide vectors, the 4016-1 computer display terminal can find application in contour mapping, seismic analysis, and energy-field modeling. It is priced at $19 500, with rentals, quantity discounts, and OEM terms available.



The 4663 interactive digital plotter has built-in processing power and can plot on up to 420- by 594-mm paper on Mylar with felt-tip, ball-point, or wet-ink pens. It is priced at $9495.

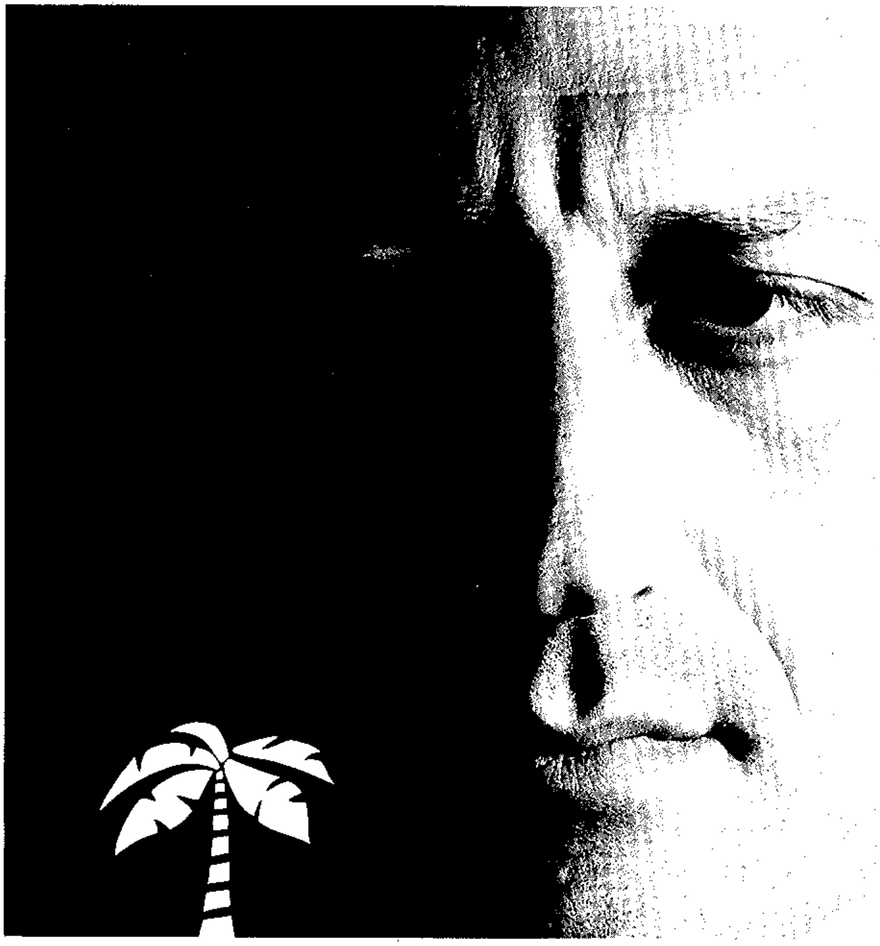
The C-size plotter offers dual programmable pen control and is capable of producing dotted or dashed lines from local firmware. A parameter-entry device provides a convenient way for the operator to identify or select operating parameters. The device replaces binary switches, straps, and status-display devices.

Information Display Group, Tektronix, Inc.,P.O. Box 500, Beaverton, Oreg. 97077.

Circle No. 60

Broadband transistors rated at 40 watts and to 1 GHz

This series of high-gain transistors is designed for military and industrial ap-



News from Industry

TI AND ROCKWELL PURSUE ONE-UPMANSHIP IN MEMORIES

Hot on the heels of Texas Instruments' recent announcement of a quarter-million-bit magnetic bubble memory, Rockwell International has introduced production versions of a similar memory. Both memories have low-volume prices of $500 each. Early last month, Rockwell was quoting delivery of 60 to 90 days whereas TI, in its earlier announcement, had said the fourth quarter of 1978. In addition to the bubble memory device, Rockwell also introduced a one-megabit linear bubble memory module and a programmable control module, both based on the 256-kbit memory, and a 1/4-megabyte development system composed of two linear modules and one control module and a Rockwell System 65 microcomputer development system.

Meanwhile, back in Houston, TI announced that sample quantities of a new 64k dynamic random-access memory (RAM) priced at $125 each would be available late this month with volume production scheduled for first quarter 1979. The new RAM, designated the TMS 4164, organized as 64k X 1, is expected by TI to be the first available single 5-volt 64k dynamic RAM on the market. It comes in a 16-pin, 300-mil standard dual-in-line package, complying with JEDEC standardized pin-out requirements allowing upward compatibility with the 16k dynamic RAM. The 5-volt power supply is TTL-compatible, offers low power dissipation, and is immune to much system noise. Access times range from 100 to 150 ns maximum with minimum cycle times of 200 to 250 ns. The memory features a 256-cycle refresh with a 4-millisecond maximum refresh period. Two clocks control the gating of the 8-bit addresses.

INTEGRATED OPTICAL DEVICE SHOWS PROMISE FOR VARIED APPLICATIONS

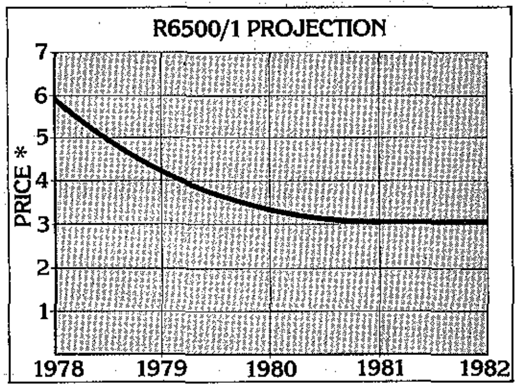
A new device developed at Bell Labs can be used as a logic element in optical memories, as a pulse shaper and limiter, as an optical switch, a differential amplifier, and an "optical triode." It operates at low optical powers over a broad band of wavelengths. The device is an optical waveguide version of a nonlinear Fabry-Perot resonator in which the nonlinearity is produced by driving an electrooptical element in the resonator with the output of a photodetector, which samples the transmitted light. Bell scientists are hopeful that the new device will find many signal-processing uses in future light-wave communications and data-processing systems. That hope stems from the versatility of the device as evidenced by these features: It accepts electric or optical inputs; its nonlinearity may be modified using a nonlinear circuit; it can accept multiple inputs for optical logic operations such as AND and OR gates; and multilevel operation is possible, which allows more complex optical logic operations and analog-to-digital conversion of optical signals.

PACIFIC INTERTIE GETS 2160-AMPERE THYRISTOR VALVE

A string of 80 series-connected thyristors is used in a water-cooled thyristor valve rated at 133 kV, 2160 amperes, and now in service for HVDC transmission at the Sylmar Terminal of the Pacific Intertie. Said by its manufacturer, ASEA, to be the world's largest HVDC water-cooled thyristor valve, it helps reduce convertor station costs and losses. According to ASEA, the basic design used for the thyristor valve makes possible the production of valves that can handle currents up to 3500 amperes without parallel connection.

Micro Power

6500 performance, one-chip price. That's Rockwell Micropower.



The fastest selling microprocessor is now a one-chip microcomputer — Rockwell R6500/1.

The low-cost solution for high speed controllers, instrumentation and much more, the R6500/1 has 6502 CPU, 2K-byte ROM, 64-byte RAM, 16-bit programmable, 4-mode counter/timer, and 32 bidirectional ports. It operates on single 5V power.

Proof is its performance. 6500 instruction power — 13 addressing modes. 1μs minimum instruction execution at 2 MHz. Benchmark it against any available one-chipper at any clock rate.

R6500/1 is totally upward/downward compatible with the entire 6500 family. It's fully supported with disk based SYSTEM 65 and high level PL/65 language. And Rockwell provides Emulator device for PROM prototyping.

R6500 on one chip—that's Rockwell Micropower!

For more information, contact Department 727-G2, Microelectronic Devices, Rockwell International; P.O. Box 3669; Anaheim, CA 92803, or phone (714) 632-3729.

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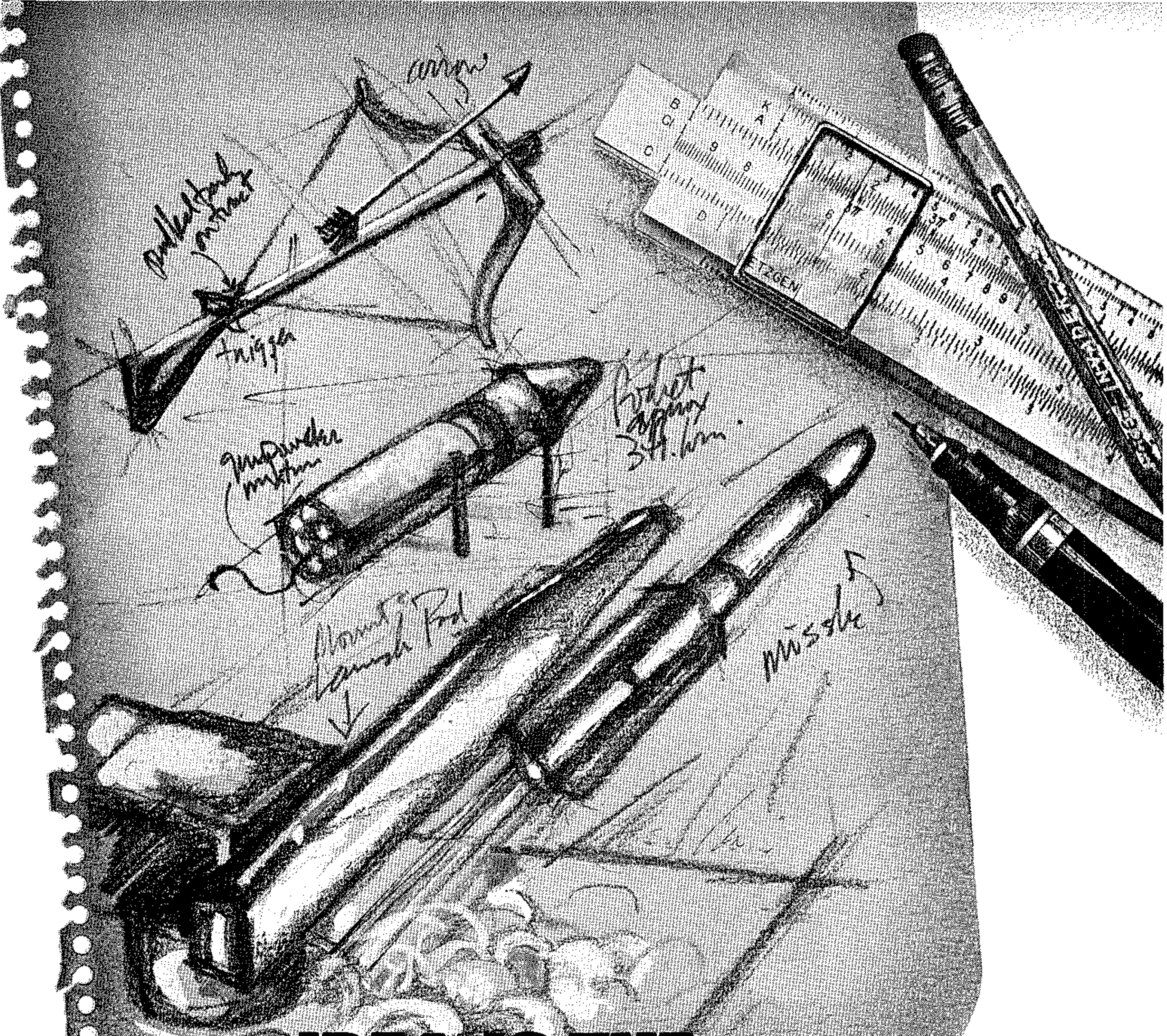
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CSC

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“ We're proud of our 12 year association with the Navy, providing a wide variety of technical and management services. Today we are serving a number of Navy clients responsible for R&D and acquisition of shore, airborne, satellite and on-board strategic and tactical submarine communications systems which operate at frequencies from ELF to EHF.

“ We assist the Navy's Research and Technology Directorate in preparing various R&D technical and management documents. We also perform analyses to support programming and budgeting. In addition, we support the Naval Material Command's Computer Science R&D Council in its effort to develop a master plan for tactical embedded computer resources.

“ Our systems efforts span the spectrum of systems acquisition. In the early phases, we develop initial concepts for command and control and communications systems, and perform technology analyses and trade- off studies. Further on, we prepare specifications, statements of work, planning guides and other technical requirements documents. Finally, we assist our clients in monitoring the efforts of production firms, and in introducing the new capability into the operating forces. Throughout, we provide plans for test and evaluation, configuration management and quality assurance of both hardware and software.

“ The people on my team possess qualities of technical, entrepreneurial, and management leadership which have contributed greatly to our growth. There are great satisfactions to be derived from the challenge and freedom of action that comes with frequent client interfacing, exchanging ideas, and bringing innovative solutions to bear on the client's problems.

If you'd like to chat further with CSC Communications and Systems Operation Director Dave Blumberg, he will welcome your call on (800) 336-0429, or telephone him collect at (703) 533-8877.

Otherwise, mail your resume in confidence to Mark Havard, in care of Dept. 393.

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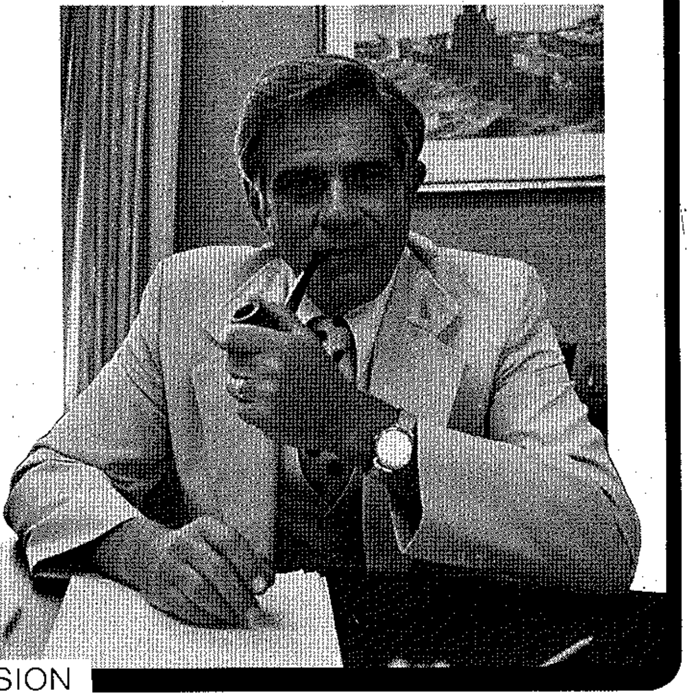
“ With recent and important increases in our contractual responsibilities, I'm vitally interested in bringing on board individuals with diverse talents. We've got excellent posts open for engineers who can apply modulation and coding theory and compression techniques to low data rate systems . . . engineers to provide technical support in the development and acquisition of submarine antenna systems as well as satellite communication systems . . . engineers to assist our clients in the analysis and evaluation of studies, test plans and procedures prepared by government laboratories and contractors.

“ The Computer Scientists we seek should be familiar with software development, from inception to life cycle maintenance including preparation of software documentation to government standards. They should also have experience in Configuration Management/Quality Assurance and verification and validation techniques.

“ Finally, I am looking for management scientists, preferably with a technical background, who can develop integrated logistics supporting documentation, program plans, training plans, program networks, and similar documentation.

“ I really want to encourage bright, recent graduates to contact me (if you're not afraid of hard work as a firm stepping stone to success), as well as mature engineers and managers who can work effectively on their own. ”



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New product applications

Computer system expandable to 2 Mbytes of main memory

The "Protos" system is a general-purpose, terminal-oriented, multiuser virtual memory computer. Features include a high-speed cache memory, overlapped instruction execution, virtual memory operation, an error-correcting memory, extensive memory mapping and protection logic, and expandability up to 2 million bytes of semiconductor memory.

The initial small configuration of the system includes a 256-kbyte processor with memory mapping, integral cache,

eight asynchronous I/O ports, a hard-copy terminal, a 300-line/min printer, an 80-Mbyte storage module, and two flexible disk drives. This system is priced at $100 000, including all software.

A larger system will include 512 kbytes of memory, 16 asynchronous I/O ports, the hard-copy terminal, a 600-line/min printer, two 300-Mbyte disk drives, dual flexible disk drives, and three video display terminals. This configuration is priced at $200 000, including all software.

Initial deliveries will start during the first quarter of 1979.

Computer Automation, Inc., 18651 Von Karman, Irvine, Calif. 92713.

Circle No. 73

5-volt MOS EPROM has 16-kbit capacity

This 5-volt, MOS, 16-kbit EPROM is organized as 2k 8-bit words and is, according to the manufacturer, the only 16-kbit EPROM completely compatible with the Intel 2716.

Offered in a standard 24-pin DIP, the TMS2716 is also pin compatible with other 5-volt ROMS and EPROMS. Operation is fully static, and inputs and outputs are fully TTL compatible. Outputs are three-state, enabling OR-tying. Other features include a guaranteed dc noise immunity of 200 mV and maximum access and minimum cycle times of 450 ns.

Power dissipation is typically 285 mW during active operation and 50 mW during a standby state. During the read mode, only a single 5-volt supply is required. Programming requires one 50-ms TTL-level pulse.

In 100-piece quantities, the EPROM is priced at $36.92 each.

Texas Instruments, Inc., Inquiry Answering Service, P.O. Box 1443, M/S 660 (Attn: TMS2516), Houston, Tex. 77001.

Circle No. 74

Spectrum's hardware review

For more information on the following products, circle numbers on the Reader Service Card corresponding to bracketed numbers.

Direct-read-after-write laser-recording material, available in prototype quantities, requires less than one half the laser power for recording than any such material previously available, Drexler Technology Corp. [90]; **Porcelain-ceramic multilayer capacitor kits for UHF and microwave circuitry contain a wide selection of values and tolerances in chip, pellet, or microstrip leaded styles,** JFD Electronic Components Corporation [91]; **Pin- and performance-compatible replacements for Analog Devices' AD7541 CMOS multiplying D/A converters need no ladder resistor trimming,** Micro Power Systems [92]; **Multijunction silicon reference diodes feature negative temperature coefficients of approximately −1.7 mV/°C per junction,** Microsemiconductor Corp. [93]; **Solid-state relays feature 2500-volt standard isolation and 4000-volt optional isolation,** Opto 22 [94]; **Ultrahigh-capacity nickel-cadmium cells in standard sub-C, C, and D sizes offer 20 to 30 percent more capacity (amperehours) than conventional cells of the same size,** Electronic Components Division of Panasonic Company [95]; **Complex National Semiconductor, Fairchild Semiconductor, and Signetics LSI devices are available in leadless ceramic chip carriers, hermetically sealed and screened in accordance with MIL-STD-883,** Sertech Labs, Inc. [96]; **Miniature three-terminal voltage regulator features adjustment-free, high-efficiency performance and delivers an overcurrent-protected negative 5-volt dc output for inputs ranging from 4.5 to 16 volts dc,** Semiconductor Circuits, Inc. [97]; **3/16-inch-diameter Temp-Plate model 410 temperature recorder is factory calibrated to within ±1 percent accuracy in ranges from 110 to 500°F,** William Wahl Corp., Temp-Plate Div. [98]; **Fixed coaxial attenuators, available in nine standard nominal dB values of 1, 3, 6, and 10 through 60 (10-dB steps), cover two frequency ranges of dc to 12 and dc to 18.0 GHz and feature low VSWRs of less than 1.20 (to 12.4 GHz) and less than 1.25 (to 18.0 GHz),** Weinschel Engineering [99]; **Vibration- and sunproof, infrared-operated line of limit switches are designed for application in extra rugged atmospheres of wet, vibrating, and dusty environments,** Xercon, Inc. [100].

†Power Demographic

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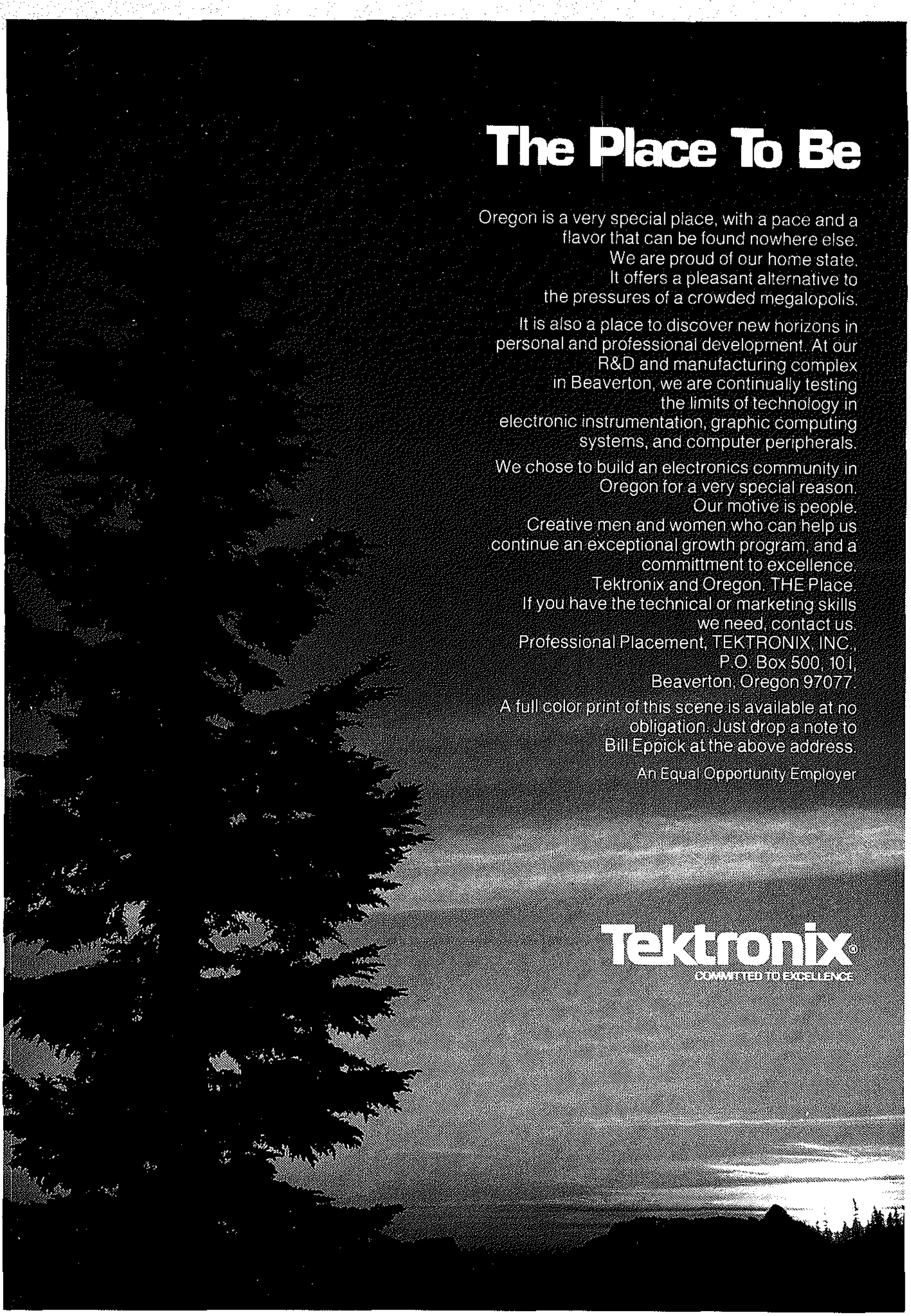

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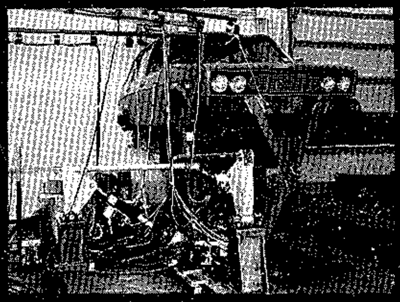

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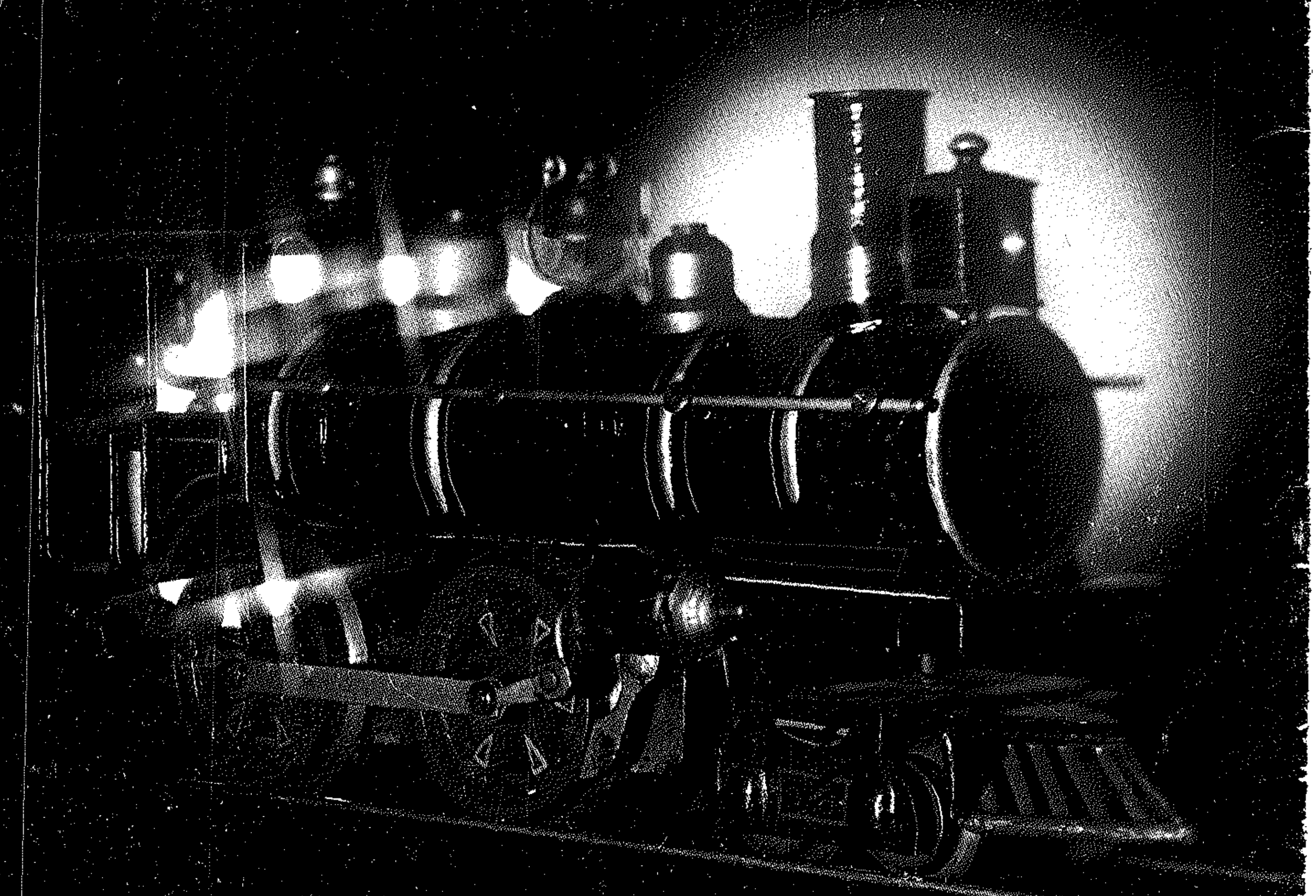

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Circle No. 21

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555

New product applications

the Intel "Multibus" interconnection standard.

The synthesizer can be used as the digital equivalent of a voltage-controlled oscillator in a phase-locked or frequency-locked loop. It includes an onboard crystal-oscillator frequency standard with 100-ppm stability. The onboard oscillator can be locked to an external reference at 1, 2, 5, or 10 MHz.

Output waveform of the PRO80 synthesizer is a sine wave with harmonics 40 dB down from 10 Hz to 600 kHz and 35 dB down from 600 kHz to 2 MHz. Phase noise is −50 dB in a 30-kHz band, excluding 1 Hz about the carrier.

Price of the synthesizer is $1300.

Proteon Associates, Inc., 24 Crescent St., Waltham, Mass. 02154. **Circle No. 70**

Digital IC tester provides low-cost multiplex

The model-725 digital IC tester is a 24-pin, MPU-based instrument with multiplex capability. Handling virtually all SSI and MSI devices, the unit performs functional as well as parametric testing.

The standard configuration operates with a single manual test site, IC handler, or wafer prober. In this mode this system can be used in conjunction with the manufacturer's cassette-taped test programs as a turnkey system.

The tester is also available as a multiplex system, or the basic instrument can be upgraded to this capability. This allows two-test-site operation. Any two-element combination of manual test sites, IC handlers, or wafer probers can be used.

The unit is priced at just under $25 000 in its basic version.

Siemens Corp., 2 Pine Oak Lane, Cherry Hill, N.J. 08034. **Circle No. 71**

Fiber-optic data link includes transceivers

This TTL-compatible fiber-optic data link combines two transceiver modules and a predetermined duplex cable 30 meters long. Interconnection of the link to a PC board is accomplished by bringing the necessary signals to a standard PC-board header.

Cable attenuation is typically 30 dB/km, and connector attenuation is 1 dB per mated pair. The transceiver modules have an infrared-emitting GaAs LED light source and a PIN photodiode light detector. The module incorporates a ten-contact socket on 0.254-cm centers that mates with the PC-board header. The link requires a microprocessor-type power supply with outputs of ±7 to ±15 volts and 5 volts.

Data rate is 10 Mbits using a biphase coded line format. Error rate is 10^{-10} at 10 MHz over a 90-meter cable.

Trade price for the complete data link is $695; delivery is within eight weeks.

Dept. EP8-26, 3M Co., Box 33600, St. Paul, Minn. 55133. **Circle No. 72**

testing to Federal Communications Commission specifications in the 902- to 928-MHz medical electronics and industrial scientific band, the 470- to 806-MHz UHF band, and the 947- to 952-MHz oral broadcast band.

A 50-ohm input is provided for communications measurements from 10 MHz to 1 GHz at an average sensitivity of 100 mV. An optional external 30-dB wide-band amplifier plugs into the 50-ohm cable system to provide sensitivity to 5 mV for troubleshooting low-level stages.

Price of the instrument, designated the FC51, is $975.

Sencore, 3200 Sencore Dr., Sioux Falls, S.Dak. 57107. **Circle No. 67**

Smart CRT terminal displays 132-column data

This smart CRT terminal can display full line-printer format: up to 132 characters per line. It can display up to 40 lines on the CRT with up to 4096 characters.

The standard font is the full upper-and lower-case ASCII character set, but, by using the supplied font editor program, the user can easily modify the set to match a new group of characters. Foreign language fonts can be implemented.

The interface does not require any special protocol from the host. It communicates via an RS-232 line and looks like a simple printer/keyboard combination to the host. This feature permits either direct hookup or remote use via dial-up lines, with keyboard-selectable baud rates from 110 to 9600.

A text-editing program permits complete off-line editing and supports the transmission of data at a character, line, or block at a time to a user. The unit will also execute user-written Basic programs.

The terminal is priced at $7900.

ECD Corp., 196 Broadway, Cambridge, Mass. 02139. **Circle No. 68**

Emulator upgrades passive terminals and ports

This emulator provides the necessary HDX interface protocol for passive terminals and passive computer ports, permitting high-speed switched network operation up to 4800 bits/s. This allows passive terminals to operate HDX modems like the 1200-baud acoustic coupler.

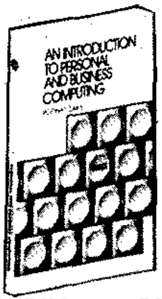
No secondary channel or modem slaving technique is needed. Normal operating procedures are maintained because there is no loss of data during the RTS-CTS delay. Because the emulator interfaces with synchronous as well as asynchronous modems, start/stop terminals can also achieve the higher bit rates.

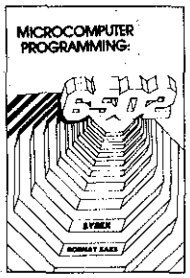
The emulator permits the computer front end, normally restricted to FDX interfacing, to use a single dial-up connection to less active terminals.

For more information, contact Com/Tech Systems, Inc., 44 Beaver St., New York, N.Y. 10004. **Circle No. 69**

2-MHz synthesizer card offers 0.0023-Hz resolution

This frequency synthesizer PC card covers the range from 10 Hz to 2 MHz with 0.0023-Hz resolution. It is designed for use with such microcomputers as the Intel SBC-80, the National Semiconductor BLC-80, and others that conform to





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New product applications

A/D-D/A data-acquisition cards fit Micronova micros

These 32 A/D and two D/A channels on a single board slide directly into Data Genera's Micronova microcomputer. The system is expandable up to 256 channels and offers speeds up to 45 000 A/D samples per second. A comprehensive systems manual and paper-tape diagnostic program are included for immediate teletypewriter printout.

The A/D section features an output resolution of 12 binary bits. Standard units are supplied with two's-complement coding and a ±10-volt input range. A/D nonlinearity is ±½ LSB maximum, with full-scale drift of ±30 ppm of FSR/°C, and zero drift of ±7 ppm of FSR/°C. Sample-and-hold aperture time is 50 ns with a 12-μs acquisition time and 8 μs of A/D conversion.

Datel Systems, Inc., 1020 Turnpike St., Canton, Mass. 02021. **Circle No. 65**

Programmable gain amplifier handles 10-mV to 10-volt signals

This programmable gain instrumentation amplifier offers 11 binary gains selected by a 4-bit TTL word. When used with a 10-bit A/D converter in a "floating point" system, the 2^{10} gain range of the amplifier, plus the 2^{10} range of the converter, produce a total system accuracy of 1 000 000 to 1.

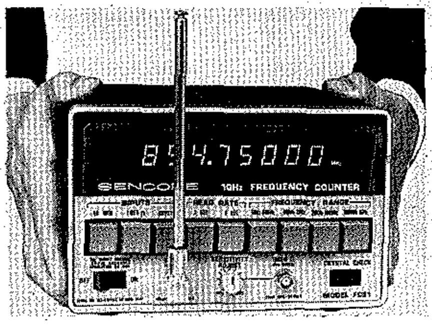
Gain nonlinearity is 0.01 percent maximum, gain error is 0.02 percent maximum, and gain drift is 10 ppm/°C maximum. CMR is 110 dB minimum at a gain of 32 V/V or more; input resistance is 10×10^9 ohms.

Prices in quantities of 100 or more range from $51.50 in a ceramic package to $70 in a metal package.

Burr-Brown, P.O. Box 11400, International Airport Industrial Park, Tucson, Ariz. 85734. **Circle No. 66**

1-GHz counter designed for 806- to 947-GHz band

This 1-GHz, all direct-reading pushbutton frequency counter measures in the newly authorized 806- to 947-MHz two-way communication business and police band.



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News from the Regions

CONTINUING EDUCATION IN IEEE

The IEEE's intensive three-day microprocessor course featuring a take-home microprocessor and power supply has been scheduled in Regions 1 and 6 next month: at the West Coast University of California on November 16-18 and at the Holiday Inn in Poughkeepsie, N.Y., November 30-December 2. The course is designed to update midcareer engineers familiar with the design of logic circuits with the use of the microprocessor as a replacement for wired logic controllers. The laboratory is based on the Motorola MEK6800D2 Evaluation Kit. Enrollment is limited to 50 participants. Fees are $475 for IEEE members and $525 for nonmembers up to 14 days in advance, and $500 and $595, respectively, at the door.

A two-day microprocessor seminar is on the agenda for Toledo, Ohio, November 9-10, and Bridgeton, Mo., November 16-17. This course covers characteristics, availability, and use of microprocessors in industry. Sample systems will be described. Advance registration fees are $130 for members and $165 for nonmembers. At the door, these fees will be $150 and $188 respectively.

Portland, Oreg., will host three IEEE courses. On November 3-4, Basic Project Planning, Scheduling, and Control addresses itself to such problems as mushrooming manpower requirements and delays that result in hasty decisions, and will suggest how to make the right choice and take the proper corrective action. Also on November 3-4, a course on fiber optics will introduce the practicing communicator to the new technology of optical waveguide digital communications via intuitive and nonmathematical notions. And Protection and Grounding of Distribution Systems is the title of a course--on November 29-30--that will describe the basic technical fundamentals of systems grounding and its influence on system protection. Course fees in each case are $130 for members and $165 for nonmembers in advance, or $150 and $188, respectively, at the door.

Information and enrollment: Vincent J. Giardina, IEEE Manager of Continuing Education, 445 Hoes Lane, Piscataway, N.J. 08854; telephone (201) 981-0060, ext. 174/175.

NEW ORLEANS SECTION WILL MEET

The tenth Annual Seminar of the IEEE New Orleans Section will be held at the Hilton Inn in New Orleans, La., November 16. Some 11 papers by authors from various parts of the U.S. will be presented in three areas: power, communications, and general engineering. Advance registration fee of $15 (before November 10) should be sent to: Roy C. Hingle, South Central Bell, 3500 North Causeway Blvd., Room 620, Metairie, La. 70035.

MARKETING SEMINAR ON FIBER OPTICS

The first fiber-optics conference devoted strictly to markets will be held in Newport, R.I., October 23 and 24. Some 16 speakers will cover present and future markets, and four sessions will focus on the specific markets for fiber-optic sources, cables, connectors, and detectors. Details: Kessler Marketing Intelligence, 22 Farewell St., Newport, R.I., 02840; (401) 849-6771.

plications in the 600- to 1000-MHz band. The family of four devices has power output ratings ranging from 3 to 40 watts.

The MRA-0610 is glass passivated and gold metallized. All units are internally matched for broadband capability, providing as much as 10 dB of usable, additional dynamic range.

In OEM quantities of 100, the device ranges in price from $38.25 for the 3-watt version to $169.79 for the 40-watt version. Delivery ranges from off-the-shelf to four weeks, depending on quantity.

TRW RF Semiconductors, 14520 Aviation Blvd., Lawndale, Calif. 90260.

Circle No. 61

Dual outputs provided by small dc/dc converter

A single 5- to 16-volt dc input is converted to a pair of positive and negative isolated outputs of the same value by this tiny dual isolated dc/dc converter (1 by 1 by 0.3 inch or 2.54 by 2.54 by 0.76 cm). Contained in a 20-pin ceramic DIP, it is designed for use in process control, but is also expected to find use in medical, clinical, analytical, nuclear, and test instrumentation.

The two output channels are isolated from the input to 3500 volts continuous (8000 volts test). Channel-to-channel isolation is 2000 volts continuous and 5000 volts test. Isolation impedance is 10^{10} ohms in parallel with 6 pF. Leakage current is 1 μA maximum at 240 volts, 60 Hz. Output channels can be connected in series or in parallel to produce higher voltages or currents.

Operating temperature is −25 to +70°C. Unit price is $30 in quantities of 1 to 24, $24 in quantities of 25 to 99, and $22 in quantities of 100 to 299.

Burr-Brown, International Airport Industrial Park, Tucson, Ariz. 85734.

Circle No. 62

Driver modules available for testing ICs

These two driver modules and a high-speed I/O switch are specifically designed for testing logic assemblies and integrated circuits. The model 10800 is a 200-MHz ECL driver with a 600-ps rise time. It can transmit data through a 50-ohm terminated 0.6-meter coaxial cable at data rates from dc to over 200 MHz, at a 1.2-volt peak-to-peak output.

The model 150 is a dc-coupled, 40-volt data/clock driver. It accepts standard TTL/DTL inputs and can be driven directly from 54/74 series gates or flip-flops.

The model 700 is a high-speed, general-purpose I/O switch that provides an inhibit switch for the driver's output. It offers a 50-ns switching time maximum, a TTL input drive level, and FET switching.

All three modules are available from stock. Prices are $115 for the 150, $90 for the 700, and $200 for the 10800.

EH International, Inc., 515 Eleventh St., P.O. Box 1289, Oakland, Calif. 94606.

Circle No. 63

Alphanumeric subsystem is on a single board

These alphanumeric display subsystems for OEM applications incorporate a single-chip display/keyboard controller. The controller, display drivers, and LEDS are contained on a single 20.3- by 8.3-cm printed-circuit board.

The boards interface directly to an 8-bit bidirectional data bus or I/O port. They can be connected directly to most microprocessors, including the 8080A and the 6800. All mounting hardware and a red filter are included.

The on-board alpha chip includes 22 intelligent commands for display data manipulation, including clear display, blink, shift, rotate, and cursor manipulation commands. In addition, the chip provides a controller for scanning and debouncing up to 64 keys.

The displays require a single +5-volt, 800-mA supply only. Prices start at $280 for a complete 16-character display ($380 for 32 characters) and drop below $200 in OEM quantities.

Matrox Electronics Systems, P.O. Box 56, Ahuntsic Station, Montreal, Que. H3L, 3N5, Canada. **Circle No. 64**

New product applications

Digital/synchro converter has 16-bit resolution

The model 1667 digital-to-synchro converter provides 16-bit resolution and 1 arc-minute of accuracy. It delivers 1.5 VA of output power for either synchro or resolver configuration. Magnetic variation is below 0.01 percent.

The series is available for 50/60 or 400 Hz and can be supplied to deliver a variety of output voltages. Dimensions are 7.938 by 9.208 by 3.175 cm (3.125 by 3.625 by 1.25 inches).

Units are available for temperature ranges of 0 to 70°C or −55 to +55 to +85°C. Reliability levels of 883B or MIL-M-38510 can be supplied.

Price is $950, with delivery from four to six weeks.

Transmagnetics, Inc., 210 Adams Blvd., Farmingdale, N.Y. 11735. **Circle No. 55**

8-bit D/A converter operates from −25 to +85°C

This 8-bit D/A converter has a standard operating temperature range of from −25 to +85°C. It operates from a single +5-volt supply.

The unit is available with either 8-bit binary or two-decade BCD input coding and requires no adjustments to meet specifications. The family also includes +15-volt, single-power-supply versions that operate from −25 to +85°C.

Each unit includes a built-in reference, a precision resistor network, and switches. The current output settles to within the specified ± D½ LSB linearity in less than 1 μs for a full-scale range change and may be converted to voltage by means of a resistor to ground.

Price is $17 each in quantities of 1 to 24.

Hybrid Systems Corp., Crosby Dr., Bedford, Mass. 01730. **Circle No. 56**

Socket connectors protect pins during disconnect

This series of 14– and 16-position socket connectors can be mass terminated to flat cable, without wire stripping or soldering. Mating contacts are completely enclosed in a plastic housing to provide contact protection during repeated disconnect/reconnect cycles.

Applications include logic or Wire-Wrap panels with 0.64-mm round or square posts on grid patterns of 2.54 by 5.08 mm or 2.54 by 7.62 mm.

The connectors are terminated by inserting the cable into the connector opening and simultaneously crimping all conductors with a hand or bench tool—an operation that takes a few seconds.

Socket connectors can be terminated to 28–30 AWG stranded or solid wire and 33 AWG equivalent flat conductor wire. Socket connector prices are as low as $0.08 per contact in quantities.

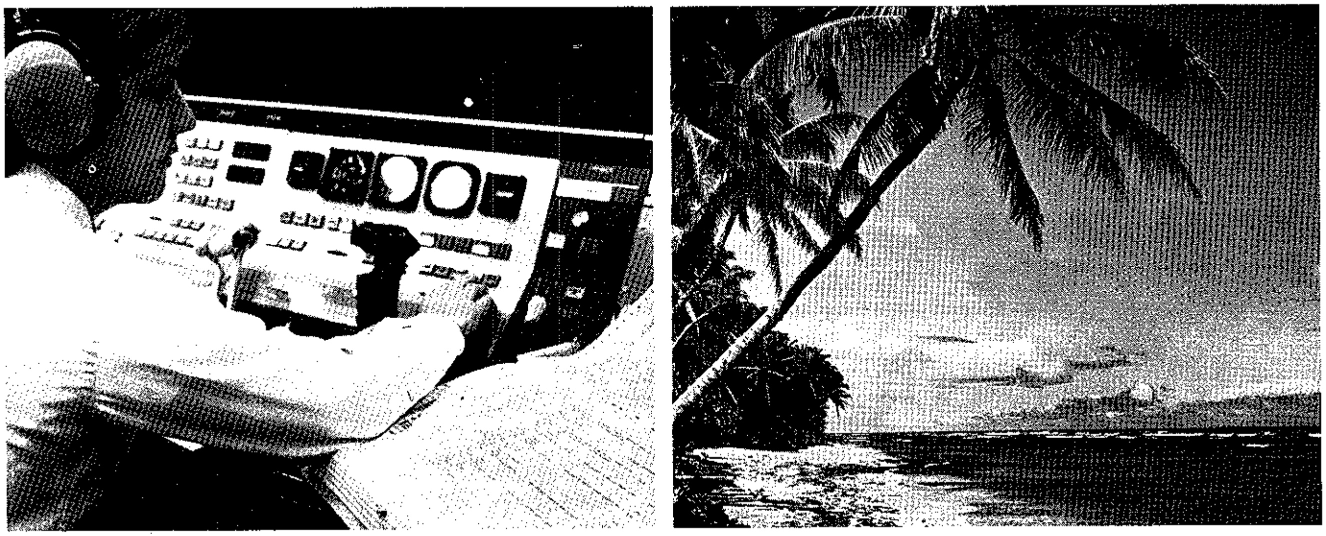
T&B/Ansley, 3208 Humboldt St., Los Angeles, Calif. 90031. **Circle No. 57**

Synthesizer interface is compatible with IEEE 488

This interface for this manufacturer's series 5600 frequency synthesizers is compatible with the IEEE Std-488/1975 instrumentation bus. It plugs into the associated synthesizer and the host system via standard cables. The interface not only satisfies all bus timing and loading constraints, but also accommodates up to 1-Mbyte/s data transfers. Full buffering of all data is provided; data entry is byte-serial, but no transfer is made to the companion synthesizer until a load command is sent.

The interface contains its own regulated dc power supply; only ac power need be supplied. It is compatible with any program source having the standard IEEE-Std 488/1975 format and signal level, including programmable calculators, many interactive terminals, properly equipped minicomputers and microcomputers, and automatic test equipment systems.

Rockland Systems Corp., 230 W. Nyack Rd., W. Nyack, N.Y. 10994. **Circle No. 58**



New product applications

Analog Devices Semiconductor, 829 Woburn St., Wilmington, Mass. 01887.
Circle No. 49

CMOS 4-kbyte RAM card has battery backup

This 4-kbyte CMOS RAM memory card has a battery backup that permits power-off retention of data for from 5 to 20 days. The model 8122 is expandable in 1-kbyte increments, with each 1 kbyte of memory having a write-inhibit switch that prevents inadvertent memory overwrites.

Upon detecting a loss of power, the recharge circuitry automatically switches to battery power and immediately write-inhibits all memory. The 8122 can be removed and transported without losing data.

Other features include a full 64-kbit address-decoding capability, a separate input and output data bus, and a jumper-selectable, three-state I/O data-bus option.

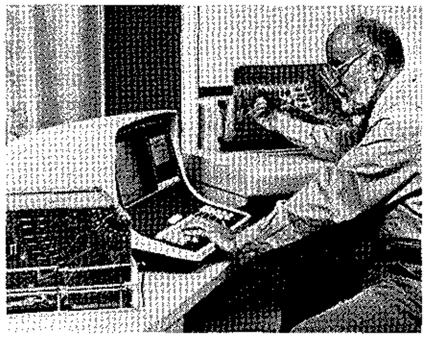
The 8122 ranges in price from $150 to $450 in single quantities, depending upon the amount of memory selected.

Pro-Log Corp., 2411 Garden Rd., Monterey, Calif. 93940. **Circle No. 50**

Modular ATE family covers wide range of testng

The modular "System 390" is a family of computer-controlled, automatic test systems that are capable of performing static, functional, and dynamic testing of analog, digital, high-frequency, and hybrid units under test (UUTs).

The system uses Atlas, a high-level language with common English test terminology. In addition to this UUT-oriented programming language, there are on-line editing and compilation capabilities and completely flexible hardware switching that minimizes patch panels and the need for adapter boards.



A remote service capability permits real-time, instant service assistance via bidirectional data transmission between the user and a factory service center.

Instrumentation Engineering, 769 Susquehanna Ave., Franklin Lakes, N.J. 07417. **Circle No. 51**

Low-cost four-channel D/A card designed for "EXORciser"

The model ST-6800DA4A is a four-channel D/A converter plug-in PC board, with the dc/dc converter on the card. It permits low-cost interfacing of the M6800 EXORciser microcomputer system to the outside world. The low price of $560 includes a diagnostic test program, as well as a comprehensive systems manual.

Organized as a 16-byte memory block, the card slides directly into the microcomputer's card slots. Features include 12-bit binary resolution; 4-μs settling time to within ± ½ LSB for a 20-volt step; and full-scale output voltages of 0 to +5, to 0 +10, −5 to +5, and −10 to +10 volts.

The converter's on-board dc/dc supply provides linear circuits with ±15 volts from the EXORciser 5-volt bus. A 12-bit digital output port can be used as a device select or control port to external logic.

Datel Systems, Inc., 1020 Turnpike St., Canton, Mass. 02021. **Circle No. 52**

Logic troubleshooter tests down to the component

The model 5700B permits the user to probe the pins of IC modules. A panel switch enables the user to select the

New product applications

Precision tape-recorder time-base corrector is available in a small bench-top instrument case

This $6995 digital time-base corrector provides on-line correction of time-base errors caused by uncorrected tape speed and stretch variations occurring in longitudinal instrumentation recorders. These time-base errors constitute a form of signal distortion that can easily obscure pertinent timing relationships or spectral features of the original signal.

The table-top or rack-mounted instrument effects this correction online, using digital processing techniques. It is a wide-bandwidth (2-MHz) system that is compatible with most standard instrumentation recorders (IRIG standards). Each recorder is configured for a given IRIG recording mode. Stock models are configured for direct (wide band—2 MHz) and FM (wide band—group II) recording.

The instrument can operate with recorders using any of eight speeds: 15/16, 17/8; 33/4, 71/2, 15, 30, 60, and 120 in/s. The operating speed is selected manually by a front-panel switch, or automatically by using a BCD "speed bus" switch. All signal levels and impedances are prespecified, and no amplitude adjustments are necessary.

The Tymcor 1000 instrumentation recorder is designed for use in applications sensitive to time-base stability and precise spectral fidelity. Those include sonar signal and telemetry processing, vibration analysis, seismic research and exploration, acoustic analysis, oceanographic research and exploration, electronic intelligence, and nuclear instrumentation.

According to the manufacturer, this is the first off-the-shelf time-base corrector. The instrument can be configured for use with general-purpose, portable, or airborne recorders, which may have relatively higher time-base errors than high-performance laboratory-type instrumentation recorders.

Bancomm Corp., 1121 San Antonio Rd., Palo Alto, Calif. 94303.

Circle No. 40

Low-cost intelligent processor module expands the computing power of PDP-11 minicomputers

Here's a low-cost method of boosting the throughput of Digital Equipment's PDP-11 minicomputer. The MIP-3/A intelligent input processor with an A/D converter can assume the burden of data processing and leave the PDP-11's CPU to do what it does best: peripheral supervision. The $3995 device (single-unit price) consists of a Unibus interface, a data-acquisition subsystem, an expandable buffer memory, and an input processor. The $3995 price includes the necessary software to operate under DOS, RT11, and RFX-11M operating systems.

The MIP-3/A includes an input multiplexer for 16 single-ended and eight differential channels, sample-and-hold amplifier, and a 12-bit A/D converter with a 100-kHz maximum throughput rate. Conversions are initiated either from an external clock or an onboard crystal oscillator. Basic memory capacity for the processor is 4096 16-bit words. This is expandable to a maximum of 65 536 16-bit words by the addition of expander memory cards, each of which contains 16 384 16-bit words.

The MIP-3/A's dual-port buffer memory may be accessed by a Unibus master, such as the CPU or any DMA device, and is also accessible via the A/D converter. Any sized window of any portion of the memory may be placed anywhere on the Unibus by setting appropriate switches.

When not used for A/D acquisition, the memory behaves as a conventional PDP-11 memory and may be used for running operating systems and Fortran and other programs.

The input processor controls the data-acquisition system and provides memory addresses for writing A/D data into the buffer memory. It may also request interrupts from the host CPU. The processor is microprogrammed and controlled by a set of registers located in the I/O page of the PDP-11 minicomputer address space.

The MIP-3/A requires 5 volts dc to operate. An onboard dc/dc converter provides the voltages for the analog circuitry. A connector and cable are provided for hooking analog signals into the MIP-3/A.

For those applications requiring no A/D converter, the MIP-3 is available at a single-unit price of $3400.

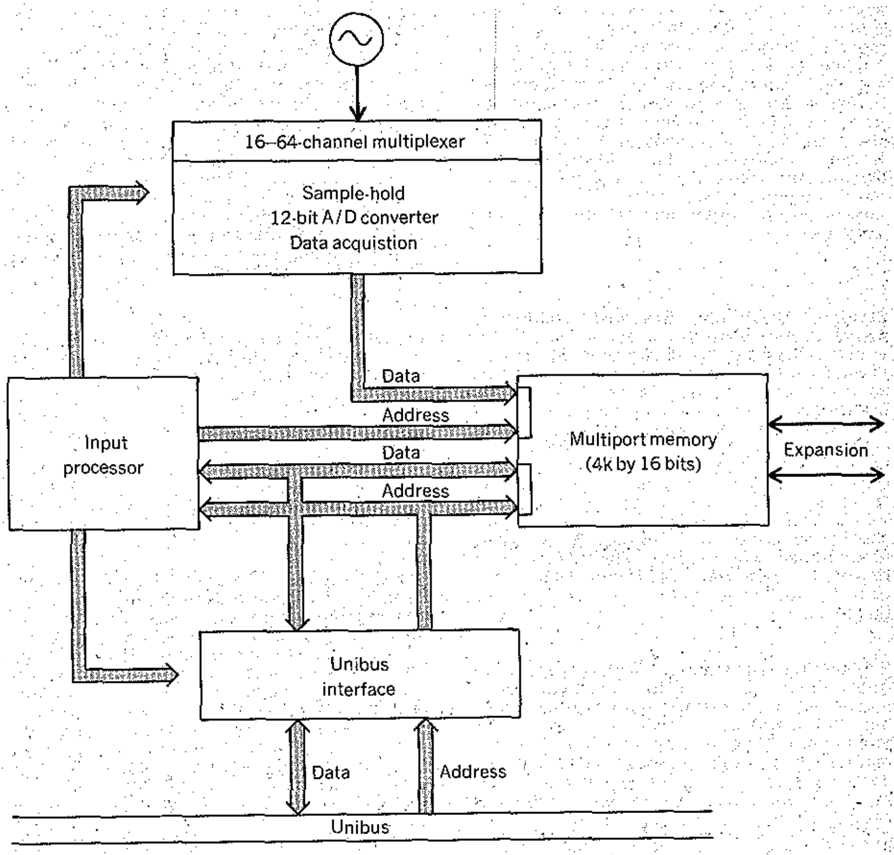
This manufacturer expects to make available shortly input processor modules specifically designed for the Data General line of minicomputers and for Interdata'a models 732 and 832 minicomputers.

The MIP-3/A and MIP-3 are available from stock.

Full specifications can be obtained from Computer Design & Applications, Inc., 377 Elliot St., Newton, Mass. 02164.

Circle No. 41

Users of PDP-11 minicomputers can now expand their minicomputers' power at low cost with this intelligent input processor module (block diagram of elements shown).



Classified advertising

(continued from p. 105)

Senior Research Associate II. Five years' experience in following areas of expertise: epitaxial growth of high purity III-V semiconductor compound from the liquid phase; metalization, photolithography and related device fabrication technology; electrical, optical and structural assessment of semiconductor materials; device testing and evaluation. Should be self motivated and have the initiative, supervisory and organizational ability to coordinate laboratory research in the area of III-V compound semiconductors. Electrical Engineering, Cornell University, Ithaca, NY 14853, c/o Dr. C.E.C. Wood. 607-256-3704. Cornell University is an Equal Opportunity Employer.

Department Head. The Department of Computer Science at Virginia Polytechnic Institute & State University is seeking outstanding candidates for the position of department head. Applicants should demonstrate research and teaching credentials indicative of senior rank. Academic administrative experience is desirable but not mandatory. The department has 17 FTE faculty positions, an undergraduate enrollment of 400, and approximately 70 on-campus and 200 off-campus graduate students. Degrees are granted at the baccalaureate, masters, and doctoral levels. Curriculum Vitae, including at least three references, should be sent by December 1, 1978 to: Professor Thomas C. Wesselkamper, Chairman, Search Committee, Department of Computer Science, Virginia Polytechnic Institute & State University, Blacksburg, VA 24061. Virginia Tech is an Equal Opportunity/Affirmative Action Employer.

Magnetic Recording Research. Applied research openings are immediately available for self-motivated, analytic-minded engineers or scientists. These positions include conceiving new knowledge of magnetic recording devices and systems via combined theoretical and experimental investigations, and evaluation of state-of-the-art components of related research projects. Candidates must have an advanced degree in electrical engineering or applied physics with a minimum of two years' practical digital/analog circuit and system design experience. A working knowledge of microprocessor interfaces and the use of computers in problem solving is highly desirable. Background in magnetic recording and signal processing or communications is preferred. Please submit your resume to the attention of Janet Porretti at the Sperry Research Center, 100 North Road, Sudbury, Massachusetts 01776: An Equal Opportunity Employer.

Research Engineer, possibly Faculty Position. A position is available for an electrical engineer to assume a major role in ongoing and self initiated research and development projects in diagnostic ultrasound. Current projects include development and evaluation of ultrasonic computed tomography for breast imaging and performance evaluation and dosimetry of diagnostic ultrasound systems. Part time commitment to general bioengineering projects available if desired. Applicants should possess a doctorate, or an M.S. with at least four years experience, and should have extensive academic training and experience in analog and digital system design and assembly language programming. Acoustical physics, scattering theory, signal processing, image analysis, pattern recognition and statistics are additional desirable areas of expertise. Salary and academic appointment up to assistant professor are commensurate with qualifications. A resume, references and copies of transcripts and relevant publications would be appreciated. Contact: Paul L. Carson, Ph.D., Radiological Sciences Division or K. C. Rock, Director of Bio-engineering, University of Colorado Medical Center, 4200 East Ninth Avenue, Denver, CO 80262. An Equal Opportunity/Affirmative Action Employer.

University of Illinois at Chicago Circle. Department of Information Engineering. Assistant/Associate Professor position is available for September 1979. Duties include undergraduate/graduate teaching and research. An earned Ph.D. in computer science or electrical engineering is required, and demonstrated teaching and research abilities are highly desirable. Preferred areas of specialization are as follows: 1) Theoretical Computer Science; 2) Computer Vision. Send resume, selected publications and three references by February 28, 1979 to: Professor B. H. McCormick, Head, Department of Information Engineering, University of Illinois at Chicago Circle, Box 4348, Chicago, Illinois 60680. The University of Illinois is an Affirmative Action/Equal Opportunity Employer.

Manufacturing Engineer/Methods Engineer, $22,000/$26,000. Industrial Engineers. Supervisor knowledge of N/C machinery, processing and fabrication of medium to heavy equipment. 3-10 years exp. Contact Selectability, Inc. 1011 E. State Street, Rockford, IL 61104 (815/964-0078).

Applications are invited for assistant professor tenure-track positions in the School of Electrical Engr. & Computing Sciences. Two positions are now available in the areas of digital systems and power systems, and additional positions may be offered dependent upon funding. Duties will include student advising, graduate & undergraduate teaching, supervision of graduate research, and development of research programs and support. Applicant must hold an appropriate doctorate & a combination of education & experience that will contribute to the ongoing program capability. Positions open Sept. 1979 or earlier if mutually agreeable. Applications must be received by Dec. 1, 1978, to receive consideration in initial screening; however, applications will be accepted until positions are filled. Address inquiries & applications to: M. E. Council, Director, School of Electrical Engineering & Computing Sciences, College of Engineering, University of Okla., Norman, OK 73019. The University of Oklahoma is an Equal Opportunity, Affirmative Action Employer.

General Manager. Our client is a joint-action public utility responsible for developing dependable and economical electric power for several growing Texas communities (current population approximately 300,000.) Our executive search is for a General Manager to exercise full management responsibility, reporting to a Board appointed by the member cities. Successful applicant must demonstrate applicable management experience with large-scale construction (preferably electric utility) and possess exceptional organization, coordinative, technical, and public relations skills. Salary open. An Equal Opportunity Employer. Reply in strict confidence to Box 6272.

Electrical Engineering and Electrical Engineering Technology: Faculty positions. The department invites applications for openings at the assistant/associate professor level beginning January 1979, August 1979. The candidate should have demonstrated abilities and interests in one or more of the following fields: control, communications, electronics, computers and digital systems. A doctorate in the field is expected although persons with exceptional qualifications will be considered. This is a dual curriculum department with a strong commitment to undergraduate instruction, creative curriculum development and scholarly inquiry. It offers a suitably qualified person excellent opportunities to contribute in those fields which support the departmental curricula. We are an affirmative action employer. Rank and salary commensurate with qualifications and experience. Please submit detailed resume and a statement of professional aspirations to: Chairman, Department of Electrical Engineering and Electrical Engineering Technology, Bradley University, Peoria, Illinois 61625.

Electrical Engineering Faculty. Openings exist for faculty in computer engineering, electronic materials and devices, and communications. Other specializations may be of interest. Direct responses to Dr. Richard F. Schwartz, Head, Department of Electrical Engineering, Michigan Technological University, Houghton, Michigan 49931. An equal opportunity educational institution/equal opportunity employer.

University of California, Davis. The Department of Electrical Engineering, University of California, Davis, invites applications for a faculty position in the area of computer software, particularly operating systems and programming language design and implementation. A broad background in computer science and engineering is also required of all candidates. The department is seeking individuals who are versatile and strong in both teaching and research who are willing and able to teach large undergraduate classes. Graduate teaching and vigorous and productive research are also expected of the faculty selected. Applicants must have a Ph.D. or equivalent degree. Position is available starting with the Spring Quarter 1979. The University is an affirmative action employer and encourages applications from women and members of minority groups. Deadline for receipt of applications: December 15, 1978. Send resume to: Faculty Search Committee/OS, Department of Electrical Engineering, University of California, Davis, CA 95616.

University of California, Davis. Applications are invited for a faculty position in a Graduate Group in Computer Science to teach at the undergraduate and graduate level and to conduct research in medium and large scale information storage and retrieval systems. A strong interest and commitment to teaching as well as vigorous and productive research are expected of the faculty selected. Applicants must have a Ph.D. or equivalent degree. The University is an affirmative action employer and encourages applications from women and members of minority groups. Position to start 9/79. Send resume to: Professor Richard F. Walters, Dept. of Community Health, University of California, Davis, CA 95616, by December 15, 1978.

University of California, Davis. The department of Electrical Engineering, University of California, Davis, invites applications for a faculty position expected to be available for academic year 1979–80 in the area of Information Systems. A broad background in computer science is also required of all candidates. The department is seeking individuals who are versatile and strong in both teaching and research who are willing and able to teach large undergraduate classes in the basic computer science courses offered by the Electrical Engineering Department. Graduate teaching and vigorous and productive research are also expected of the faculty selected. Applicants must have a Ph.D. or equivalent degree. The University is an affirmative action employer and encourages applications from women and members of minority groups. Deadline for receipt of applications: January 31, 1979. Send resume to: Faculty Search Committee/DB, Department of Electrical Engineering, University of California, Davis, CA 95616.

University of Illinois at Chicago Circle, Department of Information Engineering. Assistant/Associate Professor position is available for September 1979. Duties include undergraduate/graduate teaching and research. An earned Ph.D. in electrical engineering or computer science is required, and demonstrated teaching and research abilities are highly desirable. Preferred areas of specialization are as follows: 1) Digital Data Communications; 2) Computer Architecture; 3) Computer Design Automation. Send resume, selected publications and three references by February 28, 1979 to: Professor B. H. McCormick, Head, Department of Information Engineering, University of Illinois at Chicago Circle, Box 4348, Chicago, Illinois 60680. The University of Illinois is an Affirmative Action/Equal Opportunity Employer.

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Positions Open

The following positions of interest to IEEE members have been reported as open. Apply in writing, addressing reply to address given or to Box Number, c/o IEEE Spectrum, Advertising Department, 345 East 47th St., New York, N.Y. 10017. Classified Advertising Rates for this column: $15.00 per line. No advertising agency commission is granted. Copy must be received by the 10th of the month preceding date of issue.

Positions Available—Electrical & Electronic Eng's. Over 1000 US client companies pay our fees for selected technical referrals. Est. 1959. Send resume & salary history. Atomic Personnel, Inc., Box C, 1518 Walnut, Phila. Pa. 19102.

The School of Electrical Engineering, Georgia Institute of Technology, seeks applicants at the assistant professor level. PhD in E.E. and clear potential for distinguished performance in teaching, research, and service are required. Areas of special need include computer engineering, telecommunications, and electric power engineering. Resumes and statements of interest should be addressed to Director, School of Electrical Engineering, Georgia Institute of Technology, Atlanta, Georgia 30332. Georgia Tech is an equal opportunity/affirmative action employer.

Engineers: Recruiting for nationwide clients since 1949. Electronics hardware, software, components, systems. Military, commercial. In confidence-Brentwood-Box 11, Parsippany, NJ 07054.

Energy Search, EE, field engineer to operate electronic instruments to evaluate wells drilled for oil and gas. Various locations USA. 0-3 years experience, only U.S. citizens and immigrants. Apply Carter Robinson, Schlumberger Well Services, P.O. Box 2175, Houston, Texas 77001. An equal opportunity employer.

Communications Engineers—Exec. search and contingency placements nation-wide: Hardware/software system & component design, implementation & test. All fees paid. Call, submit resume with salary & location requirements to F. Jones, Eastern Executive Assoc., Div. F. X. Jones Assoc., 881 Allwood Rd., Clifton, NJ 07012 (201) 777-6900.

Texas, California, Florida, other SW, SE, W & Foreign location opportunities for sharp EE's having instrumentation, power, minicomputer, microcomputer, semiconductor or electronics exp.—hardware, software or systems. $19-32,000 base starting. Positions with private industry mfg., design and consulting cos having impressive growth. Each contact is made selectively (you are in control) and held in strict confidence. Our client cos assume all placement fees. Resume to J. L. Gresham, BChE, MBA will contact you at home first. Est. 1966, member AIChE. Systemation Consultants, Inc., employment service, 1410 Post Oak Tower, Houston, Texas 77056. (713) 622-1370.

Engineering Position—Our clients are involved in Communications, Telecommunications, Computer Equip., Power, Consumer Products, and Mil. in design and manufacturing. All fee paid. Call, submit resume, salary and location requirements to F. Rogers Assoc., 25 South Service Rd., Jericho, N.Y. 11753 (516) 997-4373.

GaAs Device/Circuit Designer. An opening exists for a Member of the Technical Staff to work on the design, evaluation and characterization of GaAs MESFET and other advanced digital logic devices. The successful candidate will have an advanced degree in EE or physics (or the equivalent experience) with a good understanding of device physics. Familiarity with IC layout and processing is desirable in order to interact with others on Sperry's high-speed logic programs. Please submit resume to Janet Porretti, Sperry Research Center, 100 North Road, Sudbury, Massachusetts 01776. An Equal Opportunity Employer.

Signal Processing Research. Sperry Research Center has a research staff opening for a Ph.D. E.E. with several years' experience in signal processing for sonar, radar, or communications systems. Demonstrated ability to apply advanced theory to practical signal processing problems, such as spectral estimation, digital filtering, or array processing, is required. An understanding of modern signal processing implementation technology is also desired, particularly digital techniques. Please submit resume to Janet Porretti, Sperry Research Center, 100 North Road, Sudbury, Massachusetts 01776. An Equal Opportunity Employer.

Engineers—SE Locations, Process, Powerlight, Software, Hardware, Systems, Instrumentation, Facilities. Fee Paid. No Contracts, 12 yrs. experience. Beall Associates, P.O. Box 5042, Spartanburg, S.C. 29304.

Faculty Positions. Applications are invited for two permanent positions expected to start September 1979 in electronics, one at the full professor level and one at the assistant professor level. Areas of primary interest are integrated circuits and solid state devices, including optical and microwave applications. Applications are also invited for temporary positions which may become available at the levels of assistant, associate or full professor to start September 1979. Apply to Chairman, Department of Applied Physics & Information Science, C-014, University of California, San Diego, La Jolla, California, 92093. UCSD is an Equal Opportunity/Affirmative Action Employer.

Assistant Professor—Solid State Electronics, Desired is a Ph.D. with one or two years industrial experience who will establish his/her own research and graduate training program within our solid state electronics program. Preference given to an individual with strong analytical skills and microwave interests. Teaching and curriculum development at the undergraduate and graduate level in the solid state area is expected. Qualified individuals should send resumes with professional references to: Professor Eric D. Thompson, Electrical Engineering and Applied Physics Department, Case Western Reserve University, Cleveland, Ohio 44106. An equal opportunity/affirmative action employer.

The Department of Electrical Engineering, Colorado State University, expects to fill one or more tenure track faculty positions for the Fall 1979 academic semester. Although it is expected that these positions will be filled at the assistant professor level, a higher rank is possible depending upon the qualifications of the individual. Applicants should possess an earned doctorate, experience in research, and an interest in both undergraduate and graduate teaching. Some preference will be given to the areas of semiconductor materials, solid state electronics, digital systems, and digital communications. Applicants should send an up-to-date copy of their resume, references, and copies of recent publications to Dr. D. K. Ferry, Head, Department of Electrical Engineering, Colorado State University, Fort Collins, Colo. 80523. Closing date for applications is February 1, 1979. Colorado State University is an Affirmative Action/Equal Opportunity Employer.

Chairman, Department of Electrical Engineering, University of Rochester. Applications and nominations for the chairmanship are invited. Fourteen full-time faculty offer an ECPD accredited B.S. program to about 160 undergraduate students, and M.S. and Ph.D. programs to about 30 graduate students. The faculty, emphasizes research in the general areas of biomedical engineering and bioacoustics, solid state electronics and superconductivity, computer engineering and applications, communication engineering and signal processing, and control engineering and systems theory. This research involves cooperative efforts with the nearby School of Medicine and Dentistry. The chairman is expected to have a well established research record and active research in one of the departmental areas, as well as a firm commitment to both undergraduate and graduate education. Application deadline is January 1, 1979. Send full resume or nominations, including names and addresses of references and copies of recent publications to: Chairman, EE Search Committee, College of Engineering and Applied Science, Gavett 204, University of Rochester, Rochester, New York 14627. An Equal Opportunity Employer (M/F).

Faculty Position: The School of Engineering, University of California, Irvine seeks an Assistant Professor in Computer Engineering. Duties include undergraduate and graduate teaching. Doctorate and specific research competence in computer engineering and digital systems required: Appointment will interface with Department of Information and Computer Science. Send resume to Prof. Bershad, School of Engineering, University of California, Irvine, CA 92717. Applications from all qualified candidates welcome; women and minority candidates are encouraged to apply.

Faculty Position: The School of Engineering, University of California, Irvine seeks a Professor in Solid State Electronics and Device Engineering. Duties include undergraduate and graduate teaching. Doctorate and specific research competence in the theory, design and processing technology of solid state devices, including medium and large scale integration required. Send resume to Prof. Bershad, School of Engineering, University of California, Irvine, CA 92717. Applications from all qualified candidates welcome; women and minority candidates are encouraged to apply.

Faculty Positions in Electrical Engineering. Two positions are anticipated for 1979-80. Resumes are solicited for all EE areas but particularly in electric power systems. Doctorate is required. Applicants should be interested in graduate and undergraduate teaching, and willing to work energetically to obtain research sponsorship. Send resume by February 1, 1979 to: Head, Electrical Engineering Department, VPI&SU, Blacksburg, VA, 24061. An equal opportunity affirmative-action employer.

Laboratory Supervisor in Electrical Engineering at Michigan Technological University to provide interface between faculty and support personnel. Applicants should be interested in all phases of electrical laboratory equipment maintenance and instrument calibration, have knowledge of shop procedures, be able to deal effectively with faculty and support staff, be able to handle incidental paper work, and be able to supervise support staff and student assistants. Preferred credentials are a BSEE degree with some experience; minimum credentials are an associate degree in EE technology with additional experience. Send resume to Professor W. T. Anderson, Michigan Technological University, Houghton, MI 49931. MTU is an Equal Opportunity Educational Institution/Equal Opportunity Employer.

Meetings

Distinguished speakers will keynote next month's computer software conference

COMPSAC '78—the IEEE Computer Society's Second International Computer Software and Applications Conference—will feature five keynote addresses by well-known engineers and scientists. The conference will be held at the Palmer House in Chicago, Ill., November 13-16, 1978.

Hans Mark, Undersecretary of the U.S. Air Force, will deliver the opening keynote address, setting the overall tone for the meeting. At the special Technical Keynote Session, R.W. Lucky of Bell Labs will answer the question, "Computers and Communications—Married or Just Living Together?"; AFIPS president A.S. Hoagland of IBM will discuss "Impact of Mass Memories on Software and Applications"; A.P. Ershov, U.S.S.R. Academy of Sciences, will speak on "The Golden Key of Mixed Computation"; and P.B. Hansen of the University of Southern California will address the subject of concurrent programming.

The 49-session technical program will cover a wide spectrum of topics, ranging from data-base management systems to social, legal, and regulatory issues. In addition, three day-long preconference tutorials are being offered on November 13: Software Engineering; Distributed Data-Base Management; Microcomputer Programming and Support Software.

Further information on the conference, including registration details, may be obtained from Harry Hayman, P.O. Box 639, Silver Spring, Md. 20901; telephone (301) 439-7007. The following is a list of the technical sessions, with their chairpersons

TUESDAY, NOVEMBER 14

Afternoon Sessions

Management of Computers and Computer Projects. *D. B.Simmons, Texas A&M Univ.*

ASET—A Modern Computer-Aided Software Component. *L. J. Osterweil, Boeing Computer Services*

Software Maintainability. *H. Mills, IBM Federal Systems*

Operating Systems and Languages. *J. Y. T. Leung, Northwestern Univ.*

Microprocessors: Filling the Software Gap. *G. A. Korn, Univ. of Arizona*

Management Aspects of Software Methodology. *D. Tajima, Hitachi Ltd.*

Modeling and Software Design. *T. L. Booth, Univ. of Connecticut*

Software Testing. *E. Lieblein, U.S. Army Communications R&D*

Very-High-Level Languages and Automatic Programming. *N. Prywes, Univ. of Pennsylvania*

Software and Applications for Attached Arithmetic Processors. *G. P. O'Leary, Floating Point Systems.*

Evening Sessions

Security and Privacy. *G. I. Davida, Univ. of Wisconsin, Milwaukee*

Student Papers. *H. H. So, Univ. of California, Berkeley*

WEDNESDAY, NOVEMBER 15

Morning Sessions

Software Development Approaches. *Y. Nakamura, Fujitsu, Ltd.*

Distributed Data Processing—A Tutorial with Applications. *E. D. Jensen, Honeywell*

Topics on Distributed and Relational Data-Base Design. *R. S. Kaplan, Bell Labs*

Process Computer Software—Languages and Maintenance. *A. B. Long, Electric Power Research, Inc.*

Software Testing and Analysis. *W. E. Howden, Univ. of Victoria, Canada*

The Software Development System—Experience and Evolution. *C. G. Davis, U.S. Army BMD-ATC*

A Distributed Data-Processing Development Technology. *J. E. Scalf, U.S. Army BMD-ATC*

Data-Base Design. *R. T. Yeh, Univ. of Texas, Austin*

Organization of ADP Software Development. *K. Riddle, U.S. Civil Service Comm.*

Current Software Tools. *G. Ligler, Texas Instruments*

Afternoon Sessions

Modeling Aspects of Software Development. *R. C.T. Lee, National Tsing Hua Univ., Taiwan*

Contribution of Modular Computer Systems to Software Engineering. *B. Zolotar, EPRI*

Query Languages and Retrieval Techniques. *P. Scheuermann, Northwestern Univ.*

Software Management in the ICAM Environment. *B. Luong-Hong, NBS*

Software Tools: Integration with Methodology. *T. Rauscher, GTE Sylvania*

Software Development. *N. F. Schneidewind, U.S. Naval Postgraduate School*

Distributed System Software. *L. Belttrachi, U.S. Nuclear Regulatory Comm.*

Data Dictionaries. *Y. M. Babad, Arthur Anderson & Co.*

Major Issues of Software Engineering Project Management. *R. H. Thayer, U.S. Air Force*

Software Testing Tools. *R. R. Bate, Texas Instruments*

Evening Sessions

Software Testing: Status and Prognosis. *R. R. Bate, Texas Instruments*

Software Standards. *H. Hecht, SoHaR*

THURSDAY, NOVEMBER 16

Morning Sessions

Software Reliability and Safety. *M. Marks, USAF Data Systems Design Center*

Distributed Systems. *T. Agerwala, Univ. of Texas, Austin*

Hardware/Software Tradeoffs: Different Perspectives. *W. Toy, Bell Labs*

Trends for the '80s in Computer Science and Engineering Education. *R. Fairley, Colorado State Univ.*

Software Applications I. *R. T. Chien, Univ. of Illinois, Urbana*

Fault-Tolerant Software., *S. S. Yau, Northwestern Univ.*

Communication Processes. *J. Scanlon, Bell Labs*

The Impact of Hardware Architecture on Future Data Base Management and Information Retrieval Systems. *P. B. Berra, Syracuse Univ.*

Trends for the '80s in Applications and Societal Education. *A. Dekock, Univ. of Missouri, Rolla*

Software Applications II. *H. Trauboth, Nuclear Research Center and Univ. of Karlsruhe, Germany*

Afternoon Sessions

Software Engineering Experience. *R. Williams, TRW*

Software Techniques for Reconfigurable and Dynamic Architecture. *Steven and Svetlana Kartashev, Univ. of Nebraska, Lincoln*

The Relationship and Future of Data-Base Systems and Information Systems. *P. Chen, M.I.T.,*

The Impact of Changing Technology on Computer Education. *E. C. Jones, Jr., Iowa State Univ.*

Software Applications III. *P. Enslow, Georgia Tech*

Display research is topic this month

On October 24-26, the 1978 Biennial Display Research Conference will be held at the Cherry Hill Inn in Cherry Hill, N.J. The meeting is sponsored by IEEE, the Society for Information Display, and the Advisory Group on Electron Devices.

The meeting will feature five half-day sessions: Liquid-Crystal Displays; Luminescent Displays; Passive Displays; Matrix-Addressed Liquid-Crystal Displays; and Plasma Displays. In his keynote address, Alan C. Kay of the Xerox Palo Alto Research Center will discuss "Displays in the Personal Computer."

Registration fees at the conference are $40 for members and $45 for nonmembers. The conference secretary is Thomas Henlon, Palisades Institute, 201 Varick Street, New York, N.Y. 10014.

Symposium focuses on computers in medicine

The Sheraton Inn in Washington, D.C., will host the Second Annual Symposium on Computer Applications in Medical Care (CompSoc, S-EMB, Northern Virginia Sect., *et al.*) on November 5-9. The purpose of the meeting is to bring physicians, computer scientists, biomedical and clinical engineers, and other health-care professionals up to date on the latest advancements in the expanding field of medical computing applications.

C.A. Caceres, editor of *Clinical Engineering,* will present the keynote address on "The Need for Automation in Health and Medical Care." Two tutorials are also scheduled: "Introduction to and Review of Recent Developments of Computer Technology," and "Software Concepts for Biomedical Computing."

The technical program will present the following sessions: Medical Imaging; Computers in Nuclear Medicine; Computers in Radiation Theory; Computers in Psychiatry and Clinical Psychology; Computers in Mental Health Care; Computer-Patient Dialogue; Computerized Use of Medical Knowledge. Also: Medical Data Bases; Language Processing Representation; Representation of Medical Knowledge; Computer-Directed

Book reviews

Technology and Social Shock. *Lawless, E. W.*—Rutgers University Press, New Brunswick, N.J., 1977, 606 pp., $6.95.

Edward Lawless and the National Science Foundation are to be congratulated on this pioneering effort—a readable and highly instructive summarization of 45 episodes of public alarm over technology, social shock waves created by unanticipated effects of developments ranging from the building of the Welland Canal to the introduction of a new sleeping pill and more effective detergents.

The first two-thirds of the book presents 45 case histories, each including an abstract, background, key events and roles, disposition, interpretation or comment, and list of references. An "event train" or chronology diagram is also included. Some of the cases are well known—e.g., thalidomide, the Salk polio vaccine, the Santa Barbara oil leak—but many, though less recognized, are equally fascinating. For example, from 1939 to 1949 sea lampreys invaded the upper Great Lakes via the Canadian Welland Canal System and extensively destroyed commercial fishing. The origin of the problem dates back to 1829 when the completion of the canal provided a waterway for both ships and lampreys between Lake Ontario and Lake Erie, but it was a century later that the predatory lampreys moved into Lake Huron. By 1949 the trout catch in that lake had declined from 1.7 million pounds to 1000 pounds and by 1951 the income loss to commercial fishermen alone amounted to $3.5 million. However, the story has a happy ending. After testing nearly 6000 chemicals, Dr. Applegate discovered TFM, which kills infant lampreys without harming fish. Since 1966, TFM and restocking of trout and salmon have achieved a tremendous transformation of the economy, growth, and hopes of every community in the area surrounding the Great Lakes.

Other exotic examples are the case of the bronze horse (470 B.C.), synthetic turf and football injuries, and MSG (monosodium glutamate) and the Chinese restaurant syndrome.

Of equal value is the last third of the book, an integrated analysis of the 45 cases. The following aspects are discussed: technological origins, threat development, factors influencing impact, available technological information, governmental units involved, private-sector parties involved, impacts and dispositions of cases, the role of technology assessment, and reflections on the impacts of technology on societal institutions. We find some provocative comments:

- In 40 percent of the cases, an early warning signal that could have reduced public alarm was missed (e.g., oral contraceptive safety).
- In over half of the cases, the technology had been employed, in part, with less than adequate responsibility by its users (e.g., unapproved herbicide in cranberries).
- In at least half the cases, a previous alarm had been raised over a related technology.
- In nearly half the cases, a conflict of interest existed in or between government agencies.
- Media coverage leads to public awareness; headline-size names, bizarre effects, and consumer products provide the best media focus.
- In none of the cases did initial public concern or media coverage lead to removal of the threat. Government agencies always became involved.

For technology assessment (TA), the following insights are significant:

- A good TA could probably have foreseen the future threat in 40 percent of the cases (e.g., nerve-gas disposal). It would have been of little help in 15 percent (e.g., X rays from color TV). In the remaining 40 percent, a TA might have identified a future problem correctly if the group doing the TA had asked just the right question—a remote likelihood (e.g., the corn leaf blight). In cases where a TA would have been effective, it could have been done many years in advance—in the case of artificial insemination, a century.
- Even if a threat from a technology has already been identified, a TA would still be useful in reducing the shock in over 60 percent of the cases. But timing is critical and speed may be vital (unlike the setting for the TA done to avoid a threat).

The book also contains many useful tables comparing the 45 cases, a summary of the TA process, and a discussion of causes of public concern.

All in all, this book is admirable—unencumbered by academic jargon and valuable for TA practitioners, policy analysts, bureaucrats, and public-interest groups. And its cost is reasonable.

Harold A. Linstone
Portland State University
Portland, Oreg.

Europe's Giant Accelerator (The Story of the CERN 400-GeV Proton Synchrotron). *Goldsmith, M., and Shaw, E.*—Crane, Russak & Company, Inc., New York, 1977, 261 pp., illus., $27.50.

The CERN (Conseil Europeenne pour la Recherche Nucleaire) organization, located outside Geneva in a village called Meyrin, is an outstanding example of cooperation among many countries in a scientific endeavor. Recently, a very large high-energy proton accelerator—the Super Proton Synchrotron, or SPS—came into operation there. This book is the story of how the task was accomplished.

The book is written for the moderately well-informed layman and is profusely illustrated. After a brief description of the development of science leading to the necessity for designing and building

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Short Papers

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IEEE Transactions on Power Apparatus and Systems

Vol. PAS-97, no. 5, Sept/Oct 1978
JH4402-4 M—$7.50; NM—$15.00

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Audience Requirements for Technical Speakers, *R. E. Perry;* **Techniques and Suggestions for Presenters,** *G. M. Abshire, K. L. White;* **The Writer's Role in CCTV Production,** *S. Fader, R. Whittaker;* **Preparing Poster Talks,** *A. J. MacGregor;* **Selecting the Appropriate Chart,** *A. J. MacGregor;* **Designing Slides,** *J. Reich;* **Experiments in Computer-Aided Graphic Expression,** *J. F. Musgrave;* **Perspective on Multimedia,** *C. Harkins, E. Schlesinger*

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Correspondence

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Foreword, *J. D. Heightley*

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A 920-Gate DSA MOS Masterslice, *O. Tomisawa et al.;* **Dynamic Depletion Mode: An E/D MOSFET Circuit Method for Improved Performance,** *R. W. Knepper;* **Injection-Coupled Synchronous Logic,** *N. Friedman et al.;* **Molybdenum Gate MOS Applied to an AM/FM Digital Frequency Synthesizer,** *T. Ohgishi et al.;* **A MOS LSI Capacitive Keyboard Interface Chip,** *G. Katz et al.;* **High-Speed NMOS Circuits for ROM-Accumulator and Multiplier-Type Digital Filters,** *H. J. De Man et al.;* **Submicron Channel MOSFET's Logic Under Punchthrough,** *T. Nakamura et al.;* **Sub-100-ps Experimental Josephson Interferometer Logic Gates,** *M. Klein, D. J. Herrell;* **A Josephson Latch,** *A. Davidson;* **An Experimental 64-Bit Decoded Josephson NDRO Random Access Memory,** *W. H. Henkels, H. H. Zappe;* **A 64k by 1-Bit Dynamic ED–MOS RAM,** *T. Wada et al.;* **A 150-ns, 150-mW, 64k Dynamic MOS RAM,** *T. Wada et al.;* **A High-Speed Molybdenum Gate MOS RAM,** *M. Kano et al.;* **VMOS Technology Applied to Dynamic RAMs,** *K. Hoffman, R. Losehand;* **High-Speed and High-Density Static Induction Transistor Memory,** *J. -I. Nishizawa et al.;* **A 15-ns 1024-Bit Fully Static MOS RAM,** *T. Wada et al.;* **A 50-ns 4k Static DSA MOS RAM,** *K. Shimotori et al.;* **DSA 4k Static RAM,** *Y. Torimaru et al.;* **A High-Speed Low-Power 4096 by 1-Bit Bipolar RAM,** *A. Hotta et al.;* **A Fast 7.5-ns Access 1k-Bit RAM for Cache-Memory Systems,** *K. Kawarada et al.;* **A CMOS/SOS 4k Static RAM,** *R. Hollingsworth et al.;* **CMOS/SOS Memory Circuits for Radiation Environments,** *T. P. Haraszti;* **A 4k CMOS Erasable PROM,** *Y. -F. Chan;* **A Block-Organized 64-kbit CCD Memory,** *R. C. Varshney, K. Venkataswaran;* **A New Multilevel Storage Structure for High-Density CCD Memory,** *M. Yamada et al.;* **PSA—A New Approach for Bipolar LSI,** *K. Okada et al.;* **Multiple Word/Bit Line Redundancy for Semiconductor Memories,** *S. E. Schuster;* **A Charge-Oriented Model for MOS Transistor Capacitances,** *D. E. Ward, R. W. Dutton*

Special Correspondence

An 8-mm^2, 5-volt 16k Dynamic RAM Using a New Memory Cell, *G. Meusburger et al.;* **A 1k by 8-Bit 5-volt Only Static RAM,** *G. S. Leach et al.*

Regular Papers

An Automatic Layout System for Masterslice LSI: MARC, *K. Ueda et al.*

Regular Correspondence

Transistor Noise Model for Photodetector Amplifiers, *T. Witkowicz;* **Approximation of Junction Field-Effect Transistor Characteristics by a Hyperbolic Function,** *T. Taki;* **Propagation Delay Time and Delay–Power Product of a Small-Sized DSA–ED Gate Circuit,** *Y. Hayashi;* **Quantum Efficiency and Blooming Suppression in Junction Charge-Coupled Devices,** *C. D. Hartgring, M. Kleefstra*

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Vol. SMC-8, no. 10, October 1978
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ACS.1: An Experimental Command Support System, *M. C. Pease;* **Automatic Segmentation and Classification of Infrared Meteorological Satellite Data,** *A. Rosenfeld, J. A. Parikh;*

Correspondence

Notes on Conceputal Sciences, *J. N. Warfield;* **Overlapping Coordination of Hierarchical Structures,** *Y. Y. Haimes, D. Macko;* **Stabilization of Linear, Time-Invariant Interconnected Systems Using Local State Feedback,** *O. Huseyin, E. Sezer;* **A Generalized Fuzzy Set Theory,** *M. S. Watanabe;* **An Interactive Procedure for Subset Selection with Ordinal Preferences,** *R. K. Sarin;* **Curve Formation Using Transforms for Pictures Governed by Differential Equations,** *S. D. Shapiro;* **Relaxation Processes for Scene Labeling,** *A. Rosenfeld, R. A. Hummel;* **Linear Feature Mapping,** *A. Rosenfeld, G. J. VanderBrug;* **A Quantitative Measure of the Effects of Aliasing on Raster Scanned Imagery,** *L. J. Pinson*

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Letters

Comments on "On Minimal Realization of Transfer Function Matrices Using Markov Parameters and Time Moments," *J. Hickin et al.;* **Formulation of Multiport Equation Via Block Matrix Elimination,** *I. N. Hajj;* **An Alternate Method for Construction of a Network Function from Its Given Odd Part,** *S. K. Mitra;* **A True Integrable Noninverting Integrator with Adaptive Gain Constant,** *S. K. Seth et al.;* **Comments on "Active RC Realization of RL Impedance,"** *S. C. Dutta Roy et al.;* **Integrable Circuit Principle for Synthesizing Voltage-Controlled Nonlinear Impedances,** *S. Pookayaudom, C. Surawatpanya;* **An Adaptive Approach for Designing Phase Compensation Filters,** *R. David et al.;* **Flat Magnitude Low-Pass Filters with Multiple Pairs of Imaginary-Axis Zeros,** *P. Thajchayapong;* **Identification of the Parameters of a Multicomponent Signal Class,** *S. Scavarda;* **Transresistance Instrumentation Amplifier,** *D. C. Agouridis, R. J. Fox;* **Correction to "Active Optics: A New Technology for the Control of Light,"** *J. W. Hardy;* **Imaging a Two-Dimensional Target by Means of Hologram Matrix—An Ultrasound Experiment,** *J. -I. Nakayama et al.;* **Multifrequency Hologram Matrix and Its Application to Two-Dimensional Imaging,** *J. -I. Nakayama et al.;* **Correction to "The Cepstrum: A Guide to Processing,"** *D. G. Childers et al.;* **Further Comments on Windowing in the Power Ceptrum,** *J. C. Hassab, R. E. Boucher;* **An Inherent Tradeoff in Noncoherent Detection,** *R. J. Gutmann, K. Rose;* **Load Frequency Control Using a Governor and Voltage Controls via a New Approach,** *G. Shirai;* **An Analytical Expression for the Specific Output of Wind Turbine Generators,** *J. Asmussen et al.*

IEEE Transactions on Automatic Control

Vol. AC-23, no. 4, August 1978
JH4227-5 M—$5.00; NM—$10.00

Control of Titanium Dioxide Kilns, *G. A. Dumont, P. R. Belanger;* **Self-Tuning Control of a Titanium Dioxide Kiln,** *G. A. Dumont, P. R. Belanger;* **A Microprocessor System for Multifunctional Control of Upper-Limb Prostheses Via Myoelectric Signal Identification** *D. Graupe et al.;* **Theory and Error Analysis of Vibrating-Member Gyroscope,** *B. Friedland, M. F. Hutton;* **Adaptive Control of Single-Input, Single-Output Linear Systems,** *A. Feuer, A. S. Morse;* **Stable Adaptive Controller Design—Direct Control,** *K. S. Narendra, L. S. Valavani;* **Stationary Linear and Nonlinear System Identification and Predictor Set Completeness,** *P. E. Caines;* **Canonical Forms for Bilinear Input/Output Maps,** *J. G. Pearlman;* **Estimating the Domain of Attraction of Nonlinear Feedback Systems,** *K. A. Loparo, G. L. Blankenship;* **Bounded Peaking in the Optimal Linear Regulator with Cheap Control,** *B. A. Francis, K. Glover*

Survey Paper

Tracking Methods in a Multitarget Environment, *Y. Bar-Shalom*

Short Papers

Decomposition of Dynamic Team Decision Problems, *T. Yoshikawa;* **Closed-Loop Stackelberg Strategies in Linear-Quadratic Problems,** *J. Medanic;* **A Sampled Data Equilibrium Stackelberg Coordination Scheme for the Multicontroller Problem,** *P. M. Walsh, J. B. Cruz, Jr.;* **A Preference-Ordered Discrete-Gaming Approach to Air-Combat Analysis,** *H. J. Kelley, L. Lefton;* **Profit Maximization Through Advertising: A Nonzero Sum Differential Game Approach,** *G. Leitmann, W. E. Schmitendorf;* **An Equal-Ripple Pulse Frequency Modulator in Control Systems,** *G. R. Truscott, S. Onyshko;* **Extended Levinson and Chandrasekhar Equations for General Discrete-Time Linear Estimation Problems,** *B. Friedlander et al.;* **Sufficient Conditions for Function Space Controllability and Feedback Stabilizability of Linear Retarded Systems,** *A. Manitius, R. Triggiani;* **Optimal Sensor Location Problem for a Linear Distributed Parameter System,** *S. Omatu et al.;* **Feedback Control of Flexible Systems,** *M. Balas;* **Spectral Estimation of Continuous-Time Processes: Performance Comparison Between Periodic and Poisson Sampling Schemes,** *E. Masry et al.;* **Measurable Selection Theorems and Their Application to Problems of Guaranteed Performance,** *B. R. Barmish;* **Controllability, Observability, and Duality in a Distributed Parameter System with Continuous and Point Spectrum,** *G. E. McGlothin;* **Optimal Location of Measurements for Distributed Parameter Estimations,** *S. Kumar, J. H. Seinfeld;* **ARMA System Identification via the Cholesky Least Squares Method,** *T. W. Brotherton, P. E. Caines;* **Evaluation of Process Control Effectiveness and Diagnosis of Variation in Paper Basis Weight via Multivariate Time-Series Analysis,** *W. R. DeVries, S. M. Wu;* **Bilinear System Identification by Walsh Functions,** *V. R. Karanam et al.;* **Dynamic Decoupling of a Remote Manipulator System,** *J. S. -C. Yuan;* **Robustness and Computational Aspects of Nonlinear Stochastic Estimators and Regulators,** *M. G. Safanov, M. Athans*

Technical Notes and Correspondence

A Discrete-Time Identification Algorithm with an Improved Convergence, *R. Subbayyan, R. Nagarajan;* **Model Reduction Using the Routh Stability Criterion,** *V. Krishnamurthy, V. Seshadri;* **Order Reduction by l_1- and l_{∞}-Norm Minimization,** *R. A. El-Attar, M. Vidyasagar;* **A Simple Proof of the Separation Theorem for Linear Stochastic Systems with Time Delays,** *R. E. Schmotzer, G. L. Blankenship;* **Notes on Separate-Bias Estimation,** *B. Friedland;* **An Algorithm for the Calculation of Transmission Zeros of the System (C, A, B, D) Using High-Gain Output Feedback,** *E. J. Davison, S. H. Wang;* **On Transmission Zeros and Dynamic Output Feedback,** *R. V. Patel;* **A Basis for the Controllable Canonical Form of Linear Time-Invariant Multiinput Systems,** *W. S. Chan, Y. T. Wang;* **Cyclicity and Controllability in Linear Time-Invariant Systems,** *P. J. Antsaklis;* **Some Properties of the Value Matrix in Infinite-Time Linear-Quadratic Differential Games,** *M. Pachter;* **Matrix Calculus and the Sensitivity Analysis of Linear Dynamic Systems,** *J. W. Brewer;* **Calculation of Derivatives of Characteristic Polynomials,** *S. P. Bingulac;* **Optimal-Proximity Controls,** *R. D. Barnard;* **Transfer-Function Synthesis Using PID Controllers,** *M. R. Javdan;* **Guaranteed Margins for LQG Regulators,** *J. C. Doyle;* **A Note on the Characteristic Frequency Loci of Multivariable Linear Optimal Regulators,** *I. Postlethwaite;* **On the Calculation of Optimum Feedback Gains for Output-Constrained Regulators,** *DJ. B. Petkovski, M. Rakic;* **Further Comments on "Design of Piecewise Constant Gains for Optimal Control via Walsh Functions,"** *O. N. Dalton;* **Remarks on "Author's Reply" to "Comments on 'Design of Piecewise Constant Gains for Optimal Control Via Walsh Functions,' "** *G. P. Rao, T. Srinivasan;* **Comments on "Minimal Dimension Realization and Identifiability of Input-Output Sequences,"** *V. L. Shrikhande et al.;* **Author's Reply,** *R. Liu, L. C. Suen*

IEEE Transactions on Biomedical Engineering

Vol. BME-25, no. 5, September 1978
JH4250-7 M—$5.00; NM—$10.00

The Contributions of Intracerebral Currents to the EEG and Evoked Potentials, *R. S. Hosek et al.;* **An Optimality Criterion for Processing Electromyographic (EMG) Signals Relating to Human Locomotion,** *C. Hershler, M. Milner;* **Evaluation of Methods for Three-Dimensional Localization of Electrical Sources in the Human Brain,** *R. N. Kavanagh et al.;* **Computer-Aided Analysis of Cell-Cycle Phase from Cytophotometric Histogram,** *Y. Kosugi et al.;* **A Vaginal Photoplethysmographic Transducer,** *H. Armon et al.;* **Development of Modular Laboratory Equipment for Instruction in Biomedical Instrumentation,** *D. W. Arnett;* **An Analysis of Transfer Coefficients Calculated Directly from Epicardial and Body Surface Potential Measurements in the Intact Dog,** *L. T. Hersh et al.;* **A Method for Clinical Data Reduction Based on "Weighted Entropy,"** *M. Okada;* **Influence of a Constant Magnetic Field on Nervous Tissues: I. Nerve Conduction Velocity Studies,** *J. Schwartz*

Communications

Effect of Plexiglas Animal Holders on Microwave Energy Absorption, *H. S. Ho;* **Dipole Crosstalk in an Inverse Cardiac Generator,** *R. E. Ideker et al.;* **Laminated Electrodes for Biopotential Studies,** *D. E. Brodnick et al.;* **Automated On-Line Determination of Membrane Responsiveness Curves,** *R. G. Zoble et al.;* **A New Simple Mechanostimulator with Special Reference to Its Physiological Applications,** *M. Sakaguchi et al.*

IEEE Transactions on Communications

Vol. COM-26, no. 10, October 1978
JH4301-8 M—$5.00; NM—$10.00

Rehoming Strategies from an Existing Electromechanical to a Relief Electronic Switching System, *F. T. Man;* **Cochannel Interference of Spread Spectrum Systems in a Multiple User Environment,** *S. A. Musa, W. Wasylkiwskyj;* **Digital Standards Converter by Adaptive Intraframe Line Interpolation,** *K. Kinuhata et al.;* **Surge Propagation Characteristics on Submarine Repeater Line,** *K. Takemoto*

Concise Papers

A 105-mbit/s Error-Correcting Codec, *J. E. Medlin, N. J. Bryg;* **32-Mbit/s Transmission of NTSC Color TV Signals by Composite DPCM Coding,** *K. Sawada, H. Kotera;* **Application of Fast Kalman Estimation to Adaptive Equalization,** *D. D. Falconer, L. Ljung;* **On Optimum Receivers for Analog Communication in Impulsive Noise,** *B. B. Madan et al.;* **Orthogonal Transform Coding System for NTSC Color Television Signals,** *T. Ohira et al.;* **Analog Viterbi Decoding for High-Speed Digital Satellite Channels,** *A. S. Acampora, R. P. Gilmore*

Correspondence

Broadband Coaxial Boosted Media Employing Negative-Impedance Junctions of Amplifiers, *T. Fukunaga et al.;* **Statistics of the First-Order Phase-Locked Loop with Fluctuating Signal Amplitude,** *J. E. Ohlson;* **Experimental and Theoretical Assessment of Multipath Effects on QPSK,** *R. H. Ott et.al.;* **Comments on "On Binary DPSK Detection,"** *M. K. Simon;* **A Note on Measures of Voice Transmission Performance Used by the CCIR,** *H. Akima*

IEEE Transactions on Communications (Part I)

Vol. COM-26, No. 11, November 1978
JH4302-6 M—$5.00; NM—$10.00

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Guest Editorial, *B. H. Batson;* **The Space Shuttle Program Description and Status;** *J. B. MacLeod;* **An Overview of the Space Shuttle Orbiter Communication and Tracking System,** *L. M. Carrier, W. S. Pope;* **STDN in the TDRSS and Shuttle Era,** *J. J. Schwartz, E. J. Feinberg;* **Use of Radio Equipment for Space Shuttle Navigation,** *E. R. Schlesser;* **Orbiter S-Band Communications Subsystem,** *R. Bacinski, R. Helgeson;* **Phase Noise Effects on Space Shuttle,** *W. C. Lindsey, K. Tu;* **The Effects of Residual Carrier on Costas Loop Performance as Applied to the Space Shuttle Orbiter S-Band Uplink,** *M. K. Simon;* **Delay-Lock-Loop Mean Time to Lose Lock,** *J. K. Holmes, L. Biederman;* **Space Shuttle Payloads and Data-Handling Accommodations,** *W. E. Teasdale,* **Spacelab—Its Command and Data Management Role in the Space Transportation System,** *G. R. Bolton et al.;* **Communication with Shuttle Payloads,** *J. C. Springett, S. Udalov;* **Microprocessor Bit Synchronizer for Shuttle Payload Communications,** *S. W. Houston et al.;* **Orbiter Ku-Band Integrated Radar and Communications Subsystem,** *R. H. Cager et al.;* **Performance Analysis of Pulse Doppler Digital Radars with Applications to the Shuttle Ku-Band System,** *W. K. Alem, C. L. Weber;* **A 50-Mbit/s Multiplexed Coding System for Shuttle Communications,** *J. E. Dunn;* **Effects of Data Asymmetry on Shuttle Ku-Band Communications Links,** *M. K. Simon et*

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Jacob Rabinow (F), who prefers to be called "inventor" (he holds 211 patents), was chief engineer at the National Engineering Laboratory of the National Bureau of Standards until his retirement from full-time Government service in 1975. Now, as a reemployed annuitant at NBS, his main duty is the evaluation of energy-related inventions. He has received many honors during his career with the Government and as head of his own company—the latest was IEEE's Harry Diamond Award in 1977.

Samuel J. Raff (SM) has been associated with Weinschel Engineering, Gaithersburg, Md., for more than 20 years in various capacities, including consultant and director. Dr. Raff previously had worked for the National Science Foundation, was president of Raff Associates for ten years, and has taught at the University of Maryland, M.I.T., and George Washington University.

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Edgar Weinberg has joined the U.S. Department of Labor, following the recent dissolution of the National Center for Productivity and Quality of Working Life, where he was assistant director and head of its Human Resources and Economic Research Program while writing his present *Spectrum* article. At the Labor Department, he will be responsible for special assignments on labor-management cooperation to improve productivity.

Bruno O. Weinschel (F), IEEE's Vice President for Professional Activities, has been president of the Weinschel Engineering Company, Inc., Gaithersburg, Md., since 1952. His earlier career included posts with the Industrial Instruments Company, Western Electric, and the National Bureau of Standards. He received the Dr. Eng. degree from the Technische Hochschule in Munich, Germany, in 1966.

Arthur F. Wulfsberg (F) recently completed two years as assistant professor of engineering, University of Wisconsin-Extension, studying and teaching in the areas of product innovation and project management. He is now a consultant to McDonnell Douglas Corporation, St. Louis, Mo. During his industrial career with ITT Aerospace and Collins Radio Company, he was responsible for the development of a variety of commercial, military, and space communication and navigation equipment and systems and meteorological satellite instruments.

PRODUCTIVITY For further reading

Obviously, productivity has come a long way from the village cobbler painstakingly handcrafting a pair of shoes "from the finest Spanish leather" for the lady of the manor. And although to some, the Chaplinesque production line represented on our front cover may have Orwellian implications of a dehumanized, mechanized life style, that same production line has meant that the many now can choose from a variety of goods that once were reserved to the elite few.

In this issue, *Spectrum*'s staff, and outside experts in the field, discuss many facets of this complex subject, particularly as they affect life in the U.S. today. Here are some suggested readings for further, independent explorations in the field of productivity.

The name of the game

- Berndt, E. R., "Aggregate energy, efficiency, and productivity measurement," *Annual Review of Energy*, pp. 225-273, May 1978.

Surveys alternative measures of full efficiency and economic notions of productivity.

- Berndt, E. R., and Jorgenson, D. W., "Production structure," in Jorgenson, D. W., *et al.*, *U.S. Energy Resources and Economic Growth,* final report to Ford Foundation Energy Policy Project, Washington, D.C., Oct. 1973.

Discusses energy–capital complementarity and energy–labor substitutability.

- Berndt, E. R., and Wood, D. D., "Engineering and econometric approaches to industrial energy conservation and capital formation," *American Economic Review,* 1978.

Reconciles engineering notions of energy–capital substitutability with the economic notion of energy–capital complementarity.

- Boulding, Kenneth, E., *The Economics of Love and Fear: A Preface to Grants Economics.* Belmont, Calif.: Wadsworth Publishing Company, 1973.

Describes human transactions as they have evolved from threats and simple exchanges to a system of wider social responsibility.

- Boulding, Kenneth E., *Beyond Economics.* Ann Arbor, Mich.: University of Michigan Press, 1967.

Wide-ranging essays on knowledge, information, evolution, organizations ...and the limits of "cowboy economics."

- Forrester, Jay W., *The Collected Papers of Jay W. Forrester.* Cambridge, Mass.: M.I.T. Press, 1975.

Analyzes industrial and urban systems and discusses control of urban growth, etc.

- Forrester, Jay W., *World Dynamics.* Cambridge, Mass.: M.I.T. Press, 1971.

Covers effects on economic growth of population, capital investment, resources, agriculture, and pollution.

- Gyftopoulos, E. P., *et al.*, *Potential Fuel Effectiveness in Industry.* Cambridge, Mass.: Bullinger Publishing Company, 1974.

Discusses numerous technological examples of energy–capital substitutability.

- Henderson, Hazel, *Creating Alternative Futures: The End of Economics.* New York: G. P. Putnam, 1978.

Essays on the socioeconomic transformation now occurring in mature industrial societies. Expanded models are proposed for measuring sustained-yield productivity based on renewable economics.

- Hudson, E. A., and Jorgenson, D. W., "Energy policy and U.S. economic growth," *American Economic Review,* vol. 68, pp. 118-123, May 1978.

Summarizes effects of higher energy prices on economic growth and productivity.

- Jorgenson, D. W., "The role of energy in the U.S. economy," discussion paper no. 622, Harvard Institute of Economic Research, May 1978.

Expanded discussion of the role of energy in the U.S. economy.

- Kapp, K. William, *The Social Costs of Private Enterprise.* Cambridge, England: Cambridge University Press, 1955.
- Mishan, E. J., *Costs of Economic Growth.* London: Penguin, 1967.
- Polany, Karl, *The Great Transformation.* Boston: Beacon Press, 1944.

These three books argue that a society that tries to maximize material production does so only at the cost of suboptimizing its social and ecological systems.

- Schipper, Lee, and Darmstader, Joel, "The logic of energy conservation," *Technology Review,* pp. 41–50, Jan. 1978.

When energy is short, conservation becomes the primary concern. But, as this article points out, energy is still only the tail of the economic dog—one of a number of resources that must be used wisely.

- "Productivity Centers Around the World," The National Center on Productivity and Work Quality, Washington, D.C., May 1975.

Describes the current objectives, functions, and operations of major productivity centers in Europe, Australia, Israel, Japan, New Zealand, and South Africa, and suggests some reasons for their growth and influence.

- "Papers and Proceedings of a Colloquium on Research and Development and Economic Growth/Productivity," National Science Foundation, Dec. 1971.

Four papers by leading researchers discuss the relationship between R&D and economic growth/productivity, the contributions of R&D to economic growth in the U.S., the progress-generating sector's claim to high priority, and the evidence for a positive return from R&D.

Also of note:

- Forrester, Jay W., "Changing economic patterns," *Technology Review,* Aug. -Sept. 1978.
- Morris, Morris D., *Measuring the Condition of the World's Poor: The Physical Quality of Life Index.* New York: Pergamon.

On electrotechnology

- "Load and Use Characteristics of Electric Heat Pumps in Single-Family Residences," Electric Power Research Institute, Palo Alto, Calif., vols. 1 and 2, June 1978.

Report of joint EPRI/Association of Edison Illuminating Companies project initiated to obtain information on residential heat-pump heating-systems operation based on field tests of 120 installations in 12 different geographic locations.

- Residential Demand for Electricity by Time of Day: An Econometric Approach," Electric Power Research Institute, Palo Alto, Calif., May 1978.

Data from time-of-day metering survey of residential electricity use and an FEA-sponsored peak-load pricing field test conducted on randomly selected customers of the Connecticut Light and Power Company.

- "Survey of Utility Load Management and Energy Conservation Projects. Part 2. Final Report," Energy Utilization Systems, Inc.

Account of the most innovative energy conservation programs being instituted or planned by the electric utility industry. Presents summaries of 44 projects, including objectives, descriptions, create technological opportunities, it does not automatically lead to their employment. Unutilized technological developments contribute nothing to productivity improvement. Unfortunately, many Government-sponsored inventions go unused, partly because market factors are often ignored by the developers. A notable exception is found in the U.S. Department of Agriculture. Because its research groups carefully consider market factors, the success rate of their projects has been quite high.

The influence of public policy is frequently ignored because major technological innovation and the attendant productivity improvement always look quite simple in retrospect. In fact, that is precisely the hallmark of a successful innovation.

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(The preceding material is part of a report prepared for the U.S. National Center for Productivity and Quality of Working Life.)

NSF's three-phase program helps the small-business innovator bootstrap an idea to commercial success

A new National Science Foundation (NSF) program, introduced in part as a result of interest on the part of the U.S. Congress, has among its objectives greater utilization of small science and technology firms in U.S. Government R&D, and conversion of that research to technological innovation in the private sector. Called "Small Business Innovation Applied to National Needs," the new program solicits high-risk, potentially high-payoff, proposals from small business relating to the research objectives of the Applied Science and Research Applications (ASRA) Directorate.

The NSF program is a three-phase approach; the first two phases are funded by NSF and the third is targeted for private industry. Phase I solicits small feasibility research proposals from small business to determine, insofar as possible, the practicability of the idea and the capabilities of the firm within the limits of $25 000 six-month awards. Phase II is for the principal research effort at levels of two to three professional person-years for one to two years. This phase also requests a commitment for venture capital, from a third party, that is at least equivalent to the amount of research funds requested from NSF. This capital is for a follow-on development effort (phase III) to pursue commercial objectives that will justify continuing investment. U.S. Federal funds are for research on Federal objectives. Private-venture capital is used to fund further development directed toward commercialization. Obtaining the venture-capital commitment from a third party is a key to the approach.

In phases I and II, proposals are judged principally on a scientific-merit basis; then a critical additional consideration is applied. If proposals are found to be of approximately equal technical merit, the venture-capital commitment affords an extra point of merit in the evaluation and award process. In other words, proposals that appear to have commercial potential in addition to meeting Federal objectives receive extra consideration.

The proposing firm can select any firm or institution to provide venture capital. The venture-capital firm, or manufacturer, may also initiate the contact as it seeks potential investment opportunities or sources of new technology. If the R&D is successful and the small firm wishes to continue into production and marketing, it may want to work with venture-capital firms. On the other hand, if the innovation has a potentially larger market where production and marketing capabilities are important, the small firm might increase its chances of success by working with a major manufacturer already in the field.

The use of the small firm for its innovation capability and the large firm for production, marketing, and financial support has a number of advantages. Small science and technology firms, particularly those competent enough to win in the strong technical competition, may be an excellent "farm system" for technological innovation for large business, as well as the base for a growing independent company.

The financial-opportunity incentives to the small firm are considerable. Not only does the program offer a chance to participate in Federal research, but it also opens a door to front-end high-risk capital and a path to continued support all the way to commercialization, if the performance is there and the idea has market potential. Government research in both phase I and phase II can be substantial and can serve as preventure capital. This research can lower the risk for private capital, which, in turn, can provide continuing financing to the small firm.

The program may be one of the fastest and most capital-efficient ways of bringing new technological ideas to commercial attention and to the market. Highly competent small firms are often highly innovative but lack the resources and time to pursue both ideas and capital. They need the assistance of others.

An equal opportunity is open to the small firm that wants to work alone and take its own ideas on into production and the marketplace. Here the coupling is to the venture-capital firm or small-business investment company.

A third option exists for those ideas that show promise but are not far enough along in the research stage to attract venture-capital commitments. For example, the Connecticut Product Development Corporation and the proposed Massachusetts Technology Development Corporation both have indicated an interest in the program. They would contact award winners in their states who were unable to obtain private commitments to determine if state funds should provide support for further development. And they might assist the small firms in obtaining private capital after some development effort has taken place.

The Swedish Industrial Corporation and the Israel–U.S. Binational Industrial Research and Development Foundation also have discussed possible funding support or joint R&D efforts in return for licenses to utilize the technology in their own or other selected countries.

The first solicitation under the new program resulted in 329 phase I proposals and 42 phase I awards, totaling $1 028 000, to 39 small firms. About 70 percent of the proposing firms and of the awardees in phase I stated that they felt their research also had commercial potential and that they would seek venture-capital commitments. The phase I effort was completed March 31, 1978. Phase II proposals were due by May 30. Thirty-three proposals are under review and approximately one half of these will be funded by the end of October.

About half of the firms also had venture-capital commitments or third-party letters of conditional intent from venture-capital firms or large businesses, with the degree of commitment varying widely. Some received more than one offer. One found a Japanese firm more willing to commit support than were U.S. companies.

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Roland T. Tibbetts
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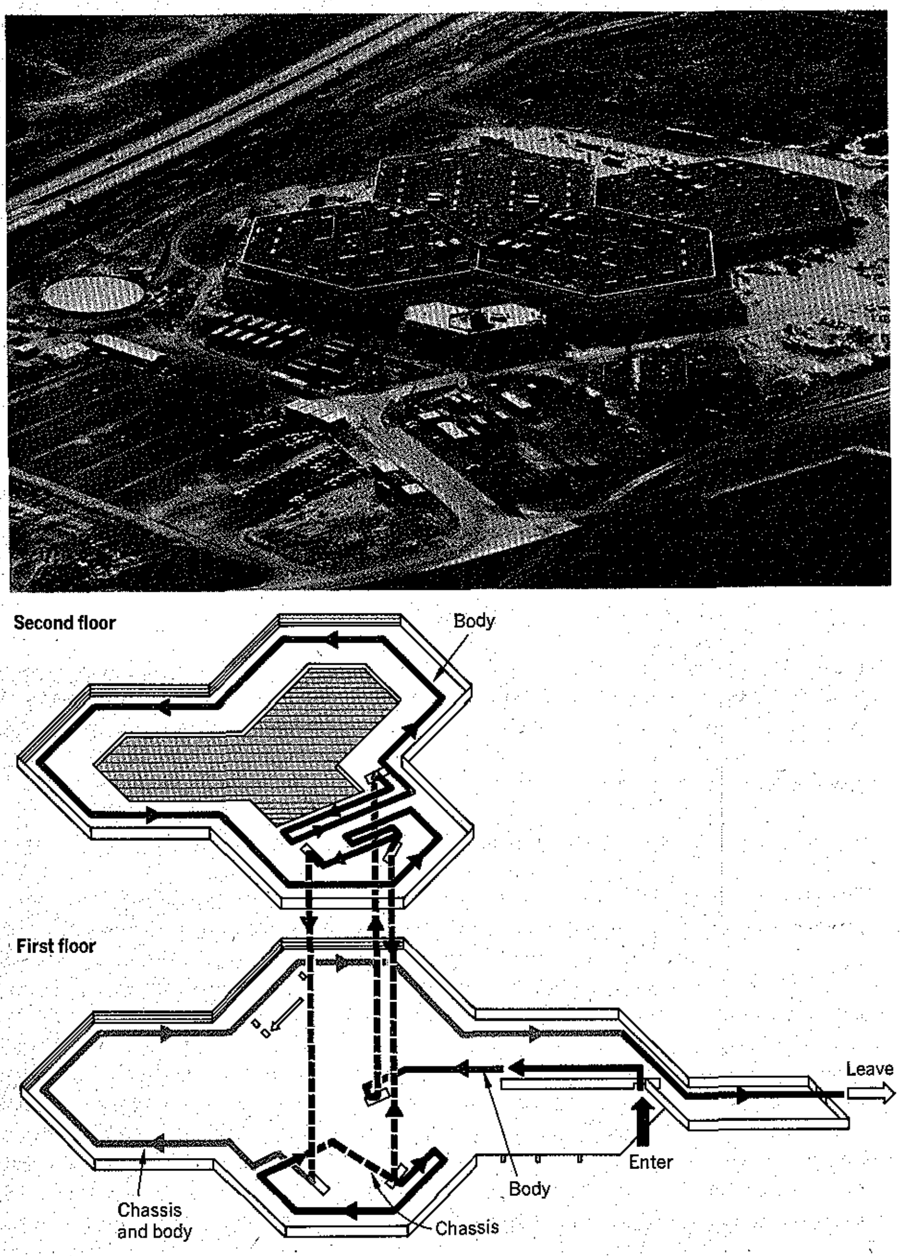
more satisfying (it was also agreed that any productivity gains would be shared equitably). Distrust between management and union made it impossible to start the project with the goal of improving productivity. The workers would have considered that an attempt at speed-up. Only later, once trust had been created, was it possible for the union to work cooperatively with management toward economic as well as social–human goals."

Though all employees were part of the program, changes were allowed to ripple out from volunteer "experimenting" groups through "core" groups and a working committee to the rest of the plant. This allowed a continuous search for alternative ways of doing the required work, with the "best" ideas eventually being adopted by everyone. This is how the concept "earned time off" originated. Maccoby explains just what happened once the program was underway.

"Gradually, ideas for improving the work began to emerge. Changes included production methods, alterations in the distribution of work, and the introduction of team work where previously jobs had been carried out individually. The experiments also included trying out alternatives for using time when the production standards had been met. Where previously an employee was free to stop working when he had produced his quota, but was required to stay at his work station, the experimenting groups invented their own bonus systems, including accumulating paid time off through over-producing, extra pay for extra production, and leaving the work station when the entire group had met the standard for the shift. One experimenting group agreed to meet for a social hour after work, and later its members developed a first aid class.

[1] Volvo's auto assembly plant at Kalmar, Sweden is a two-story hexagonal design (top). The car body and chassis move around and between floors (bottom) before a finished car leaves the plant. Painted bodies entering the plant are washed (purple) then sent to the second floor (red dash) for assembly. Chassis assembly begins on the first floor (green dash). At the proper moment, chassis and body are brought together and "married" (solid green). Further assembly continues on the first floor (orange), then the car is given a final rust-proofing (black) and leaves the factory.



"What most attracted the attention of employees outside the experimenting groups was the use of the time that could be earned by getting finished early. More than anything else this motivated additional groups of employees to ask the Working Committee to allow them to form experimenting groups. Several additional groups were formed. Other employees pressured the Working Committee to expand the opportunity to earn time to all employees. Eventually, the Company and the Union agreed that every department in the plant, through its core group, could develop a plan for earning time.

"What are the results of the Bolivar project? Overall, the factory's workforce has doubled, profits have risen, and the average hourly wage is more than twice what it was before the project was initiated. Where the work was at 70 to 80 percent of standard before in the polish and buff department, now it is 100 percent in less than a full eight hours. In other departments, the rise has been less dramatic, but significant. Probably, the major productivity gains since the beginning of the project are due to new technology and methods. but even here the project has helped in the acceptance, and in some cases, the participative design of these innovations.

"However, the narrow economic concept of productivity (i.e. output per man hour) is inadequate to describe the economic gains of the project. The new cooperative spirit has resulted in workers helping to gain new business by coming in on the week-end to set up new equipment for a rush order.

"The first notable instance of improved effectiveness through management-union trust occured in 1975 when Harman International Industries was in danger of losing a major contract and with it one hundred jobs. Management tried to save the contract by accepting a lower than usual profit margin. Management opened its books and, with the union, re-examined all work standards in order to make the lowest possible bid. The bid was accepted and the jobs were saved."

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of the control group increased about the same as that of the test group." The control group response may simply be the worker's reaction toward being "studied." Obviously, both the test group and the control group knew they were under observation.

Interviews were used in Hawthorne to find out first hand what employees thought about their jobs, supervision, working conditions, etc. It was discovered that very often complaints could not be taken at face value. Unhappy childhood experiences and current personal problems were often found disguised as grumbling about bosses and piece rates. For example, Cass and Zimmer report "An employee complained that his piece rates were too low. As he continued to talk, he related that his wife was in the hospital, and that he was worried about his doctor bills. In effect, the complaint about piece rate is an expression of his concern about his ability to pay his bills."

With Hawthorne outlining the problem as multifaceted and complex, defying a simple solution, we skip forward to the 1970s, to examine a few case history "solutions" to worker morale and productivity problems; Volvo's Kalmar plant; Jamestown, N.Y.'s Labor-Management Committee; and Harman International Industries' "earned time off" program.

Teamwork tackles monotony

The Volvo factory in Kalmar, Sweden has gained renown because it has eliminated the traditional assembly line in order to give employees greater opportunity to influence their own work. How has it worked out? Management and employees of the Kalmar plant jointly requested the Rationalization Council to look into the situation.

The Rationalization Council is a nonpartisan body established in 1972 through an agreement between the Swedish Employers' Confederation and the Swedish Trade Union Confederation. Its purpose is to serve as a body for communication and joint consultation with respect to improved productivity, increased job satisfaction, a better work environment, and stronger job security. Here are highlights of what they reported about Kalmar.

During the 1950s and 1960s, Volvo's auto manufacturing facilities were thoroughly overhauled and modernized. The production process became increasingly mechanized and automated, and numerous narrow and highly specialized jobs were created. For individual workers, this process meant constant changes in the work environment. In some respects, the work became easier; in others, more burdensome. One indication that personnel problems were deteriorating was turnover, which in some departments during this period rose to extremely high levels.

It was against this background that the search for new car assembly methods began at Volvo. The central new idea was that more attention should be focused on the individual and his job. Furthermore, the new working methods should also provide a spur to efficiency, primarily lower turnover and less absenteeism.

The basic shape of the factory (Fig. 1) emerged from the idea of production teams. Each assembly team has its own area of the factory where it carries out its part of the assembly operation. The autonomy of the teams has been emphasized through the shape of the building and the supplying of each team with its own personnel facilities. The components inventory that supplies materials to all the teams is located in the center of the building. The teams are spread out along the outer walls of the building. Production began in February 1974. The factory is designed for the assembly of 30 000 cars per year, with one shift of assembly workers.

An important innovation in the new production system is the battery-powered assembly carrier that functions both as a transport device and assembly platform. A central computer keeps track of all the carriers and checks their movement along the production process between work areas. They are powered through magnetic tracks embedded in the floor and can be maneuvered manually with operating levers.

Thanks to this ingenious carrier, assembly can be carried out on stationary cars, which is an extremely important difference from conventional moving-line-fixed-pace assembly. Moreover, the carrier is designed so that it can be easily tilted by 90 degrees when components are being assembled on the underside of the car.

Before and after each work team's area, there are places for incoming and outgoing assembly carriers. These buffers make it possible for the team, within certain limits, to work ahead and accumulate time for extra work breaks. The work is arranged so that it takes the same amount of time to carry out the tasks at one work station as at another. The basis for this balance of task cycles is worked out with the help of method-time-measurement studies, and the task packages at the various stations are normally known as "balances."

After observing the Kalmar operation at close range, and interviewing many employees, the Rationalization Council's investigators reached a number of conclusions, among them:

- Assembly times in the Kalmar plant and in a conventional plant are the same. However, indirect time (planning, quality control, etc.) is less at Kalmar. In addition, the Kalmar plant has some advantages that the conventional factory lacks, though it is somewhat more costly. The extra investment is to some extent offset by production advantages, such as a smaller number of supervisors, ease of altering production arrangements, and low absenteeism and turnover.
- The total effect of these advantages will become even more marked at full capacity production, and it is estimated that at that point the extra investment cost will be completely offset.
- The team organization and the technological production apparatus permits a higher degree of influence by employees on their own work than in a conventional assembly system.
- The design of the factory has provided a good basis for team organization.
- Most workers are very positive toward the team organization, and have a strong feeling of belonging to their team.
- Switching between teams, which is sometimes necessitated by such factors as absenteeism, is regarded by workers quite negatively.
- The company has delegated responsibility to the teams to design their own organizations within a certain framework. In a traditional organization, all division of the work is planned at a superior hierarchical level in the line organization. At Kalmar, considerable leeway has been left to the teams to decide the distribution of the work. What happens between the time the incoming materials are received and when completed assembly is dispatched is largely up to the teams to decide. In order to fulfill their assignments, the team members must organize their own work. This includes, among other things, setting rules for job-switching and working ahead of extra breaks.

Though Kalmar may be considered a qualified success since it cost around 10 percent more than a conventional plant of equal capacity, over a half dozen new plants (one in Holland, six in Sweden) have been built recently based on the Kalmar experience. These installations cost no more than conventional plants. Recent statistics from Volvo show that their total blue collar turnover, which ran 25–30 percent annually prior to Kalmar, now runs at only 6.5 percent—at Kalmar. Likewise, sickness typically ran 20 percent annually, while Kalmar boasts only 9 percent.

In both cases, the Kalmar figures are well below Sweden's national averages. It should be noted that high absenteeism and turnover are often attributed to Sweden's liberal social benefits system, which provides sick should undertake the task of complementing the private sector in providing the nation with a pool of basic knowledge. With close cooperation between the two sectors, improvement of productivity in research activities may well offer the most significant opportunity to accelerate growth and reduce inflation.

Dwindling leadership

The United States still maintains leadership in microelectronics, computers, aerospace, and some weapons systems. However, it is lagging behind the rest of the industrialized world in areas such as shipbuilding, steel production, textile machinery, and consumer electronics.

The reasons for the success of other countries are complex and varied. Countries like West Germany have stressed innovation, product quality, and reliability of service. Their tax laws favor innovation and their educational systems emphasize practical applications of acquired knowledge.

Countries such as Japan have focused on the development and understanding of world markets as well as on emphasizing the style and quality of their products. Japan's success depends to a great extent on the rapid growth of private investment, which, in turn, has acted as a catalyst for the growth of the whole economy. Rapid domestic growth made possible huge economies of scale that enabled the Japanese companies to lower costs sufficiently to penetrate markets overseas. In turn, the growth of export markets helped to increase domestic-scale economies still further and so enhance productivity and reduce unit costs.

The "learning curve" principle applied to the economy as a whole summarizes the positive effects of greater use of standardized parts, longer production runs, improved work methods, and accumulated managerial experience. The combined rates of growth for Japan and its major export markets are so high that in many industries accumulated experience doubles within less than five years, whereas in the U.S. reliance only on the growth of the mature U.S. market requires a much longer period to increase production experience.

Many of the successful technological drives in other countries are due to their rebuilding efforts after World War II. It was a natural reaction after the destruction of the war, a "catching-up" effort made easier by the absence of constraints such as consumerism, concern for quality of life, and emphasis on welfare, which have hindered the innovative process in the United States. In time, other countries will go through the same phase of development as the U.S. and those same constraints will begin to slow their innovative spirit.

The U.S. could do better, of course. Other countries enjoy more favorable tax laws (particularly in the area of capital gains), stronger export promotion, and fewer antitrust restrictions. Moreover, almost half of the U.S. R&D effort is spent on defense, space, and socially oriented activities whereas virtually all Japanese and about three fourths of the German R&D are aimed at economic development and advancement of knowledge.

In particular, Japan's R&D efforts differ from those in the U.S. in several respects:

- A focus on commercial application and economic payoff
- High reliance on private-industry technology
- Improvement of overseas technology to lower production costs
- Active Government policy to encourage and set the terms of technology flows
- Strong cooperation between industry and Government
- A world-view perspective on the part of business

The orientation of the educational system is also important. One striking difference between engineering education in the U.S. and West Germany is in the production of engineering graduates for careers in manufacturing. This tradition is well established in Germany and weak in the U.S.

Lastly, a word of caution: Rather than formulate uncoordinated policies or adopt the government policies of other countries, the U.S. first should examine and set its priorities. Then it should reduce the barriers that would hinder or discourage creative solutions to the problems.

It is only with clearly defined objectives and a good understanding of the technical difficulties that an intelligent policy can be formulated.

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In praise of the small company and the technical manager as innovators: they're not afraid to take a chance

Sam Raff
USAB Task Force on U.S.
Innovation in Electrotechnology

New companies in high-technology fields tend to be more innovative than the large, mature companies—and they also have other characteristics that are desirable to the economy. In the United States, for example, *Science Indicators 1977* shows that from 1953 to 1977 an R&D dollar spent by a company with fewer than 1000 employees produced 25 times as many innovations as a dollar spent by a company with more than 10 000 employees.

Another interesting fact, revealed by a survey conducted in 1977 by the American Electronics Association, is that employment growth rates in 1976 for high-technology U.S. companies that were started between 1971 and 1975 was 57.5 percent, compared with 0.5 percent for companies in the same industry established before 1955.

New high-technology companies are usually managed by engineers, scientists, or inventors, whereas older companies are directed by management specialists, accountants, attorneys, or financial or marketing specialists. This difference in management philosophy is certainly a factor in the company's relative willingness to innovate and take longer-term R&D risks.

However, a factor of more immediate interest is probably the role of chief executives of small high-technology companies who generally hold large, not readily negotiable, equity interests in their companies. Thus, their long-term economic future depends directly upon the company's performance. Subject to constraints of cash flow, this relationship leads them to favor R&D investment entailing immediate financial sacrifice for the benefit of increased earnings 5, 10, or 20 years in the future.

The presidents, board chairmen, or managers of larger U.S. companies rarely have this kind of motivation. The principal financial benefits they derive from their work are in the form of salary, retirement accrual, and sometimes stock options, all of which depend on the short-term performance of the company.

Stock options confer some long-term interest, but this is greatly mitigated by the ready market for the stock of large companies. These options can usually be exercised in a few years and the stock sold. In fact, an executive often has to see the stock "bean counter" should not anticipate a cordial reception to the idea, and probably not even a vague understanding of the concept. Certainly the idea must be presented with a sense of proportion. Company management should not be expected to invest in a money-losing product development solely for the purpose of capability-enhancement, unless a "buy-in" strategy is clearly indicated.

The fact that a dollar number cannot be put on something does not mean that it is without value. The ability to conceptualize such values and see well beyond this year's bottom line seems to be an important factor in differentiating the innovative companies from those destined for decline, moribundity, or, at best, a "me-too" product line. ◆

Texas Instruments' short-term 'Idea' programs and its long-shot 'Wild Hare' programs stimulate the company's innovators

J. Fred Bucy
Texas Instruments

People make innovations. But one has to create an environment in which people will be stimulated to innovate. And what few of us realize is that one can actually plan and organize systems to spur innovation.

The system used at Texas Instruments is called OST—for objectives, strategies, and tactics. It's designed to help the company foster and manage innovation. The TI system starts with the idea that innovation has to be nurtured very carefully. It can starve if it isn't quickly nourished. Moreover, innovations perish without champions—so at TI we make initial resources available quickly and easily. Being able to allocate resources properly is the real key to the system. The best way to motivate innovators is to provide resources to help them carry out their ideas.

We have two basic ways to provide funds for innovations: the Idea program and the Wild Hare program. Under the Idea program, we distribute modest sums of money to a large number of Idea program representatives throughout the company. An engineer who says, "I have an idea for doing such-and-such, and I think I can prove its feasibility in six months," merely has to convince the Idea representative, who has authority to provide funding without further approval.

The engineer will have a timetable to prove that progress is being made. At some point, an extension may be needed. And at some point, the idea may develop to the point where it enters into competition with other ideas for further funding. If the idea proves successful, the engineer may move with it as it goes into further development and into production.

We believe deeply that someone who sees an opportunity to be pursued outside the immediate area has the responsibility to do something about it. Perhaps it should be brought to the attention of one's peers, the boss, or a committee. Then, if the engineer is given responsibility for developing a new idea, and has to call on resources in other departments, the OST system will provide the funds to buy those services. That happens frequently.

In TI's Wild Hare system, we're looking for ideas that are more nebulous. We're working long shots. In these programs we may make large investments, but they are spread over a long period of time. Since these are important programs, possibly with long-range impact, we don't fund them as quickly as we do the Idea programs.

Of course, when thousands of people in a corporation are encouraged to innovate, we must often face the problem of deciding what business we're really in, especially when we examine some of the Wild Hare proposals. And that's precisely one of the functions of the OST system. A new business can sometimes be an outstanding payoff of the OST system, which, remember, is first and foremost a philosophy—a philosophy that keeps pointing to the fact that we are in the business of innovation. There are two critical aspects to this philosophy. First, we try to make the status quo uncomfortable. Second, and very important, we don't punish innovators for unsuccessful programs.

The OST system helps us to generate new ideas. To help us improve on these ideas, we instituted the concept of design-to-cost (DTC).

In the first step of the DTC approach, we determine basic performance requirements: What does the potential customer want the product to do? Next, we determine the price elasticity: How will the market expand as the price of the product is lowered? After this careful market study has established prices and volumes, we determine and apply profit margins necessary to finance growth and reward stockholders. In this way, working backwards from price, we establish the unit production cost objectives. Taken together, these estimates of performance, price, cost, and volume give us a definite target for product design.

Engineering support of a product does not end with that product's entry into the marketplace. During both design and production, the designer continually encounters new findings, such as lower cost estimates, new performance-enhancing ideas, and new technologies. The designer must continually trade off these new findings against existing performance to optimize performance without violating the market-price demand.

Design-to-cost evolved as an engineering discipline for high-volume manufactured products. Creative managers recognize, however, that its power can be applied in modified form to limited-volume: custom products, service sold outside the company, and products and services delivered within the company. In every case, the basic questions must be, "How can we deliver the best possible combination of user benefits, quality, and reliability without exceeding the lowest reasonable price?"

Long-term perspectives

Technological innovation can be encouraged by managers who maintain a long-term perspective. Thinking long term, however, is analogous to thinking strategically. Any student of corporate strategy would agree that technological innovation will always make competitive advantages—such as size, cost, and efficiency—obsolete. Therefore, behind corporate growth and longevity is the careful management of the technological innovation process.

If the allocation of strategic funding is left to individual managers, they are forced into conflicts between today's profitability and tomorrow's growth. For the same reason, one must segregate the reporting of strategic and operating expenses so that one doesn't unwittingly penalize managers who carry out strategic programs.

In our OST system, an innovator is responsible for the project. Most of the time the innovator is in a group and it's most likely that the idea will be in the manager's own area of interest. Thus, the manager has a great deal to gain from supporting the fresh idea, as it might result in additional resources that will make the business a success.

The OST system is dedicated in large measure to stimulating managers into effort, but by how frequently we find ourselves caught by technical surprises."

A complex process

The innovative process is extremely complex and a need exists for a high degree of interaction between problem exploration and knowledge exploration. Neither single-minded devotion to determining market needs nor emphasis on technical development and awareness is likely to be sufficient for success. It is the subtle and synergistic combination of both that seems to work.

In the early 1960s, for example, Collins Radio Company (now a part of Rockwell International, Inc., in the form of various divisions still retaining the Collins identity) introduced a new line of airborne communication and navigation receivers called the "Triple-S" line (for Solid State Systems). These receivers, which proved highly successful, incorporated three major innovations: elimination of all electron tubes, made possible by advances in transistor technology; elimination of motor-driven tuning mechanisms, made possible by the development of electrically variable capacitors; and elimination of mechanical rotary switches, through use of high-performance switching diodes developed for computers.

Were these innovations driven by the known needs of the market for improved reliability and lower power consumption, weight, and cost? Or were they driven by the emergence of new technologies and someone asking the question, "How can we apply these interesting new devices?" The answer must be that knowledge of, and concern for, market needs *and* knowledge of new technology *and* curiosity about potential applications were present. Similarly, was the innovation exploitive, to get a jump on the competition by being the first to employ the new devices, or was it defensive, to protect the market position of an existing product line?

And what about the recent development of liquid-crystal display (LCD) technology, now so widely used in digital watches and calculators? Was that development stimulated by knowledge of a general need for alphanumeric displays employing very little actuating power, or was it driven by knowledge of the curious optical behavior of certain compounds when an electric field is applied to them?

Why innovations falter and fail

The consideration of the two major variables in product innovation, and of the risks (as well as the opportunities) that departures from the home base of existing products bring, naturally raises a question: Which direction of innovation—moving to new markets on the basis of existing technology, or adopting new technology to serve familiar markets—is the more hazardous to follow?

A recent study of innovation failures in the producer goods industry (equipment, machines, and materials marketed primarily to other manufacturers) by the Denver Research Institute appears relevant to this question. In this study, only innovations that had entered the development, test, production, and marketing pipeline, but at some stage of the process were canceled, set aside, or significantly delayed, were considered.

Of the 200 innovations that failed, only 11.5 percent failed because of technology-related obstacles. However, over 50 percent failed because of market and management problems, and the management problems were largely related to marketing. Of the "market-blocked" innovations (27.9 percent of all failures), the five largest obstacles cited were limited sales potential, no perceivable market for "public-interest" innovations, unacceptable cost/price ratio, unfavorable customer cost/benefit ratio, and inability to combine or aggregate a fragmented market for the new product. Of the "management-blocked" innovation failures (23.5 percent of all failures), about 30 percent were the result of poor market analysis and 20 percent related to organization and staffing, particularly in the marketing organization.

The predominant causes of technical failure, according to the survey, were the existence of a superior technical approach, design problems, and difficulty in controlling process quality, in that order. A specific case was cited in which lack of staff technical capability delayed the completion of a product by two years, at which time the market was no longer penetrable. This case, however, was identified as a management organization and staffing problem rather than a technical failure.

The study did not specifically indicate that the innovation failures identified as market- and management-related occurred in products planned for introduction into new markets. But from the nature of the failures reported, it would appear that new products introduced to established market areas would not have had the same kind and number of problems that were indicated.

The fact that there are substantially more market- and management-blocked innovations than innovations that fail for technical reasons suggests that the feasibility of a new technical approach can be, and usually is, adequately evaluated in an advanced development or technical feasibility phase before major funds are committed. Market-related research, evaluation, and planning, on the other hand, tend to be done poorly, or not at all until late in the overall product program.

Technical information is relatively easy to communicate, but knowledge of the subtleties of the marketplace is not. A product designer familiar with the needs of a market can easily obtain technical data from colleagues, suppliers, and the technical literature. Technical information tends to be quantifiable; it is expressed in a common language of scientific terms. Existing channels of communications are such that with a little ingenuity and diligence, one can normally learn what one needs to know rather quickly.

It is difficult to communicate market information to scientists and engineers who are technically competent but without experiential knowledge of customer needs and requirements. This difficulty manifests itself when optimizing the "performance dimensions" of a product design to provide the most attractive combination of such factors as technical performance, reliability, maintainability, appearance, and operating convenience for the target set of customers. Achieving this optimization, particularly in products used by sophisticated customers, seems to require intimate knowledge of the customer and the operating environment of the product. A track record of success in designing products for a specific market would appear to be a most important predictor of future success.

Although the Denver Research Institute study was addressed to a specific segment of the industrial market, its results and conclusions should be applicable to other market segments as well. The evidence is rather strong that adventures in unfamiliar markets are substantially more prone to failure than is the adoption of new technology. The evaluation and utilization of a new technology is a reasonably objective and predictable process. Effectively assessing and acting upon information in new markets, however, is subjective and difficult.

As the Denver researchers put it, "Innovations do not seem to fail because management lacks information about the market—although there is some evidence of that problem. They seem to fail primarily because management does not correctly evaluate the plethora of information that is already available. The chief management problem with respect to marketing is not the lack of market information, but poor organization, staffing, planning, and judgment..."

The difficulties a company, especially

PRODUCTIVITY III

Management to the rescue

Despite some earlier analyses suggesting the contrary, management and labor have demonstrated time and again the validity of the old adage that where there is a will, there is a way—in this case, to increase productivity. Behind the various strategies described in this section is the recognition that technological innovation, if it is to be completely successful, must be nurtured and protected as it evolves through several stages. Hurdles will appear at the point of conception, through development, in production, and last, but hardly least, in the marketplace.

The point is underscored in the lead-off article by Arthur Wulfsberg. He points out that wise management policies directed toward minimizing both the technical and marketing risks of new product development can make the difference between a low or high corporate batting average.

Next, the strategy aimed at encouraging innovation at one of the world's most innovative companies—Texas Instruments—is described by the company's president, J. Fred Bucy. It is a strategy that makes it possible for any designer to receive support for a new idea, one that might even lead the company into an entirely new business.

In the succeeding article, a proposal is put forth by Sam Raff that would tie financial rewards of top executives of large corporations to the company's long-term performance. In this way, Mr. Raff contends, more large, established corporations would be encouraged to make long-range R&D commitments.

Finally, Associate Editor Don Mennie describes ways labor and management have cooperated to devise novel and unusual strategies to improve worker motivation.

Measuring risk, both technical and marketing, is an important step in launching successful innovative products

Arthur H. Wulfsberg
Consultant

There are two primary factors of risk in product innovation—technical risk and marketing risk. Technical risk is the possibility that the new product will fail for technical reasons, either in laboratory and field tests or in actual use by the customer. Marketing risk is the possibility of failure in the marketplace even though the product is a technical success.

Any organization with a strong aversion to accepting these risks is not likely to be innovative. However, if risk cannot be avoided completely, it seems logical to assume that it can be minimized. Thus, identifying the nature and magnitude of new-product risks should be an important factor in the conception and assessment of new-product ideas.

A matrix model of technical and marketing novelty is proposed to assist in analyzing and minimizing technical and marketing risks. It can be used to stimulate and guide innovative efforts toward products that will have a better probability of commercial success than might otherwise be the case. And it can be used to explicate the strategy of concurrent and progressive product innovation and capability development that some successful innovation-oriented product-manufacturing companies appear to follow.

A major assumption used in developing the matrix is that the levels of technical and marketing risk are approximately proportional to the degree to which the new product employs technology new to the organization, and the degree to which the efforts required to market the new product are new. An indication of the marketing efforts required, for example, would be the need to deal with a new set of customers or to establish a new advertising and distribution system.

The matrix

Figure 1—a simple matrix of product technology and marketing capability—indicates, in each axis, two degrees of departure from present products and hence increasing risk in product technology, marketing capability, or both simultaneously. The matrix does not take into account such important factors as manufacturing capability and quantitative economic aspects of new-product planning and analysis (for example, cash-flow and return-on-investment projections). These topics are well covered in the literature and are beyond the scope of this discussion.

The propositions relating to the matrix chart are as follows:

1. Each currently successful item in a company's product line (indicated by the A-1 block of the matrix) implies the existence of a specific set of technical and marketing capabilities. The rationale for this proposition is that if these capabilities did not exist to an adequate degree, the product would not be successful.

2. Any proposed new-product ideas (other than, for example, a minor improvement in an existing product for sale to the same customers) implies some degree of technical and/or marketing risk.

3. As mentioned previously, the degree of risk in either axis is roughly proportional to the degree of departure from the familiar grounds represented by present products.

The classification of a proposed new product as A-2—a product incorporating modest technical novelty but sold in the same market as a present product—would imply moderate technical risk but low marketing risk. Similarly, a B-1 product implies low technical risk and moderate marketing risk.

Any product proposal requiring departure in both dimensions probably implies compounding of the total risk factor. For example, if a market is not well known, it may be difficult to ascertain what kind or

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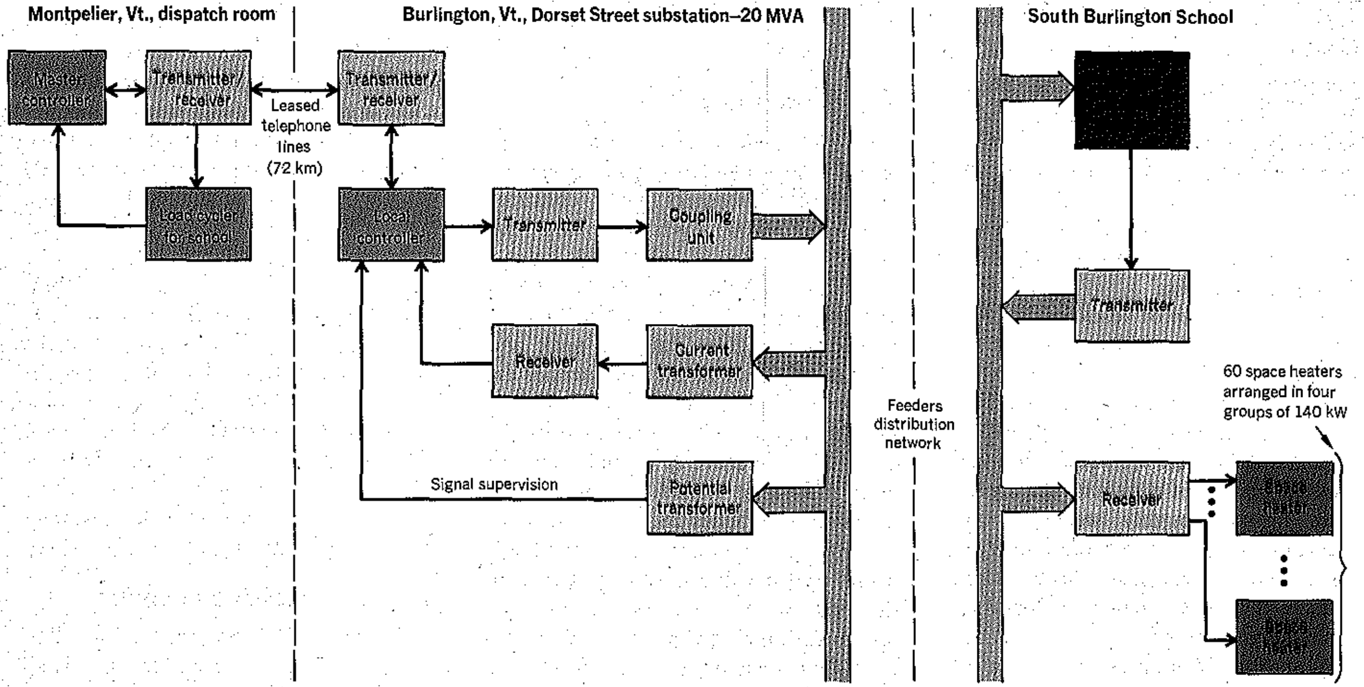


[2] Automatic cycling of load—in this case, electric space heaters at the South Burlington School in Vermont—is effected by the "ripple control" method. The Green Mountain Power Corporation of Burlington is conducting the test. Cycling is initiated either by a signal from the demand meter at the school, when the total power is excessive, or by a command from the utility's control center, when the total system load is excessive. The cycling arrangement helped to reduce the peak demand at the school by 26 percent in January 1977, compared with demand in the same month the year before. The school's total electric bill was about $11 000, or 18 percent less in 1977 than in the previous year.

distribution lines, and utilities' control locations will be examined under a program cosponsored by the U.S. Department of Energy and the Electric Power Research Institute. These techniques involve the use of carrier signals sent over the power lines, and using telephone communications exclusively. Different approaches to the former technique are to be tested by three utility-manufacturer teams, whereas the latter is represented by a fourth team.

Another concept has already been undergoing testing at the Massachusetts Electric Company (Aug. '77, pp. 46–50). Since last year, the DOE–EPRI program has been expanded to include another group of participants using radio equipment—LILCO itself and Westinghouse, as manufacturer.

The manufacturing of the components for participants in the nationwide two-way communication experiment is already well in progress. By the end of this year, the equipment is expected to be installed, and the preliminary results of tests of the various systems in the project may begin to appear in early 1980.

Elsewhere, other two-way communication systems are being tested for monitoring customer power loads and for controlling appliances. One system (Fig. 2) at the Green Mountain Power Corporation, Montpelier, Vt., is about to complete its second year of operation. Using the utility's power lines as well as a leased telephone line for communication, this system involves the automatic cycling from the company's dispatch center of 60 space heaters at the South Burlington School. Load cycling is initiated by a signal, sent by a transmitter at the power-demand meter in the school, as soon as the demand exceeds a predetermined value, or by a command from the dispatch center, whenever the total load of the power system exceeds its allowed limit.

The system is based on the so-called "ripple-control" technique, which employs a low-frequency signal (200 to 1000 Hz), superimposed on the utility's power-line frequency, to transmit the measurement and control data.

The injected control signal is small, compared with the power-line voltage, and when viewed on an oscilloscope, it looks like ripple—hence, the name. Ripple control has been used successfully by utilities in other countries for more than 30 years to turn on and off the power supply to water heaters and space heaters. However, in those applications the signals travel in only one direction—from the utility's control center to the customer's appliance.

Curtaining industrial demand

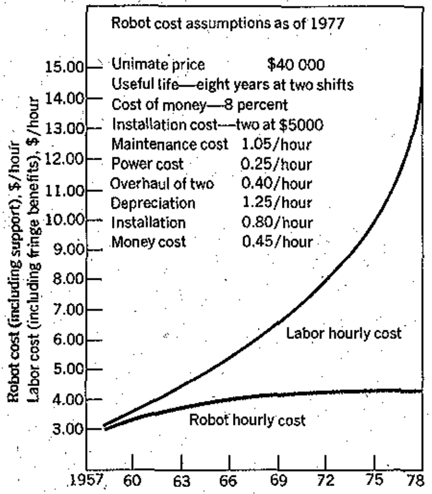
Industry is the biggest consumer of energy in the United States, and techniques for reducing its consumption, as well as for curtailing power demand at peak periods, have been available for some time (Dec. '77, pp. 26–32).

Demand controllers (Fig. 3) are in use for rearranging "deferrable" loads. These are power loads whose continuous operation is not vital. Computers employed in control, for example, are nondeferrable loads, as is lighting in critical manufacturing areas. The controllers include logic, memory, and input–output boards. With one out of several possible types of logic, the controller continuously monitors the incoming total power. It begins to shed load (disconnect it from power source) according to a preprogrammed sequence, whenever that input power exceeds a predetermined value.

The potential economic benefits from

I. Twelve-month savings in steam (for space heating) and electric energy, in three buildings in Manhattan (New York City), as a result of various energy conservation measures.

Building No.	Total rental space, m²	Steam Saving 1000 kg	Steam Saving $	Electric-Energy Saving 1000 kWh	Electric-Energy Saving $
1	45 300	5 943	154 400	629	49 200
2	20 800	3 015	50 200	22	3 100
3	58 000	12 230	179 800	1 212	111 200



[3] Hourly costs of human labor vs. robot labor in the automotive industry.

predictions for robotics. From a 1977 base of about $40 million in sales, an estimated compound growth rate that takes into account capital availability and government employment policies points to a mature annual market of $3 billion.

That forecast assumes that robots will take over 5 percent of the blue-collar jobs in the United States and Europe in the next 50 years. By its nature, a robot is not nearly so labor-displacing as, for example, a grain harvester in agriculture or a multiple drill press in industry. Moreover, whenever the economic leverage of the robot is only marginal and a job is attractive to a human—at premium pay rates, for example—the choice is likely to be the human. Nevertheless, widespread apprehensions are often expressed that robotics causes unemployment.

Despite repeated refutations of that charge over the years, it still remains in the public consciousness. The latest refutation comes from Ruth M. Davis, Deputy Secretary of the U.S. Department of Defense. She cites a British research paper that concluded that every 10-percent rise in industrial productivity yields a 7-percent increase virtually across the industrial board.

As for the reactions of the workers to robots, some are finding the displacement beneficial. In the forging shop at the Taylor-Wharton Company in Easton, Pa., two men used to work the hoist that removed the glowing, white-hot steel billets from the forging press. The labor turnover for the job was frequent. When a robot was installed to take over the dangerous and exhausting work, the two men who held the job last were reassigned to more pleasant work. And in numerous automobile-assembly plants, the spray-painting of car bodies, long considered among the most difficult, unhealthy, and fatiguing of jobs in assembly work, is being turned over to robots.

The delegation of such tasks to robots is also relieving manufacturers of conflicts with OSHA and its stringent rules. In case after case, workers have been removed from high-heat, noisy, and polluted environments. The robots that have taken over their jobs are largely immune to the dangers and discomforts.

Robotics is clearly part of the answer to the search for humane use of humans in employment. ◆

Techniques that optimize the use of the world's dwindling energy supply inevitably affect productivity as well

Gadi Kaplan Associate Editor

Energy—an inescapable input in all products and services—is becoming scarcer and more expensive. Every fluctuation in availability and price affects the world economy, in general, and national productivity growth rates, in the specific. Just how to make the most "productive" use of energy resources is therefore a subject of great importance.

With electric energy, techniques for making better use of power-generating equipment are being studied. Utilities have devised electricity rates that encourage a more even spread of electric power use throughout the day than the present pattern, and these rates are being tested as part of load management—the process of altering the pattern of use of electricity. The tests involve technological innovation in measuring power demand and energy consumption. However, the techniques themselves face legal, technological, and economic problems that must be resolved before there can be large-scale implementation.

There are various ways in which energy consumers can curtail power use during the hours of peak demand as well as reduce overall consumption. These techniques, which involve a variety of steps—from changes of operational procedures of equipment, at minor or no expense, to use of sophisticated, computer-based, demand-control, and energy-management systems at a large investment—have already helped cut energy costs.

Watching power with meters

Most industrial and commercial users of electricity pay not only for the amount of energy they consume each month but also for their power demand, based on a predetermined formula. The formula, which varies from one utility to another, depends on local energy availability, and regulatory and other factors. For example, at Public Service Electric and Gas of New Jersey, the value of power demand employed in billing large customers—those whose demand exceeds 1000 kW—is computed as the average of the four highest demands in 15 minutes on different days.

At PSE&G, the power-demand element comprises about 35 percent of the total electricity bill for such customers. The rest is the actual energy consumption. It is anticipated that in a few years, when the utilities expect more nuclear power-generating plants to come on line, the demand component may increase even further, to about 50 percent of the bill. This rate structure is to reflect the higher capital costs of nuclear power plants, as compared with fossil-fueled generating facilities.

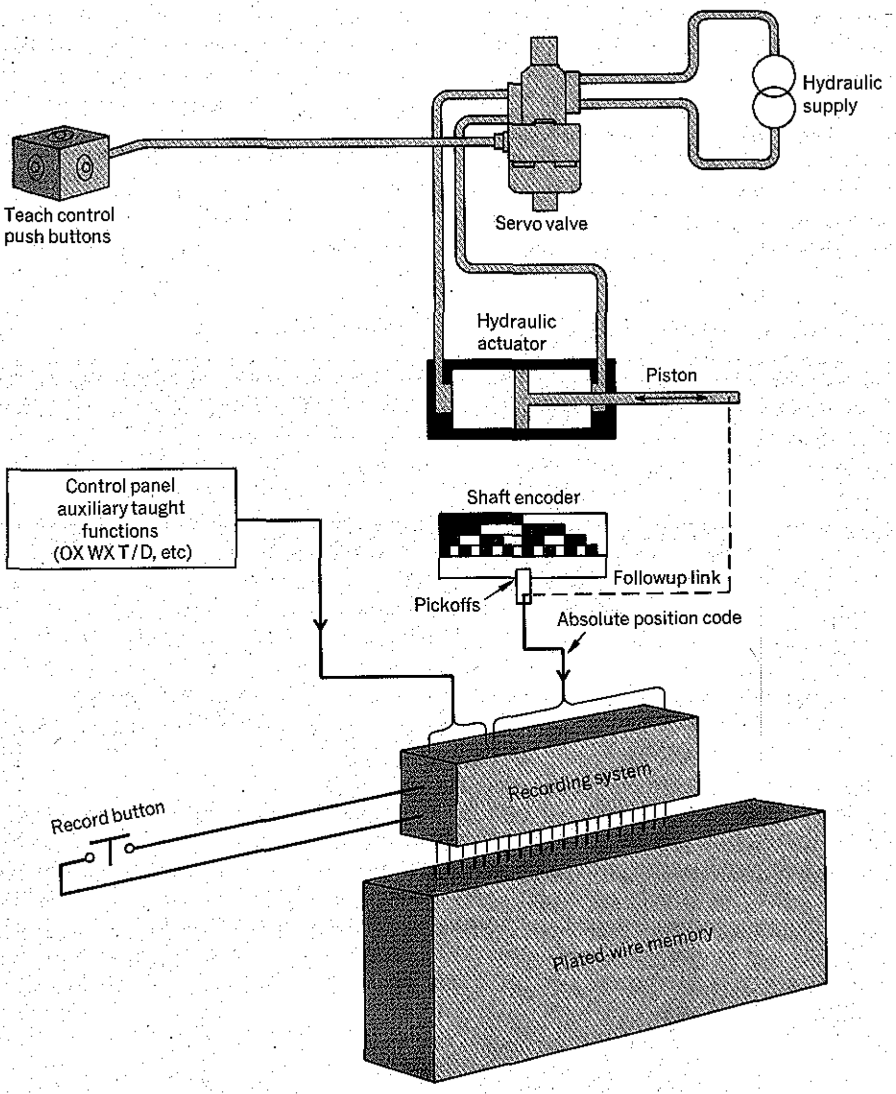
To bill its medium to large customers for power demand, PSE&G employs a technique that it initiated about ten years ago for its largest customers only. It involves the recording of pulses derived from the revolving mechanism of the customer's wattmeter. An optical arrangement is used. The rate of the pulses is proportional to the instantaneous power, and the pulses are recorded on magnetic tape at the meter itself. In addition, time pulses at 15-minute intervals are also recorded on the tape, on another track. At the end of the billing month, the tape cartridge is unplugged from the recorder at the meter and plugged into a "translator" that automatically computes and produces the bill from the pulse information.

One possibility offered by such metering and recording is the much talked about billing of customers according to the time when they use power from the utility. The basic object is to improve the utility's "load factor"—the ratio of the ioms of robotics. One is that the engineer should not attempt to duplicate a human operator's exact manipulations but rather should deploy the robot according to its superiorities and limitations. Another rule is that the robot be mated with compatible equipment. For example, although the robot may have no problem in inserting a workpiece into a stamping press, it may not be able to keep up with a press capable of 1200 strokes a minute. And obviously the marriage of a robot with an ancient machine that has no automatic chucking would be a disaster. But even with an automatic machine, if no means exist for presenting workpieces to the robot in correct orientation, the result will be low productivity at best or wrecked tooling at worst. Nor can the robot overcome basic manufacturing deficiencies, such as usually exist in an environment with vagrant machines, tools, and workpieces.

The antithesis of that situation is, of course, the modern automative assembly line, and the 1970 installation of the 26 robots at the General Motors plant in Lordstown placed robotics squarely in auto production. But what is not as well known is the proliferation of robotics in smaller-volume batch manufacturing processes, best typified by the die-casting industry. Many high-volume foundries employ robots, but the greatest concentration appears in smaller, independent shops where batches are as small as 1000 castings and dies are changed as often as twice a day. The robots not only unload the hot castings; they also assist in secondary operations, such as die lubrication, trimming, and quenching. The easily reprogrammable robots lend themselves well to changeover of tooling, so that setup time is minimized and productivity of the capital equipment is maintained at high levels.

A variation of the batch approach occurs at the Inland Division of GM, where robots spray foam into molds for making automobile instrument-panel members and other interior items on moving conveyor lines. The great variety of spray patterns and the random nature of the sequence of products moving down the line made necessary a multitude of robot programs, which are stored in a disk file in the central system computer. Upon identification of each product as it arrives at the work station, a program appropriate to the required spray pattern is fed into the robot's internal memory.

[1] Key parts of the internal control computer of a Unimate industrial robot.



A highly sophisticated adaptation of robots to manufacturing is the Unimate robot designed for assembling small parts to tight tolerances. This robot is used alongside people engaged in assembly operations with parts that weigh less than five pounds. The robot holds positions to tolerances within 0.1 millimeter, and it can even be programmed to a new job while still engaged in the previous one. The human working with the robot can teach it with a few simple instructions expressed in English. Thus the operator informs the robot's microprocessor where a part is to be found, its destination, and so on. Software language does the hard work of determining the best routine for the robot to follow.

Laboratory to production line

An acknowledged pioneer in robotics is George C. Devol. In the 1950s he set out to design a machine that would be "teachable"—that is, reprogrammable, not restricted to one specialized task, and therefore immune to obsolescence. His concepts were promising enough to attract the attention of Joseph F. Engelberger, at that time a physicist involved in the design of aircraft controls. Messrs. Engelberger and Devol joined forces in 1956.

Their earliest efforts were in a mechanical format that has become the prototype for most robots since: a hydraulically powered arm, controlled in its movements by solenoids and servos and equipped with a "hand" that does the work. In 1961, they introduced the first commercial Unimate industrial robot, a unit with five axes of motion and equipped with a magnetic drum memory. It simply stepped from one instruction to the next upon completion of each task. It also initiated signals to start or stop external devices or equipment.

In most of the applications of that period there were islands of robots within conventional plant arrangements. Robots unloaded die-casting and injection-molding machines, fed stamping and punch presses, system is a broad base of implementation within a company—a systems approach directed by top management. Introduction of CAM techniques should be a major managerial decision, and the program should be assured strong high-level support, in view of the long delay experienced before tangible returns are realized. Such a total systems viewpoint encourages optimization of the company's overall operations, rather than undue concentration on an isolated aspect, that may account for only a small savings potential.

Cooperation is the key

Most industrialized nations are aware of the forces that act to change the character of manufacturing through development and implementation of computer-integrated manufacturing systems. Many companies realize that the years ahead will be filled with innovation and evolutionary change. The term "evolutionary" is appropriate, because computer automation of the total manufacturing system, from engineering design to assembly and inspection, must follow social and economic needs, education, understanding, and, finally, standardization of the numerous subfunctions to be automated.

The computer is available as a fundamental tool, but manufacturing, still far from a science, must be standardized before it can be automated. Generally, CAD and manufacturing techniques exist and have individual merit; they do not necessarily lend themselves to integration into a total cohesive interactive system. Development of such a system demands that there be modules within the system, such as detailed design, process planning, and workshop technology, which today have a stand-alone capability, but must be redesigned for integration into the whole system. Also, communications within the system modules must be based on standards that are agreed upon by the system participants.

The problems encountered in creating and understanding such systems are, in general, beyond the capability of any one company or single industry. Lack of a universally applicable standard, insufficient funds, and traditionally competitive drive has hindered intercompany cooperation. The required skills and technology are fragmented, and manufacturing R&D funds are traditionally invested in short-term proprietary projects. Therefore, cooperative work and discussion must take place before a better understanding and optimal solutions are obtained with CAM systems.

Computer-aided manufacturing is a dynamic and evolutionary development that will continue to expand its influence over design and manufacturing proceses and their management. The results of the Delphi-type forecast mentioned earlier are based on expert knowledge, and represent the best available opinion over a given period of time.

Although the growth of CAM does not appear to be fast enough, depending on technology and economic and social trends for its realization, the role of computer-integrated manufacturing systems will expand in importance. Thus, the future will be filled with the excitement of innovative change as technical, economic, and social ostacles are overcome. ◆

The author acknowledges the cooperation of Robert Berdine, Caterpillar Tractor Company, Peoria, Ill.; Joseph ElGomayel, Purdue University, Lafayette, Ind.; Watson N. Nordquist, Cincinnati Milacron, Inc., Cincinnati, Ohio; and Robert L. Moraski, CAM-I, Inc., Arlington, Tex.

Robots quietly take their places alongside humans on the production line to raise productivity—and do the 'dirty work'

Contemporary robots do not at all resemble science-fiction humanoids. But they can do much of the work still performed largely by humans, even in plants filled with automated heavy machinery. They can handle materials, load and unload, sort, stack, and do assembly operations. They can position workpieces on machines. They weld, spray, rivet, ladle, rout, sand, and grind. They can do many of the monotonous, hot, disagreeable, dangerous tasks formerly assigned to humans, as well as new tasks that humans can't do. They can work for thousands of hours with, typically, less than 2-percent downtime. Humans can reprogram robots to different tasks by literally leading them by the hand through the new routines. And the digital electronics of their control systems places them squarely on the computer-aided manufacturing scene of the near future.

George E. Munson
Unimation Inc.

It is beyond dispute that the economics of industrial productivity inevitably demand the substitution of robots for humans in an increasing variety of tasks, and indeed it is estimated that at least 3500 robots are already at work in the world, with their numbers increasing every month.

Versatile and teachable

Because robotics is such a dynamically changing field, it is difficult to attempt a definition of robot that will stand the test of time. But it is probably safe to limit the definition to this: A robot is an easily programmable manipulator with several axes of movement. This embraces a variety of such machines, all of which can be taught to perform a multiplicity of actions. Examples include the robot shown in the lead illustration and Unimate's Series 2000 robot, which has six axes of articulation: The arm can move out or in, up or down, or in rotation; the wrist of the hand can bend up and down, yaw, and swivel. Clearly, these replicate the movements of human shoulders, elbows, wrists, hands, and fingers, though obviously the rotational movements exceed human capabilities. The prime force for each movement is a hydraulic actuator. For the rotational movements, racks and gears convert hydraulic linear travel to rotary motion. The payload is 25 pounds at high operating speeds and up to 125 pounds at reduced speeds. Positioning accuracy is 0.05 inch in every dimension. Other models are available with 500-pound lifting capability.

The robot is programmed by being "led by the hand" through the sequence of operations to be performed. Playback speed is independent of teaching speed. The nonvolatile memory has capacity for 1024 program steps, adequate for point-to-point travel or continuous-path operations, such as seam welding or spraying (Fig. 1). Multiple programs can also be stored in memory and called upon at random; base and subroutines can be taught to facilitate complex tasks; program portions can be altered to accommodate external variables without interrupting operations; motions can be synchronized with moving objects, such as conveyors; and programs can be extracted from memory for external storage. Further, the internal robot com-

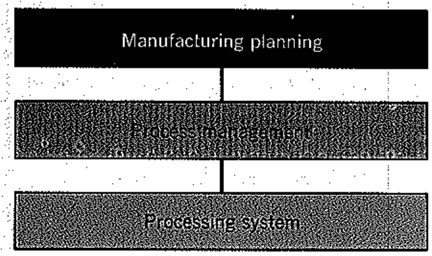
Caterpillar shop supervisors with ten to 25 years of machine-shop experience and about three weeks of intensive training became proficient at routine and elementary diagnostic tasks. One problem is that continuous higher-level software support from the manufacturing department is required indefinitely. For example, the company found that to implement some of the benefits gained from operational experience into the system would require significant changes in software configurations.

Manufacturing people generally understand best what works on the shop floor. In attempting to change control logic of a machine, it often becomes more of an effort to change software than it would be for an electrician to change the wiring in a relay panel. The technology requires highly trained professionals with competence and successful software design, debugging, and maintenance experience. Thus, a tendency is to purchase software from the NC-system supplier. Of course, users of computerized manufacturing systems with in-house software expertise have the advantage of flexibility compared with those who purchase software from the system's vendor. But how many end users have trained programmers who are involved in changing the operating program in a DNC system?

Flexible manufacturing systems

"Flexible Manufacturing Systems" (FMS) is the name given to its concept of multipart, midvolume production machining systems by the Kearney and Trecker Corporation, Milwaukee, Wis. Sundstrand's "manufacturing systems" approach is similar to FMS in that both systems employ custom-designed arrangements of various machine tools linked by mechanical parts-handling equipment, with the entire system under computer control. An FMS is also a turnkey project, as defined by the customer. The machine tool vendor must be capable of providing full floor-plan design, centralized chip and coolant systems, piece-part programming, tooling, fixturing, prove-out, and system start-up and implementation.

In any plan involving production, manufacturing planning, processing management, and the processing system itself must be treated as interrelated but individual major functions.



Computer model simulation plays a very important part in designing and utilizing an FMS. The work stations in the system may be a mix of standard NC machining centers, process-specialized machines (used, for example, to do heavy-duty or high-speed drilling), and other machine tools performing specific operations on one or more of the parts processed in the system. Washing, assembly, and inspection stations may also be included. One such FMS is located at the Allis-Chalmers Corporation's Agricultural Tractor Division in Milwaukee.

Allis-Chalmers had planned the introduction of a line of new tractors that would require the machining of eight new major castings, with planned production levels of the various castings/housings ranging from 6000 to 15 000 pieces per year. Various machining techniques were investigated, including the purchase of an individual transfer line for each type of housing, the rebuilding of existing transfer lines to handle both the old and new parts, the continued manufacturing of many of the larger castings on standard NC machining centers, and FMS. The computer-aided manufacturing (CAM) approach was selected because it best met the objectives of minimum operating cost and high flexibility, and the choice of the FMS was based on considerations that included:

1. Only two basic machine types are involved: horizontal machining centers and head indexers. If any machine were to go down, it would be possible to work around it and continue production by rearranging tooling.

2. None of the machines was designed to accommodate a specific workpiece. If sales forecasts were not met, Allis-Chalmers could retool at modest cost.

3. If the forecast of product mix was inaccurate, the system could be adjusted quickly and inexpensively.

4. The system offers a redundancy in machine control and a progressive backup capability. The machines could be operated automatically, or as stand-alone DNC machines (computer supplies tape data, as selected by the operator at the machine), or by using punched tape at each machine.

5. The system employs a simple material-handling system, already proven in other industrial applications. The cart-type system fits well into the low-overhead shops at Allis-Chalmers, yet leaves all machines easily accessible from the floor.

The system utilizes ten computer-directed machine tools, five standard Milwaukee-Matic Modu-Line machining centers, one NC rough milling machining center, and four duplex head indexers. Each head indexer stores approximately 20 heads, each randomly selectable and tooled for drilling, tapping, boring, grooving, and other needed operations. The computer-directed material-handling system carries fixtured castings mounted on steel pallets through various process loops, via a floor-mounted towline system.

The system is controlled by two minicomputers. A subordinate DNC computer performs the functions of parts-program storage, data distribution of a parts program to the machine tools, monitoring and reporting from the machine tool, and parts-program editing. The FMS minicomputer controls the DNC minicomputer, handles system control of materials, maintains status knowledge of all materials-handling system features, and locates pallets, transporters, and parts in the system. It also handles communications with the load/unload and inspection areas, performs traffic and machine-shuttle control, and monitors tool life. Communication with the system manager is via teletypewriter.

The system is capable of randomly processing eight different parts at an aggregate volume of about 20 000 parts per year. Up to 48 palletized parts can be accommodated at one time. Allis-Chalmers reports that the FMS has excellent flexibility and is particularly well suited to intermediate volume production for complex parts. However, it requires highly skilled maintenance people, particularly in the electronics area, to keep the system running.

Variable mission manufacturing

Early in 1965, Cincinnati Milacron Inc., Cincinnati, Ohio, initiated a study to find a better way to manufacture parts at production rates too high for conventional NC and too low to justify transfer-line methods. The company considered medium-volume production to be in the range of 2000 to 3200 parts per year, based on a two-shift operation. The study group evolved a plan that would:

1. Identify deficiencies in present manufacturing systems.

2. Assess the magnitude of the deficiency in terms of various levels of improvement.

3. Assess the probability of develop-

tractor-type transporters, each equipped with two cross-travelling shuttle mechanisms capable of handling two-piece parts in any combination, and capable of servicing any station in the system, thus providing in-process material handling.

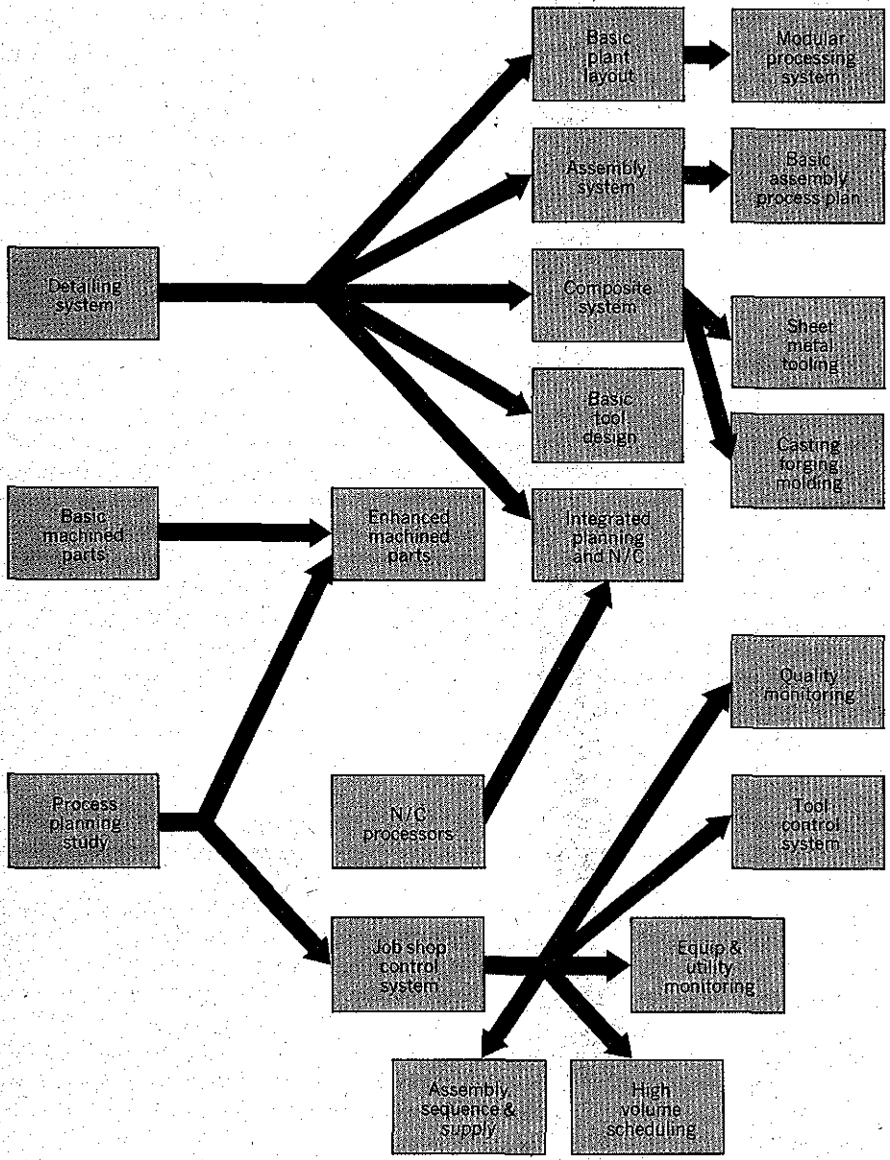
Directed by the computer, the CONCO shuttle cars also deliver parts to the DEA coordinate-inspection machine. The machines and the transporters are fully controlled by a Sundstrand Level One Omnicontrol computer system. Seven plug-in type CRT display and keyboard consoles can be used at each machine station for inputting data, or for interrogating the computer from the shop floor.

The parts being machined on this line are two families of housings for automatic transmissions. The smaller housing weighs approximately 300 pounds (135 kg) and the larger one approximately 600 pounds (270 kg). Each housing is made up of two units—a case and a cover. The units arrive at the facility in rough casting and leave as an assembled pair.

The system operates in a nearly automatic fashion and revolves around a 16-station load/unload area located midway along the line's length. The rough case and cover are manually loaded at a dedicated load station. After loading, the system recognizes the part and delivers it to the appropriate machine tool. While the machine tool completes the operations on the part, the system builds successive commands to the transporters to deliver the part to the next station. The part is processed through all machining, inspection, and refixturing operations in a similar manner. The system operates around the clock, with five operators per shift. Personnel refixture the parts, monitor and change tooling, and perform all required rework. A machine repairman and an electrician are also assigned to the line, full-time, during the first shift.

The computer performs many functions beyond the direct control of the hardware components of the system. They include an elaborate scheduling or priority system for maintaining system flow, balancing the burden of the machine tools, monitoring machine downtime and cutting time per tool in minutes, reporting on the frequency of tool changes, and counting operations per shift on each machine. A standard utility package is available with diagnostic programs for library maintenance and system backup.

CAM-I's Advanced Technical Planning Committee has developed a long-range plan for the durable-goods industry.



Wanted: supervisors with computer expertise

The Sunstrand system has been in production for about 4½ years. As expected, design errors and software bugs were uncovered and corrected during the start-up phase of this system. The most reliable component of the system was the computer, with a 99-percent-plus uptime, but other electrical problems, particularly with the transporters, had to be resolved.

Even when the system (including all the programs, hardware, and data sets) was designed to be near perfect, a significant amount of debugging had to be done on-site to make it operational. In addition to technical problems, the people involved had to learn how to manage a very complex system, from both a software and a hardware standpoint. Supervisory personnel who monitor the system require more than personnel management capability. They need experience in highly technical fields of computer hardware, systems software, real-time process-control programs, communications hardware and noise control, machine-tool service systems, computer terminals, NC processors, and machine-tool design. And they need the judgment to make difficult tradeoff compromises.

At present, there is no such array of competence in many of the companies that have ventured into DNC. To obtain the necessary experience, supervisors must be more directly involved with the machine-tool, control, and computer builders during the design, debugging, and maintenance phases of the system.

After several years of operation of its DNC line, Caterpillar feels that manufacturing-oriented personnel can learn how to handle the computer.

this last step, the computer takes over completely. Since the mask coordinates are already stored in the computer, it drives an optical beam to make a 10X enlargement of the final mask on film or an electron beam to make a life-size master on glass.

Before the computer took over, each mask layer started as a sheet of Rubylith several feet on each side. An operator cut the Ruby by hand after placing it over master layouts. Such a process could take months today, but now few cut such patterns. Even if they wanted to, there aren't cameras large enough in the world to photo-reduce the Ruby for complex patterns—a hypothetical VLSI Ruby would now be room-sized.

While the computer has interacted at many states with the designers in the mask-making process, and may or may not have contributed to the designer's decision making, it has contributed nothing to the design in any *creative* way. Nor, according to many designers, is it likely to do so in the foreseeable future.

Many companies are looking at additional ways for the computer to ease some of the burdens of design and layout error detection and correction. One such technique, which is described in the box on page 58, has been under continuous development for a number of years by designers Dave Gibson, Scott Nance, and Steve Sapiro at American Microsystems, Inc. While the system does not actually "think" for the designer, its authors say that it does help the designer to think more clearly about complex topological problems in the mask layout.

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The author wishes to thank Hisashi Takamoto of the Nippon Steel's Oita Works, Lionel Cartwright and Julius Miklosy of Inland Steel, for some of the information used in this article.

Experts look ahead to the day of the full-blown computer-integrated automatic factory

Gustav Olling Bradley University

Sweeping changes and rapid advances are taking place in U.S. industry at an ever-accelerating pace, characterized by new trends in labor and product markets. The devices, machinery, and processes of industry are continually being updated or replaced by more complex instrumentation and more sophisticated techniques. And the digital computer is helping industry automate functions to a degree not contemplated in the past.

Changes in industrial production methods have not been unforeseen. The International Institution for Production Engineering Research (CIRP—for Committee Internationale de la Recherche et Productione) conducted a Delphi-type survey among its members worldwide on the evolving technological future of manufacturing from 1975 to the year 2000. Results of the study show that one overall trend stands out: development and implementation of computer-automated manufacturing, leading to the realization of the computer-integrated automatic factory as a full-blown entity. Of the 94 forecast events in the study, 24—or over one fourth—strongly forecast such a development. Three of those 24 forecast events summarize its nature and timing:

1. By 1980 (median date), a computer software system for full automation of all steps will be in wide use.
2. By 1985 (median date), full on-line automation and optimization of complete manufacturing plants, controlled by a central computer, will be a reality.
3. By 1990 (median date), more than 50 percent of machine tools produced will not have a stand-alone use, but will be part of a versatile manufacturing system featuring automatic parts handling between stations and control from a central computer.

Problems with batch processing

Less than 25 percent of the U.S. industrial output is the result of mass production. The rest is produced by batch manufacturing, a system plagued by long lead times, high in-process inventories, low machine utilization, and very little automation. Studies have shown that, on an average, a part in production spends less than 5 percent of its time on a machine, and the rest moving or queueing between operations. And of the time spent on the machine, only 30 percent is in a cutting mode. Fortunately, most batch-manufacturing people are aware of the digital computer's potential to correct these problems.

One area in which the digital computer has found increasing use over the past 20 years is in the numerical control (NC) of machine tools. An estimated 40 000 NC machines are in use today, and NC sales are running at an annual rate of 4000 machine tools and are increasing. Many machine-tool builders are producing significant quantities of NC equipment—from 40 percent to 60 percent of their total machine-tool output. A few are approaching an output of 100 percent.

Development of NC systems is fast moving and highly competitive, and is being pursued aggressively by many control manufacturers. The result is continuous pressure for lower costs and higher reliability. Thus, the more-than-20-year-old technology of hard-wired NC controls has peaked out and has given way to computerized numerical control (CNC) with microprocessors.

Despite the fact that NC machine tools are widely used in manufacturing in stand-alone contexts, even for small shops, the proportion of NC equipment in basic industries is low. In the U. S. metalworking industry, for example, only about 2 percent of all machine tools are of the NC variety.

The main reason for the slow introduction of NC is the inability of current production management methods to utilize the potential of this technology fully. Analysis of the activities involved in keeping an NC machine tool cutting metal for its entire running time indicates that human involvement in the production process is the primary slowing-down factor.

A number of independent studies have shown that a solution is to automate as many of the production functions as possible, in the same manner as the NC cutting process. The concept of the Computer Integrated Manufacturing System (CIMS), which represents an automatic computerized job-shop section, has thus evolved.

CIMS has the flexibility of a group of general-purpose machine tools, and is composed of several NC machine tools, integrated with materials-handling systems, to perform machining operations on randomly sequenced parts. All parts of the system normally operate under computer direction. Direct labor

SLIC layout saves time

Symbolic layout of integrated circuits (SLIC) is a mask-design method that uses symbols to represent mask topologies. The symbols are converted to the mask topologies by a computer program.

Consider a simple four-mask MOS process, where the first mask is diffusion, the second mask gate oxide, the third contact cutout, and the fourth metal. The table shows a set of symbols that could be used to draw simple circuits in this process, and the color illustration shows a symbolic layout on an interactive color CRT system. (In actual practice,a more complex symbol set is used.)

Symbolic layout techniques have been around for several years, but have not gained general acceptance in the semiconductor industry.

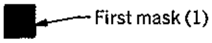
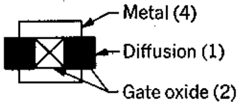
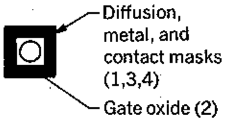
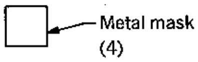
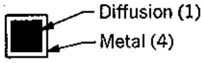
If a section of circuitry that was previously "hand drawn" is redrawn with symbols, the area used for the symbolic layout can be as much as 30 percent greater than the area required for the hand-drawn layout. This happens because the symbolic-layout designer is forced to use a coarse grid system in order to trade off area for speed.

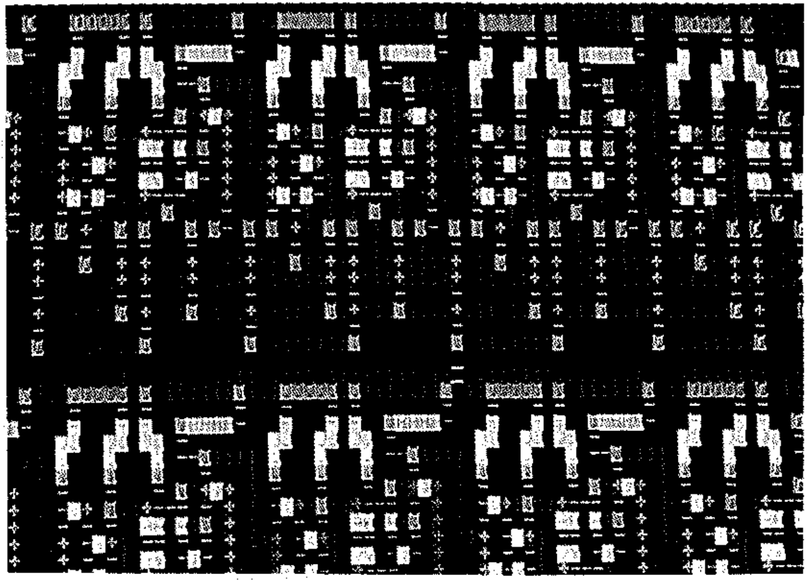
But we have found that experienced layout designers find ways of making the symbolic layout spacings work to their advantage. Since the circuit is on a much coarser grid and, rather than the many layers of the real topology, the layout designer is able to see the entire circuit, he can get a feel for how it is developing and make appropriate changes. The layout designers can "play" with and redraw a given area several times, improving the packing density each time, and still take less time than it would have taken to draw the same area once by the hand-drawn technique.

Because the symbols are very simple, very sophisticated computer-aided design programs can be used, and these do not have to deal directly with the topological complexitites until the actual masks are needed. A printer is used to print out the layouts, instead of a costly plotter. Design rule checking is reduced to checking symbol-to-symbol adjacency and location.

We have found that SLIC maintains circuit sizes, on the average, within 10 percent of the hand-drawn method. With SLIC, the time from drawing to mask generation can be cut approximately in half, compared with the hand-drawn approach, and with half the cost. The resulting circuits have no design or logic errors and require virtually no turnarounds. Tailoring of layout rules and grid sizes can reduce area loss even more.

Scott Nance
American Microsystems, Inc.

Symbol	Definition	Geometry represented by symbol
–	Diffusion	 First mask (1)
×	Transistor	 Metal (4) Diffusion (1) Gate oxide (2)
0	Contact	 Diffusion, metal, and contact masks (1,3,4) Gate oxide (2)
1	Metal	 Metal mask (4)
+	Metal, diffusion	 Diffusion (1) Metal (4)



Simplified table (left) shows how symbols replace topology. A color (right) CRT symbol display, shown here for a random-logic design, can indicate all the mask layers with a single frame.

tion for its on-line steel-automating system and the Kimitsu Works of Nippon Steel has reported a cut of 2000 workers out of 17 000 through automation. The Nippon Steel Oita plant has cut its scheduling work force in half through a program that can route 85 percent of its orders through the mill without human assistance. But Inland Steel, the leading U.S. automator, says that adding computers so far has only added people, with no work-force reduction seen for the future.

To a large extent, this paradoxical difference in the results of automation in the U.S. and in Japan may be resolved by keeping in mind that when the Japanese plants were designed to cut labor, unemployment was not, as it is today, a problem, and Japanese management was happy to employ the dispossessed workers elsewhere. Also, Inland Steel is expanding its facilities, so its total job count must go up, with or without labor-union prodding.

Computers in the semiconductor industry

While steel sells its products by the ton and the semiconductor industry by the gram, that is not really an important distinction for process automation. What does matter is that the semiconductor industry is really selling a unique product—functionality, or the number of electronic functions that can be performed by a single integrated circuit (IC). That functionality is increasing some 50 percent per year per package, whether it be logic functions or the ability to recall stored bits of information.

The major strides made by the industry in increasing functionality have been learning, as a continuing process without increasing cost, how to put more functions on a given area of silicon, and how to increase at the same time the total area of each silicon die. This discovery process has required the combined work of IC designers—whose concepts lead to the photolithographic system will wind down if peak-power premium rates are about to go into effect and will reschedule the casting cycle for lower rates.

Hierarchical control

What of the programming concepts available for implementing steel-mill automation? Referring to Fig. 1, we see that automation control these days is programmed and installed in hierarchical levels. At least theoretically, it starts at the top of level 4, with a management information system (MIS), and ultimately winds up with local machinery, valve, and furnace control loops. The last may be directly digitally controlled (DDC) or, as in premicroprocessor days, be controlled by analog electronics. Each layer controls the immediate layer below it and interferes as little as possible (except for feedback information) with any level above it.

The top level may indeed consist of a single mainframe, which all the steel companies have already installed for order-entry processing. But as one goes from the top down, the number of computers increases at each level to form an inverted pyramid of distributed processing machinery. The computers at each level "talk" to each other via either a high-speed data highway or phone link, depending on the urgency of communication.

Complete automation of a yard would require dozens of computers and hundreds of controller systems, depending on the intelligence content assigned to each. The big advantage of microprocessors at the lower levels of automation is that a microcomputer can be placed next to man and machine. In steel-processing automation, the machines can't be moved, the unions don't want the men moved, and the automation experts are willing to leave the operators just where they are, even if in the future they do less operating and more monitoring.

The basic layout of lower-level control is shown in Fig. 2 for a basic oxygen furnace. The consoles in the operator's pulpit are likely to change from analog indicators to color graphics as automation proceeds, as in the new Inland Steel blast furnace at Indiana Harbor, but the console remains in place.

The theoretical hierarchy of Fig. 2 starts with an area-supervisory computer (level 3 of Fig. 1) controlling a group of basic oxygen furnaces (BOFs). Each BOF computer, which may internally have several control layers, manages the furnace during the iron-to-steel conversion; routes input from the hot-metal and scrap yards; and controls output hot-metal ingot pouring.

At present, steel management in the U.S. decides the production scheduling strategy, and dispatchers implement that strategy by matching the incoming order stream against finished inventory, work in process, and future steel runs. If this matching is to be computerized, Dr. Williams feels that the overall strategy for decision making, based on management's input rules, has been pretty well developed with excellent linear program algorithms. But at the yard production-scheduling level, he feels a great deal of analysis remains.

The missing algorithms

Production supervision, which takes place both at levels 3 and 4 of Fig. 1, involves difficult nonlinear programming, much of it proprietary to each plant. What is involved are the kinetics of ore reduction and metal purification; energy transfer rates, equipment fouling, or jamming; and the interaction of product quality and price with processing effort. Also to be optimized is the cost of raw materials, and the price paid for fuel.

At level 3 of Fig. 1 is the production and inventory-locator program. Its job is to keep track of each piece of steel. The program is supposed to prevent a piece from being lost; it directs people to pull stock from inventory at any stage of passage through the mill and processes the stock to customer order.

Inland Steel already has a locator program on two IBM 360-168s, at its Indiana Harbor mill. The program suggests to a human yard scheduler what slab to pull from inventory, but the operators make the final decision.

Dr. Williams says, "No one has come up with a programming model for complete production supervision that can run cost-effectively on today's computers." His associates at Purdue—as well as the Japanese and at least Inland Steel in the U.S.—are working on such a model. The Oita Works reports a fairly effective one already in place.

At the lowest two levels of direct control, while specific process control languages—like those of Honeywell, Westinghouse, Texas Instruments, and others—can be used with great saving of programming time, they take too long to execute and use up too much memory space, Dr. Williams feels. So he is looking forward to another order of magnitude in DDC computer operating speed.

Present DDC computers, he says, also have too rigid a software communication interface, which makes it difficult to connect them to their supervisory computers. Even small details in language incompatability chew up a lot of program writing time at the higher levels, and Dr. Williams is hoping for industry-wide compatability of Fortran compilers, so programs written for one make of computer won't have have to be rewritten for another.

Data collection

Then there is the physical problem of collecting massive amounts of data to implement automation. To get an idea of the inventory problem, consider the stock lying around Inland Steel's huge Indiana Harbor plant, which occupies roughly a one- by four-mile peninsula jutting into Lake Michigan. The area locator has to track about 7000 ingots, 15 000 slabs, 50 000 billets or bars, and 30 000 finished products. The inventory is used to produce over eight million raw-steel tons of steel a year.

Gathering data from a single furnace is also difficult. Inland's new blast furnace has 4000 sensors, and to collect the data, the company went to a multiplex system. All sensor information is combined into a single FM time-multiplexed 50-MHz carrier on a single coax cable at a 2.5-MHz data rate. The carrier is demultiplexed by a Camac-standard microprocessor, is processed by two Westinghouse DDC computers and passed on to a PDP11-70 at the top of the control hierarchy. The CAMAC interface, which has been used extensively by nuclear physicists for hooking computers to their experiments at particle accelerators, has so far been used only by Alcoa to supervise furnace control. This interface is as good a candidate as any, according to Dr. Williams, for a standard interface badly needed by the steel industry.

The Indiana Harbor electrical designers feel that getting a good data highway with carrier rates to 300 MHz is going to be crucial to further automation.

Computer modeling of furnaces

Most steel-process-control experts agree that while the steel industry understands the steady-state behavior of blast furnaces and basic oxygen furnaces, few have a good handle on predicting how any change will affect the metallurgical quality of the yield. Even routine changing of the brick lining of a blast furnace will change performance in unknown ways.

Unlike a blast furnace, a basic oxygen furnace works in 20-minute cycles by machinery and perhaps new processes, neither of which may yet be on the drawing board.

So with these limits to analysis in mind, let us explore the present state of the computer art for both steel and semiconductor making with an eye to estimating payoff in productivity now and in the future. The big difference in required payoff between the two industries, as one might expect, is based on big differences in their growth strategies. "High flying" semiconductor makers count productivity gains by factors of two or three as impressive whereas steel makers rarely achieve gains of two or three percentage points. The other difference is that to get these big gains, semiconductor makers can install new machinery in new plants, since they are continually expanding and their machines usually cost well under a million dollars. Steel makers are more hobbled. Inland Steel, for example, unlike many steel makers is also expanding, but its new blast furnace and a coke battery are costing a cool $500 million at the company's Indiana Harbor Works in East Chicago.

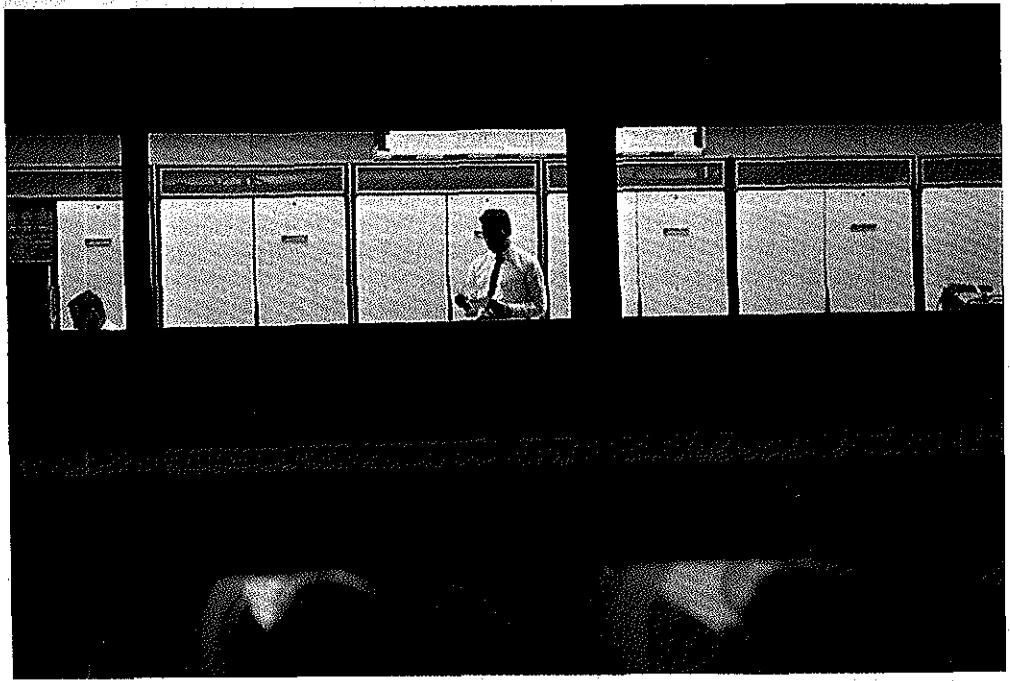
The steel industry paradoxically has had to become more knowledgeable about hierarchical computers in process control than the semi makers, who furnish the integrated circuits for every computer. Inland Steel, for example, keeps a staff of 60 programmers and hardware experts just partly automating its Indiana Harbor plant and the Japanese Nippon Steel Oita plant on the island of Kyushu is said to have put 160 programmers to work for four years to automate that operation in part.

In the semiconductor industry, while hand assembly is still the rule, and complete hierarchical control still in the future, microprocessors are used to control almost all other new processing machinery from beginning to end of the production cycle. This includes control of mask-exposure cameras, ion-beam implanters, diffusion furnaces, and various sorting, testing, cleaning, and machining operations. But in contrast to steel making, many of these intelligently controlled operations both are hand-loaded and operate independently of each other. Linking them cost-effectively with hierarchical computer control may be more difficult than for steel making, although partial automation is under study in the early production phases prior to assembly.

In the steel industry, microprocessors and minicomputers do save fuel for some types of furnaces and cut time and product waste in rolling mills, while large computers keep track of some 10 000 to 100 000 pieces of steel in various stages of production proceeding through a plant.

Computers in steel making

But sometimes, at least in the steel industry, computers are installed just to gather data to figure out what to do next to automate production.



The Westinghouse supervisory computers for the Inland Steel Indiana Harbor Works 80-inch hot-strip mill, which is shown here, control a hierarchical arrangement of other computers. One of these, a Digital Equipment Corp. PDP 11-34 controls 11 sequential roll stands and is located a quarter mile away in the motor control room.

Inland Steel's new blast furnace at its Indiana Harbor plant is the largest furnace to date in the Western Hemisphere, with some 4000 computer-analyzed checkpoints. Many of the checkpoints, however, will be used, not on-line, but by the research department to figure how to run a blast furnace more efficiently—with less energy, optimum raw materials, and less sulfur in the molten iron.

Since almost every piece of steelmaking machinery, from furnaces to rolling mills, is already under some sort of electronic control, it doesn't make a lot of sense to ask how computers are going to affect steel productivity in the U.S. without further definition of what is meant by computer automation. This was the subject of a study by Theodore Williams, head of the Purdue Laboratory for Applied Industrial Control at Purdue University.

If one means total hierarchical control of the whole process, including linking up the main office sales and inventory mainframes with the mills and furnaces, then Dr. Williams estimates a 6- to 8-percent gain in productivity, though he points out that this figure is really only an educated guess. This wouldn't produce any gleeful somersaults in the boardrooms of U.S. semiconductor firms, but that could be a telling differential after freight charges between U.S. and Japanese steel. And it also explains why the Inland Steel programmers are extending their computer systems vertically upward and downward—ultimately to forge a hierarchical chain for the company's Indiana Harbor Works.

Even if Dr. Williams is correct, that doesn't mean all steel yards are going to reach a 6- to 8-percent gain in the productivity figures. It won't be cost-effective to computerize antiquated machinery that can't be accurately controlled, and no totally new plants are in the offing, except one from U.S. Steel at Conneaut, Ohio. The Indiana Harbor Works is worth updating because, although not new, it is a blend of old and new equipment and is judged to be one of the most efficient in the U.S.

If one asks what computers can do to save energy costs in steel making, again one must pursue the matter and ask further whether the saving is in real energy (Btu's) or through the use of cheaper fuels. Many of today's steel-making, energy-saving computer programs save fuel dollars, not Btu's, by switching to that day's most cost-effective fuel or, in the case of electricity, holding off production temporarily if the mill is apmand for energy sufficiently, the demand for physical capital may also fall. So it can be argued that energy and capital are complementary rather than substitutable inputs; an increase in the price of one decreases the demand for both, for a fixed output. The results of recent research convincingly demonstrate that, on balance, energy and capital are complementary in the U.S. economy as a whole rather than substitutable inputs.

These seemingly contradicting theories can be reconciled as follows:

Engineering-economic studies consider the task to be performed as delivered energy—for example, the delivery of space heat or manufacturing process heat. If delivered energy is held constant, energy and physical capital are substitutable inputs, as shown in the graph (T_0). But they are complements when the delivered energy is allowed to vary, but the total output is held constant.

Empirical evidence on the energy-capital relationship indicates that results vary in different sectors of the U.S. economy. Both we and other authors have found that in the manufacturing area, energy and capital are complements. However, we have found that in the service sector, energy and capital tend to be substitutes. In the overall U.S. economy, the net effect of higher energy prices is to reduce the rate of capital formation—the purchase of machines, buildings, and other durable goods that contribute to the production of other goods and services—and to increase the amount of labor in production processes.

Energy and economic growth

In view of the relationships between energy and other productive inputs—capital, labor, and materials—we expect the U.S. economy to behave very differently, compared with earlier periods, as a result of the dramatic rise in energy prices in late 1973 and early 1974. The salient features of the recessions and recoveries of 1974–1977 and 1970–1973 are compared in Table I.

We see that real economic growth in the United States, measured by the growth rate of the Gross National Product over the 1974–1977 period, is a little less than in the earlier 1970–1973 recovery. But it is about average in comparison with the five other past recoveries. The GNP refers, of course, to the total output of goods and services produced by the nation. Also, the recovery of capital spending in 1976–1977 has been weak after the collapse of investment in 1975.

Another result shown in the table is that employment has grown relatively rapidly in 1976–1977. Even though the GNP grew more moderately in 1977 than in 1976, employment has continued to grow very rapidly, well above rates that characterized the recovery of 1970–1973.

Closely related is the very recent lag in growth of average labor productivity, compared to the growth during the 1970–1973 recovery. And we find that the rate of return on physical capital for the economy as a whole, corrected for inflation, has been drifting steadily downward compared with the earlier recovery.

Up to this point, we have described the demand side of the impact of higher energy prices. To provide a complete picture of the economy, we must also address the supply aspects. In the short run, when the supply of capital plant and equipment is relatively fixed, the effect of higher energy prices is to depress both the demand for capital spending and the rate of return. The table shows that in the current recovery, rates of return have deteriorated steadily compared with earlier recoveries. Moreover, a fall in the rate of return leads to decline in the rate of new capital formation and a rise in consumption. This is precisely what has happened in the current recovery—the recovery of investment in plant and equipment has been disappointing, while a rapid increase in consumer spending has led the economic recovery.

I. Two postwar economic recoveries in the U.S.

	Growth rate of Real GNP,[1] percent	Growth rate of Real Business Fixed Investment,[2] percent	Employment Change,[3] million manhours	Growth Rate of Average Labor Productivity,[4] percent	Rate of Return on Capital,[5] percent
1970	−0.4	−3.6	2.0	−1.2	3.7
1971	3.3	−0.6	1.4	−0.3	4.0
1972	6.2	9.1	1.6	3.7	4.6
1973	5.9	12.8	2.2	4.3	5.5
1974	−2.1	−0.4	2.3	−3.5	3.8
1975	−2.9	−13.2	1.6	2.2	3.6
1976	6.0	3.6	2.1	4.0	4.2
1977	4.9	8.6	3.5	2.2	4.6

1. Real GNP (Gross National Product) is the nation's output of goods and services, adjusted for inflation.
2. Real Business Fixed Investment is private sector expenditures on plant and equipment (nonresidential structures and producers' durable equipment).
3. Employment is the annual manhours of labor purchased by the nation's private sectors.
4. Average Labor Productivity is output (Real GNP) per manhour of labor input (of nonfarm workers).
5. Rate of Return on Capital is the annual percentage return on investment in physical capital, adjusted for inflation.

Turning to the supply side of the labor market, we note that as workers face greater demands for their services, wages rise and employment increases at first. This also has happened in the current recovery; most of the impact has been to increase employment. (The persistence of a high percentage of unemployment, in spite of rapidly expanding employment opportunities, is attributed to the rapid growth of the labor force.)

Outlook for productivity

In the short run, the economic effect of higher energy prices will be to boost the demand for labor and materials and to dampen the demand for capital. In the near future, then, we can expect continued growth of employment at high levels; continued deterioration in the rate of return on physical capital, compared with earlier recoveries; relatively weak growth of investment in plant and equipment; and continued strength in consumer spending.

To consider the long-term impact of these developments, we must focus on the level of capital formation, since the accumulation of capital provides the capacity for future growth of output.

Historically, gains in U.S. productivity can be attributed about equally to increases in the capital portion in production processes, through the substitution of capital for labor, and to increases in the efficiency with which all inputs—capital, labor, energy, materials—have been used. Because higher energy prices tend to depress the rate of capital formation, and thereby to reduce the rate of substitution of capital for labor, the long-term outlook for labor productivity is a slowdown in its rate of growth.

Finally, since higher energy prices reduce the rate of capital formation, the stock of plant and equipment passed on to the next decade will be smaller than in the absence of energy price increases. Because of this smaller stock, the prospects for future economic growth are also dampened. ◆

For further reading, see page 88.

the underprivileged, and aid farmers, are accused of a giveaway when they permit an inventor to retain rights to his or her own inventions?

A patent that is available free to everyone is not a patent but simply a piece of paper. If inventions produced under Government support really become useful to society only when everyone has free access to them, then one cannot support the logic for any patent system at all. Instead, society should pay an inventor a sum of money equal to so much per hour for the time spent in developing an invention and for out-of-pocket expenses and then turn the invention over to the public.

If this free-for-all procedure were seriously suggested, of course, it would provoke laughter. Yet it is exactly what is done under most Government contracts. When Government-supported R&D results in an invention, the Government should certainly get a license for its own use but everything else should be left to the inventor or the company that employs the inventor. There is no reason for the Government to keep complete rights or receive royalties.

When the Government permits a company to retain patent rights it automatically becomes a 50-percent partner in any income that accrues for that invention or any other inventions that relate to it. Actually, the total taxes on profits are much greater than 50 percent when one includes taxes on wages and sales, and taxes by the city and state. Moreover, collection on the share of profit in the form of taxes is much simpler than the collection of royalties, the defense of the patent, suits or infringements, etc.

In the private sector

It is unrealistic to propose a system whereby an inventor keeps the rights to an invention when it is made directly as part of his or her work. On the other hand, it is highly unfair that many companies demand rights to *all* inventions made by their employees, whether or not these inventions are related to their jobs. Even an invention in the same field in which the company is involved should not necessarily belong to the company since large corporations cover various fields of efforts in their subsidiaries scattered all over the globe.

A fair way to treat an employee is for the company to receive full rights to an invention made by the employee when the work is related directly to the employee's job or is related directly to the work done by the company at the place where the inventor works and when the inventor has access to the knowledge of the company's art involved. All other inventions should belong to the employee and arbitration procedures could be established to take care of those cases in which a conflict of interpretation arises ◆

How energy, and its cost, enter the 'productivity equation'

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Dale W. Jorgenson
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Energy use, economic growth, and average labor productivity are closely related to one another, and an analysis of these relationships in the United States shows that the next decade is likely to be one of reduced rate of growth of labor productivity, accompanied by a lowered rate of economic growth. These reductions can be traced to the fourfold increase in petroleum prices in late 1973 and early 1974.

To examine the link between energy use and productivity we analyzed relationships between fuel, capital, labor, and materials inputs in production tasks. Focusing initially on the first two inputs, we studied the relationship between fuel efficiency and the design of machines and equipment that use energy. The results indicate, as might be expected, that higher energy prices provide incentives to conserve energy and to increase capital spending to accomplish conservation.

We further considered the relationship between the use of fuel and fuel-consuming equipment and the use of labor and materials. Empirical evidence here shows that increases in energy prices provide an incentive to economize on both energy and capital by substituting labor and materials for fuel and equipment.

Finally, by weaving the relationships among capital, labor, energy, and materials into the picture of the economy as a whole, we arrive at the conclusion that the growth rate of labor productivity and economic growth itself are both headed downward.

Fuel-capital relationship

It is possible to calculate the minimum amount of fuel that a given piece of equipment will need to perform a specific task. The actual process of transforming both fuel and the use of equipment—"physical" capital—into the task "output" obeys a functional relationship—namely, the task is a function of both fuel and capital inputs (see graph in accompanying box). In the residential sector, the task could be space heat delivered by a furnace to a home in winter. In industry, the task could be heat delivered to an industrial process by, say, a blast furnace. Such tasks can be measured in calories (or BTUs). The quantity of fuel itself can be measured in calories or in physical units, such as tons of coal.

The capital input consists of the services performed by structures and equipment—blast furnaces, boilers, turbogenerators, pipes, insulation, heat pumps. These services can be measured in hours, months, or years of output.

As for fuel efficiency—the ratio of minimum fuel theoretically required to actual fuel used to perform a given task—it is now but 5 to 15 percent of the maximum possible value, if the Second Law of Thermodynamics is taken into account. This raises two questions: Why is present fuel efficiency so low? Can we expect it to improve in the coming decade? The accompanying graph answers the first question. It shows ($F^{\min}$) that the optimum will never be achieved without limitless capital spending.

As to the second question, that needs more elaboration. The graph (AB) shows that the factors that give economically optimal energy conservation for a given task are a combination of physical capital and fuel that will hold the total annual cost of that task to a minimum. It is useful to note that because of the recent fuel price increases, many investments in energy-conserving plant and equipment that would not have been economical in the golden age of cheap energy have become cost-effective. Further fuel price hikes would reinforce this move toward less energy-intensive (and more capital-intensive) production techniques.

Energy and productivity

We now consider delivered energy in the larger context of labor and material inputs, trying to become successful leaders of small businesses. Their task is not to have a mass gripe session about what they think is wrong with Government, but to focus positively on Government and innovation. Specifically, they are being asked to answer the question, "What options are open to the Federal government that will encourage industrial innovation in the United States at minimum cost to society and without sacrificing other national goals?"

They are not being asked to provide unfounded advice or vague generalities. They are being asked to bring the weight of their own experience to the problem, to present data, relate anecdotal evidence, demonstrate their contentions with respect to actual decisions made in firms in their industries, and otherwise exercise a judicious approach to the question. Despite our constraints and the extremely short timetable, we have had a marvelous response from the private sector. Over 300 senior executives from businesses both large and small have volunteered to work. Their response demonstrates clearly the perception in industry that a collaborative approach to this problem can generate a solution. We are particularly impressed that executives from small firms—executives with small staffs and enormous time pressures—have responded with enthusiasm.

One particular option area—patents and information policy—should be mentioned briefly. Questions concerning the functioning of the U.S. patent system, commercial exclusivity of patent rights and its relationship to small-business formation, and a host of similar questions will be addressed. I have little doubt that much of the information we receive will be of value to the Committee on Intellectual Property and Information (CIPI) as it considers its recommendations on the treatment of patents resulting from Government-sponsored research. This question has not been included in the overall study because of CIPI's current activities, but it is clearly relevant to the question of technological innovation.

We are committed to the industrial development of the United States and recognize the critical role that technological innovation and the small-business community play in that development. We are also committed to exploring how the Government can influence and encourage that development in the public interest. ◆

This article is based on a statement by Dr. Baruch before a joint hearing of the Senate and House Committees on Small Business, August 9, 1978.

How to improve the U.S. patent system, and encourage the 'middle level' inventor

Jacob Rabinow Consultant

An invention is both an artistic and an economic phenomenon. An elegant invention, like anything else that is elegant, is truly a form of art. But any invention is influenced by the technological and economic climate.

Even though I enjoy inventing, I certainly would not spend the money or effort that it takes to develop an invention and bring it to commercial fruition just for the fun of it. What worries me is the difficulty of working in the present technological and economic climate in the U.S.—which discourages invention and innovation, and the increased productivity that results from them. Of course, there are many factors that contribute to the U.S. patent situation: the patent system, corporate unwillingness to support radical innovations, the question of Government support of R&D and innovation, and the right—or lack of rights—of an inventor employed in industry.

The U.S. patent system

The U.S. patent system is probably the best in the world. Here, more than anywhere else, the inventor is its center. However, the system is not perfect. Employees of the Patent and Trademark Office are human and, on occasion, issue patents that should not be issued. Such technical errors—or errors in subjective judgment—are inevitable in the handling of approximately 100 000 patent applications, and the issuing of approximately 70 000 patents, each year.

The U.S. is the only country where the person who is "first to invent" can win an interference against other inventors who file applications on the same subject matter at about the same time. Other countries issue patents to the "first to file"—who is not necessarily the first to invent. The first-to-file approach simplifies the entire procedure and eliminates interference proceedings such as those that plague the U.S. patent system.

I am a strong believer in the first-to-invent system, but I also think that the interference proceedings, in practice, are far from optimal. A simple interference proceeding, for example, may go on for 10 or 20 years. The result is that an inventor may receive a patent that dominates a field to which he has made no contribution, a field that developed while his application was still secret. Most interferences could be handled more expeditiously and be resolved in one or two years.

A middle class of inventors

When one looks at the great technological innovations of history, one is struck by the fact that these innovations almost never come from the large laboratories of large organizations. Instead, the innovations come from what I call the middle class of inventors.

In an oversimplification, inventors can be placed in three classes. First is the basement or attic inventor, who is not highly trained technically and whose contributions are not likely to be basic or extremely important even though they may earn money for the entrepreneur.

Second, and most important, is the inventor who is highly trained technically and who does not work—or at least whose inventions are not part of his or her basic work—in large laboratories. Typical inventors in this middle class are engineers, physicists, and chemists who are either teachers, managers of their own companies, or Government workers who are permitted to keep certain inventions that are done outside of their assigned work. Or they may be inventors who work for large companies and, again, are permitted to retain invention rights for inventions in fields outside of those of their employers.

Among innovations that were the result of efforts by people outside of large corporate laboratories—the important second class of inventors—are atomic energy, computers, radar, microwave technology, the cyclotron, inertial guidance, mechanized wiring, the mercury dry cell, optical character recognition (OCR), and rockets. Interestingly, these particular inventions all came out of Government-sponsored research, mostly due to the war effort during World War II.

Other innovations produced by this "middle class" include the vacuum tube, Xerography, FM radio, lasers, penicillin, insulin, the jet engine, fiber optics, flotation glass, magnetic recording, heterodyne radio, DDT, streptomycin, the gyrocomcupations in which they can be utilized most productively. High-technology industries have increased employment at an average annual rate of 2.2 percent. In comparison, this rate has been 1.8 percent for the mixed-technology industries and an almost negligible 0.1 percent in the low-technology industries (Fig. 3).

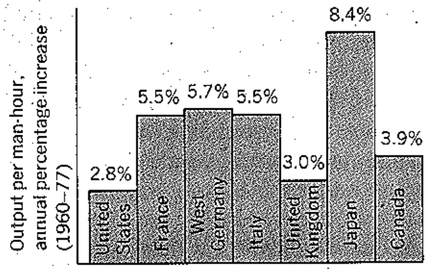
Another incipient myth is that the service sector, because of its very nature, is incapable of achieving high productivity gains. Theodore Levitt, of the Harvard Business School, summed it up nicely:

"Service has been historically assumed to be humanistic. Yet it is precisely our attachment to that ancient conception of intimacy that has for so long kept service so backward, kept it from seeking alternatives to personal attendance in solving the modern problems and approaching the new tasks to which service addresses itself.

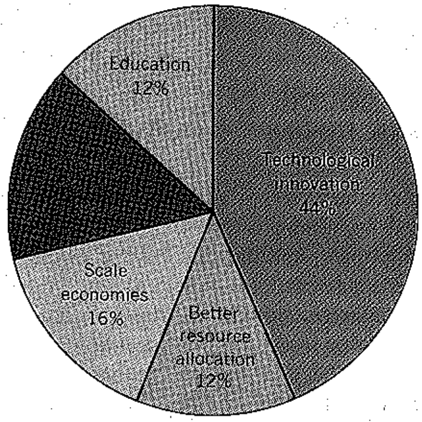
"The humanistic bias of service failed to reach out for new solutions and new definitions. It prevents the kind of thinking that might redesign the tasks themselves, that might create new tools, new processes, new organizations; that might figure out how to eliminate the conditions that require servicing in the first place."

Barriers to innovation

In the United States, the major barriers to be surmounted in the area of technological innovation include:

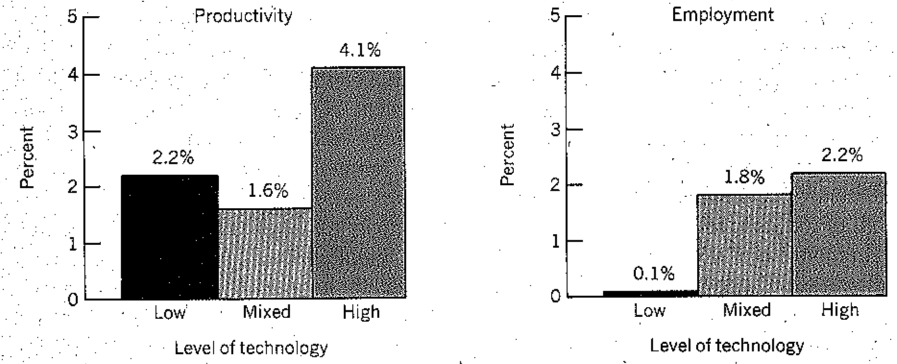


[1] Although the absolute productivity level in the U.S. remains high compared with other industrial nations, annual productivity gains in terms of output per man-hour are among the lowest.



[2] Technological innovation is the single most important element affecting productivity gains. In this Brookings Institution analysis, it accounts for almost half of U.S. increases in productivity.

[3] In U.S. manufacturing industries, productivity gains in high-technology industries have led to relatively high increases in employment. Figures shown reflect an average annual growth from 1950 to 1976.



Excessive Government regulation. The recent past has seen a massive expansion of governmental controls over the private economy. For the most part, the motives behind efforts to regulate economic activity have been well intentioned. Ostensibly, Government regulates in an effort to improve economic performance and promote individual welfare.

But regulation imposes heavy costs on society. One of these is a reduction in the rate of technological innovation. The longer it takes for a new product or process to be approved by a Federal regulatory agency, the less likely it is that new products and processes will be forth coming. For example, the main impact of drug regulation has been to delay the introduction of effective drugs by about four years and to lead to higher prices. The loss to consumers is in the neighborhood of $300 million annually.

Federally mandated cost increases have also had an unfavorable effect on productive capital formation. A growing portion of new investment in plant and equipment is being directed toward the installation of antipollution and safety devices, expenditures that do not result in modernization of existing plant or the construction of new capacity.

The United States must acquire a more realistic understanding of the limits to which social change can be brought about through legal compulsion. Legislation, litigation, and regulations may be useful for achieving some social goals, but today Government is regulating more than it can handle.

Adverse tax legislation. Increases in the U.S. capital-gains taxes in 1969 and 1976, along with inflation—which helped create a poor stock market during the entire period—have pretty much dried up venture funds from people who were willing to take high risks solely on the strength of an innovative idea. Professor Levitt reported recently in *The New York Times* that the number of high-technology companies founded annually in the U.S. declined from more than 300 in 1968 to zero in 1976.

Innovation cannot be forced by the application of funds, but it can easily strangle without them. Innovation is a fragile thing and needs nurturing during early stages, but the payoff to the economy can be large. There is a lot of untapped potential in the United States, and a lot of venture capital that has retreated to tax shelters and municipal bonds. It is essential that both potentials be tapped through the creation of an improved environment for risk taking and innovation. That is the country's best hope for the future.

Uncertain economic environment. Innovation is inherently risky. Without the necessary market opportunities and climate for risk taking, the flow of innovation will dry up.

Today's inflationary climate is extremely deleterious to innovation. Inflation creates uncertainties about future costs and returns, increases the cost capital required for the innovative process, reduces the real value of individual savings and business profits, thus contributing to the shortage of investment funds, and leads to shorter-time horizon planning.

As stated by Lowell Steele (manager of R&D planning at General Electric) in testimony before the Senate Subcommittee on Science, Technology and Space: "R&D managers report a heavy shift in emphasis to shorter-term projects aimed at incremental change and regulatory compliance. Further evidence of the shift toward shorter-term emphasis in industry is the declining support of basic research.

"According to National Science Foundation data, constant dollar funding by industry fell by 21 percent between 1966 and

Morgan Guaranty Bank in New York, which wrote in its January newsletter, "On January 27th the U.S. economy will pass the $2 trillion GNP mark. Although reaching the first trillion required over 200 years, the second trillion was added in a little over seven years....Of the second trillion, nearly two-thirds was inflation."

The essence of this issue is that while we are all familiar with the typical S-curves associated with diminishing returns and the plateau stage of many specific technologies—for example, the progression from radio and the vacuum tube to the transistor, to integrated circuits and microprocessors—we are less familiar with the idea of the scenario of diminishing returns and the plateauing of an entire constellation of technologies underpinning an entire type of society: industialism itself. There are many evolutionary pathways out of the trap—all we need to do is invent them.

Hazel Henderson

Economic growth is the realization of a kind of evolutionary potential. What we do not know is how large the potential is, and how much of it is still unrealized.

There is considerable evidence that we have passed the peak of the realization of this particular potential that created the modern world and that we are now in a period of continually decelerating growth, like a human being in late adolescence, and that unless there is recreation of evolutionary potential, which is always possible, we have entered the age of what I have called the "great slowdown."

In terms of the kind and quantity of human artifacts, the great age of change was between 1880 and 1930. When I first came to New York in 1932, I saw the Empire State and Chrysler buildings, automobiles, telephones, radios, movies, airlines. New York today, in general appearance, is not very different from what it was in 1932, 46 years ago. Suppose I had come into New York harbor 46 years before that, in 1886. I would have seen a rather charming, almost medieval city—no skyscrapers, no electricity, no telephones, no automobiles, no airplanes, with a structure of human life and human artifacts not really very different even from ancient Rome. I have seen perhaps greater social changes than my grandfather did, though I am not even quite sure of that.

The slowdown in the rate of increase in productivity in the United States, therefore, may be something that is as natural and inevitable as the slowdown in the growth of an adolescent when maturity is approached. If, for instance, Japan and Germany are growing faster than the United States, it may be that in terms of realizing their evolutionary potential they are a little younger, just as a 14-year-old boy grows faster than his 20-year-old brother or sister.

On the other hand, we cannot be quite sure of this. There may be some malformations, even social cancers, that have also stunted it. We need to look into this. What we must not do, however, is to suppose that we will grow forever. Constant rates of growth are very rare in nature and occur, approximately, only in the middle of a period of realization of potential, like adolescence. Furthermore, in maturity growth means fat and can become pathological. An increase in human-value efficiency, however, is never pathological and it is this by which we have to judge all the other things that are happening.

Kenneth E. Boulding

The industrial economies exhibit several modes of cyclic fluctuation—business cycles; investment, or Kuznets cycles; and Kondratieff cycles, or the so-called long wave. The long wave, which spans some 45 to 60 years, is closely related to what is now happening in capital plant and productivity. The latest long wave seems to have started with the depression of the 1930s. During the depression and World War II was a period of about 15 years when little new capital investment was made. By the end of World War II, capital investment was very subnormal, and economic incentives existed for increasing capital plant per worker.

In consequence, the capital-producing sectors grew to a size that could replace capital plant in a short period of time—about 20 years. Probably the U.S. came to about the right balance between capital and labor around 1965. After that, capital plant continued to pour into the economy at a high rate because of the momentum from the prior 20 years.

In spite of changing economic conditions, there has been a continuing belief that more capital plant means more productivity. Banks continued to believe they could loan successfully for new capital plant, even in industries that were showing excess capacity. Managers had developed the conviction that the road to success forever lay in more capital investment. The momentum has led to overexpansion of capital plant in most Western economies.

We are now at a point, I believe, where capital plant is excessive in many sectors of the economy. This is demonstrated by the decline of return on investment, which has been going down since 1965. It is indicated by the failure of the rate of new capital investment to come back up to the old trend line after the last recession, as has been much discussed in recent years in politics and the press.

A long wave consists of recurring cycles of capital investment. One wave culminated in the 1920s. Another is culminating now. Each capital boom of the long wave revolves around a particular mix of technology. The technology of any one wave is restricted to mutually supporting developments. Everything is interconnected with everything else. Each wave is built around a style of living and an accompanying technology that carried with it an expensive infrastructure. In time, that mix of technology is pushed as far as is practical.

Our present technology is entering the kind of mature phase that the railroads reached around 1920. We have achieved about as much from airplanes and centralized electric systems and oil technology as is reasonable to expect. When one arrives at a fully developed technology there is a huge capital investment that one does not want to extend further, but which still has a high book value so that one does not wish to throw it away and replace it with something else. That means a period of coasting, a period of using up what we have built. That period can go on for 15 or 20 years, as it did in the 1930s and '40s.

I think we are now entering a time between capital investment waves. We will use our existing capital plant until it wears out. Then, as it again becomes insufficient, there will develop a new technological wave that may be of a totally different character from the present one—which brings us to the question of research and development.

There have been political moves toward trying to solve present national problems through research and development. But what problems through what R&D? Continuing with present R&D would mean incremental improvements in products that are already showing declining return from R&D expenditure. And radical innovations that might be suitable for the future do not fit the existing infrastructure of capital plant and education. We now need to look toward the R&D that will come into its own in some 20 years. We face a hiatus in technology while we disengage from the technology of the last 30 years and learn how to engage ourselves in the technology of the year 2000. The big institutions that have been successful in chemical fibers, microelectronics, and aircraft probably will not be able to shift gears and look at a kind of technology that will be as different from today's as today's is from that of 1910.

Slowing of the rate of rise of man-hour productivity is directly related to a peaking of the long wave. Through the 1950s and 1960s, productivity rose because capital equipment per worker was increasing rapidly from a deficit condition in capital investment. But now capital-investment needs in many sectors of the economy have been substantially satisfied; more capital plant of the existing kinds does not significantly in-tion that gives rise to them. The chicken egg never produces a hippopotamus. It does not have the know-how. It only knows how to make a chicken. Paleolithic humans could never have made an automobile. They did not know how. Any particular process of production is limited by the know-how in the genetic material that originated it.

The ongoing processes of evolution, of which economic development is merely a recent example, are limited by the evolutionary potential of the system. This is a puzzling phenomenon that we understand very little. The development of an evolutionary potential, however, follows the same kind of principle as the development of the potential of an egg. It never produces exponential growth. It produces a pattern of growth, maturity, stability and eventually death.

These considerations may seem rather remote from the problem of U.S. productivity, but in fact they underlie that problem. The modern world has been developed as a result of the creation of a remarkable evolutionary potential in the rise of science and science-based technology. Science is a small, specialized subculture, specializing in the cumulative production of knowledge, especially "know-what," which is constantly translated into "know-how"—which is technology.

Kenneth E. Boulding
University of Colorado

But even if all of this is set aside, if we hold to GNP and view its decline with great alarm, even then the conventional wisdom may be completely wrong.

For example, future articles in this issue will discuss the decline of U.S. R&D—supposedly the cause of the alleged decline in "productivity." But what if it turned out that U.S. R&D was not declining? That there was no connection between productivity and R&D? And that government-funded R&D did not have much impact anyway? According to one team of researchers, that is what the evidence shows so far. . . .

Three observations recur in discussions about the performance of U.S. economic growth and about Federal actions suggested to improve the situation:

- U.S. growth and productivity improvement have both been slow throughout the past quarter century, compared with other industrial nations.
- During the past decade U.S. R&D spending first declined and then levelled off while other industrial nations have increased their R&D efforts in comparison.
- Compared with other industrial nations, R&D in the U.S. is heavily concentrated in defense- and space-related activities.

These observations have been used to support claims that the relatively poor performance of U.S. economic growth results in part from the relative levels of R&D funding, and its distribution over various industries. Such conclusions are made plausible by the widely believed hypothesis that U.S. R&D is declining and that there is a causal connection between relative international differences in R&D spending and in economic growth. The usual result is suggestions for Federal action to stimulate R&D or redistribute it throughout industry.

We set out to examine some of these assumptions by comparing international R&D levels and looking at correlations between R&D, output growth, and productivity improvement for four classes of manufacturing industries. Comparing available data is not easy, and presents problems we are well aware of. We just wanted to see to what extent the available data support the simple causal arguments that are often made on the basis of even more aggregative observations.

Our analysis indicates that arguments for Federal actions to stimulate industrial R&D cannot be based soundly on the three observations described earlier. Our data show that from 1963 to 1973, the period studied, U.S. R&D intensity in manufacturing compares favorably with that of other industrial nations. And we could find for manufacturing no clear relationship between international differences in R&D intensity and economic growth. More work can be done to see whether this is merely the result of statistical problems, or whether there is some other reason why no such relationship turned up. The point is, when we went looking for these relationships, which are widely assumed to exist, we found no evidence for them.

The relevant data usually presented show that U.S. economic performance (output growth and/or productivity improvement) during the past 25 years falls substantially short of that for nearly all other industrial nations. Taking, for example, the annual growth of domestic product per employee in constant prices in 1961–72, U.S. productivity improvement compares favorably only in the sectors of agriculture and transportation. In manufacturing, wholesale and retail trade, and public utilities, the U.S. performed less well than Canada, Belgium, France, Germany, Italy, etc. These general relationships hold across a variety of measurement and computational methods.

A decline in the U.S. ratio of R&D to GNP in absolute terms, and relative to other nations, frequently is cited as a cause of the relatively poor U.S. economic performance. From 1964 to 1973 the U.S. devoted a declining portion of its GNP to R&D, while the ratio increased in most other countries or remained constant. Since 1973 the ratio has stabilized in the U.S., and a number of other industrial countries have reduced the share of GNP that they allocate to R&D.

Interpreting these figures is not easy, however, because productivity improvement depends on using scientific knowledge and technology in production. R&D expenditures only represent the effort to generate the required knowledge and technology. Those expenses say nothing about the economic application of the results of R&D activities, or about the extent and effectiveness with which the information is applied to production. Application depends on investments in equipment, education, training, and managerial improvements, and on the willingness and incentives to change.

Also, in the aggregate, the impact of government R&D spending tends to have only a low short-term effect, since it is focused on applied R&D that goes for such public needs as defense and health. Its effect is partial and indirect, especially compared with industry, which provides the predominant near-term influences on economic growth.

These observations suggest that to look at R&D levels from one country to another we should look at enterprise-funded R&D for the manufacturing sector, where the bulk of it is found.

We picked 12 industrial Organization for Economic Cooperation and Development (OECD) nations and divided the manufacturing sector of each into eight groupings: electrical machinery and equipment; nonelectrical machinery and instruments; chemicals; aircraft; other transportation equipment; metals; food, textiles, rubber, and plastics; stone, clay, paper, wood, and other manufacturers. Then we used R&D data from the OECD International Statistical Year surveys. The first step was to establish the intensity of enterprise-funded R&D in these nations from 1963 to 1973. The results are intended as indicators of the average level and trend of economically motivated R&D. The intensity was figured by comparing the R&D expenditures with the value added, which represents a measure of economic activity or economic contribution by a sector or industry. Value added is a clearer measure of the services used to produce a given output than is gross output or sales.

Table II shows the ratio of R&D expenditures to value added in manufacturing. One part shows enterprise-funded R&D and the other part shows the total funds available to firms for R&D from enterprise, government, and overseas sources. By including the total funds, it is possible to assess the importance of government fund-

A minority report: Experts look at some of the assumptions used in traditional measures of productivity and probe productivity's impact

Tom Collins
Contributing Editor

The conventional wisdom about productivity generally consists, these days, of a lot of hand wringing about the terrible things that are about to occur because of the alleged decline in the rate of productivity growth. This point of view is well expressed by Edgar Weinberg in the previous article (p. 34), and will be taken up in detail throughout the rest of this issue.

First, however, the reader ought to be warned that not everyone agrees with any of the assumptions involved in all that worrying. In fact, a number of very distinguished people, who have been studying the matter, have come to rather startlingly different conclusions. For example, objections to the GNP have been raised. . . .

"Productivity," as measured by the output per unit of input, is both conceived and applied inappropriately to the analysis of the U.S. socioeconomy, its institutions, and its human environment. [The most widely published set of productivity statistics is issued quarterly by the U.S. Bureau of Labor Statistics and is based on gross national product divided by a measure of input labor.] Such productivity measures as this are excessively simplistic and based on the historical ability of producers to externalize costs to others—including taxpayers, municipalities, and consumers.

A typical example of misunderstanding these factors is a recent study, by Edward Denison of the Brookings Institution, being circulated by the U.S. Department of Commerce. Denison is one of the most widely quoted experts in the area of productivity. Although only part of a major, long-term study that he is conducting, his published work represents an important statement of the "conventional wisdom" on this subject, and as such is worthy of examination.

He focuses on three factors that "reduce" output per unit of input (as conventionally defined by economists). These are antipollution requirements, job health and safety requirements, and a rise in dishonesty and crime. He estimates the social costs of these factors, quite credibly, at $40 billion, or almost 2 percent of the GNP. However, this detracts attention from the systemic array of social and environmental costs already produced by our particular type of ecologically and socially incompatible technologies.

This much wider array of social costs includes many far greater than the three he cites; for example, the costs—borne largely by the public—of smoking and alcohol abuse, recently estimated at $60 billion, or on the cost of reducing sulfate and particulate levels in the air by 50 percent, which would save an estimated $7 billion by decreasing pollution-related sickness and death. Both these groups are created and "externalized" by producers.

A better approach than focusing on areas of interest to producers, rather than to consumers or taxpayers, is to plot the costs of all major sectors of the U.S. economy (including the costs borne by the public) such as those created by the tobacco and alcohol industries, rising drug abuse costs attributable to drug companies and their advertising, health costs of tooth decay and poor nutrition due to advertising promotion of oversweetened cereals and snacks, cleanup costs of polluted waters, costs of cancer related to environmental carcinogens, etc.

During the past decade, producers have been forced to internalize many of these costs through new laws and regulations, rather than continue passing them on to others as both monetary and nonmonetary costs—whether for municipal refuse collection or cleaning costs, or for ill health, stress, and environmental degradation.

"By 1975," Denison says, "output per unit of input in the nonresidential business sector of the economy was 1.8 percent smaller than it would have been if business had operated under 1967 conditions. Of this amount, 1.0 percent is ascribable to pollution abatement, and 0.4 percent each to employee safety and health programs and to the increase in dishonesty and crime. The reductions have been small in 1968–70 but were rising rapidly in the 1970s."

All Denison is saying is that under 1967 conditions, output per unit of input was overstated. He then proceeds to draw an incorrect conclusion: that we should try to focus on reducing regulations and their costs, rather than deal with the much more structural problem of identifying and modifying the particular types of socially and ecologically disruptive technologies that inevitably require regulation, and, where necessary, replacing them with more socially and ecologically compatible technologies.

By using the traditional input-output measures Denison focuses on costs to producers, including those of regulation, while omitting classes of costs not reflected in the price system or borne by others. It sounds dramatic to say that $40 billion a year is lost due to pollution control, job safety regulations, and rising crime, but that leaves out many other important socio-economic factors because of his own, often unconscious, weightings, judgments, and biases—just as economists have traditionally employed "productivity" measures that simply have overstated productivity gains for decades. Now those overdue social and environmental bills are coming due.

Also, because it is simplistically linear rather than multidimensional and dynamic, Denison's model fails to describe the systemic decline in productivity due to the rising information and bureaucratic costs of complexity in all late-stage industrial societies of Western Europe and the United States today. Those societies can only be understood in multidisciplinary terms that require going beyond GNP to one of the more holistic "quality of life" indicators like Japan's new Net National Welfare, the Tobin and Nordhaus Measure of Economic Welfare, or the Physical Quality of Life Index (PQLI) created by the Overseas Development Council.

Any of these are an improvement over the GNP, which is shockingly inappropriate as the catch-all index of general "progress" that it has become. For example, if we went home at night and all served dinner to our neighbors for a fee, and let them serve dinner to us for the same fee, and all slept at each other's houses at commercial rates, the GNP would soar. In fact, the easiest way to raise the GNP is for us all to go out and start breaking windows.

The American Economics Association, the National Association of Business Economists, and other groups have known all this for years, but have done nothing as professional societies to come up with an alternative, or to warn people that the GNP is not a sensible measure to use as an overall basis for allocating our resources. What other professional societies would so abdicate responsibility for quality control as to permit such a situation to go unchecked?

Hazel Henderson
Princeton Center for
Alternative Futures

The alternatives to the GNP just mentioned may deserve some elaboration. The Measure of Economic Welfare, which has been around for at least a decade, is not greatly different from the GNP, and by its calculations, GNP overstates gross product by about 5 percent. A more elaborate formula is used to calculate the Net National Welfare, which attempts to combine "real" different incentives, and are rewarded in different ways.

The Center concentrated on this innovation process and on the opportunities that exist at the interface of producers of new technology, potential users, and the universities, among others. Industry and university experts report a variety of barriers, which slow the diffusion of new technology. These include:

- Producers' lack of information about the specific needs of their potential customers
- Neglect of industrial marketing of innovations in management education
- The tendency for more decisions on innovations to be made by conservative financial managers of large companies who resist innovative ventures that do not pay off in a short time
- The difficulties of small firms, which have contributed substantially to technological progress, to raise capital for new projects

The lack of a close relationship between university engineering schools and manufacturing industries is also an impediment to productivity improvement. Although the supply of engineers appears to match the demand, the direction and relevance of engineering education have been questioned. According to engineering educators and industrial employers, recent graduate engineers often lack the practical knowledge needed to encourage productivity improvement at the factory level. One reason for this deficiency may be that engineering educators are rewarded more for theoretical research than for participating in solving practical problems of industry. And one interesting comparison is provided by the Japanese educational system, which involves potential engineers in industrial techniques.

Two prime targets

Numerous examples of productivity-enhancing technology that are commercially feasible have not been adopted widely because of barriers that individual firms are not able to overcome. For instance, we identified technologies in two major industries—metalworking and food distribution—as having substantial potential if system improvements could be made.

In metalworking, greater use of numerical control and flexible manufacturing systems could help raise productivity in many batch-processing firms, but adoption of these technologies is impeded by economic, social, and managerial problems that can be resolved only through closer cooperation among producers, users, and educational institutions. A report to the Center by the Illinois Institute of Technology identified as major barriers to wider adoption of new metalworking techniques the inability of a small manufacturer to analyze his operations, to estimate cost/benefits of new equipment for making his products, and to repair costly complex machinery quickly. Another study reports that the lack of an adequate system for training workers in new maintenance skills is a serious handicap to manufacturers who wish to use these productive tools.

National Center for Productivity and Quality of Working Life

In November 1975, the U.S. Congress passed the National Productivity and Quality of Working Life Act to create a national awareness of the benefits of productivity growth and to encourage initiatives for improving the nation's performance. The law emphasizes joint deliberation and action by leaders of business, labor, and the public, and success requires the commitment and contribution of each group.

Although there is general agreement about the national importance of productivity growth, people from varying backgrounds differ about the methods of achieving progress. The National Center for Productivity and the Quality of Working Life was formed on the premise that a bipartite or multipartite organization might provide a forum for reconciling these differences and for developing a consensus in support of productivity improvement.

At time of writing, it was expected that this center would be disbanded on September 30 in an Administrative Branch reorganization effort toward greater productivity.

In food distribution, modularization of shipping containers could reduce food wastage, raise truck capacity utilization, and increase productivity in warehousing. However, adoption of this simple innovation requires that grocery manufacturers, truckers, retailers, and wholesalers agree on container standards, and such agreement has so far been elusive. Significant productivity increases might also be realized if industry-wide agreement could be achieved on standard symbols for identification of the contents of shipping containers; but here again a workable consensus among food processors, wholesalers, retailers, container manufacturers, and equipment vendors has yet to emerge.

Accelerating the introduction of productivity-enhancing technology requires a broader perspective than often exists. While market forces are the prime movers of technical change, some industries need a mechanism to coordinate the various elements. In fragmented industries, no single firm can introduce certain critical operational changes without the cooperation of many others, both in the industry and outside. In such cases, careful intervention of the government—by acting only as a catalyst—can play an important role in helping those involved resolve not only technological but also economic, social, and political issues that cannot be settled through the working of the marketplace alone.

Besides innovation, a second major element in productivity is capital formation. A steady flow of capital investment is necessary for the application of more and improved productivity-improving technology. Expenditures for new plants and equipment, whether for expansion or replacement, allow the stock of capital to be modernized and more efficient automated technology to be introduced.

In assessing opportunities for increasing productivity-enhancing investment, the Center, in cooperation with a committee of business, labor, and government leaders, examined studies on the outlook for capital formation. Much of the research emphasized the importance of inflation, business uncertainty, employment instability, and the insufficient return to investment as restraints on the volume of saving and investment. A number of unfavorable trends are noteworthy.

First, the rate of growth in the capital-labor ratio since 1967 has slowed down significantly. This measure of capital intensity is closely related to the growth of labor productivity. The capital-labor ratio (i.e., the ratio of the net stock of fixed, nonfirm business capital to total employee-hours) increased at an annual rate of 3.3 percent for the 1947–67 period. The rate for the 1967–73 period declined to 1.9 percent a year, and to 1.2 percent a year for the 1973–77 period. These figures exclude investment to meet environmental standards. Economic adjustments to take cyclical fluctuations into account in the capital-labor ratio show about the same degree of slowdown.

Second, real fixed investment in productive facilities is lagging behind the 10-percent annual rate of increase that the Administration estimates is needed to bring recovery along a balanced path to full employment and to meet the capital requirements of the 1980s. The increase in 1977 was 8 percent; in the

The experience of the early 1960s demonstrated the anti-inflationary implications of high productivity growth. Price stability was achieved in the first half of the 1960s because output per employee-hour gained at the substantial rate of 3.6 percent a year, which was about the same rate of increase as hourly compensation. In the period when real hourly compensation increased at a slightly slower rate than rising productivity, unemployment gradually fell below 5 percent.

During the past decade, however, hourly compensation increased at an average annual rate of 7.8 percent while output per hour rose, on the average, only 1.6 percent a year. The result has been a 6.1-percent annual increase in unit labor cost, and about a 5.9-percent rise in prices. Compounded over a decade, a 6-percent inflation rate reduces the purchasing power of fixed incomes by almost half.

Productivity affects jobs in another way. As the historically higher rate of productivity growth offset higher U.S. wage costs, U.S. industry's competitive position in expanding world markets was strengthened, conserving domestic jobs without resorting to restrictive trade policies. However, the more rapid increase in manufacturing productivity in Japan, Germany, and elsewhere has narrowed, and in some key industries (such as steel) eliminated the U.S. productivity advantage.

Between 1970 and 1975, other countries experienced more rapid increases in hourly compensation and unit labor cost than the U.S., which diminished the advantage of higher gains in productivity. But in 1976 and 1977, the increase in unit labor costs was slower in West Germany and Japan than in U.S. manufacturing. Currency devaluation and protectionist trade policies can serve only as short-term palliatives for overseas competition. Long-term stability and job conservation depend on improving the underlying productivity growth rate of U.S. industries. To the extent that U.S. firms increase their market by improving productivity, employment in the U.S. can be increased.

The third area directly affected by productivity is standard of living. The growth of productivity is a key factor in the long-term expansion of the economy, which, in turn, enables the U.S. to raise its average level of living. In the 30 years since 1947, the real output of the nation's private business increased two and a half times. Only a small fraction of the increase reflected an increased labor force. About three fourths of the rise was accounted for by increased productive efficiency of the work force. Moreover, it will be even more urgent to maintain a high rate of productivity growth over the coming decade if the economy is to expand at its historic potential growth rate of 4 percent per year. Since the potential work force is expected to increase at only about 1 percent a year—a reflection of the steady decline in U.S. birth rates since 1960—the potential growth of the economy could fall below its historic trend, unless output per hour increases at a rate close to 3 percent a year.

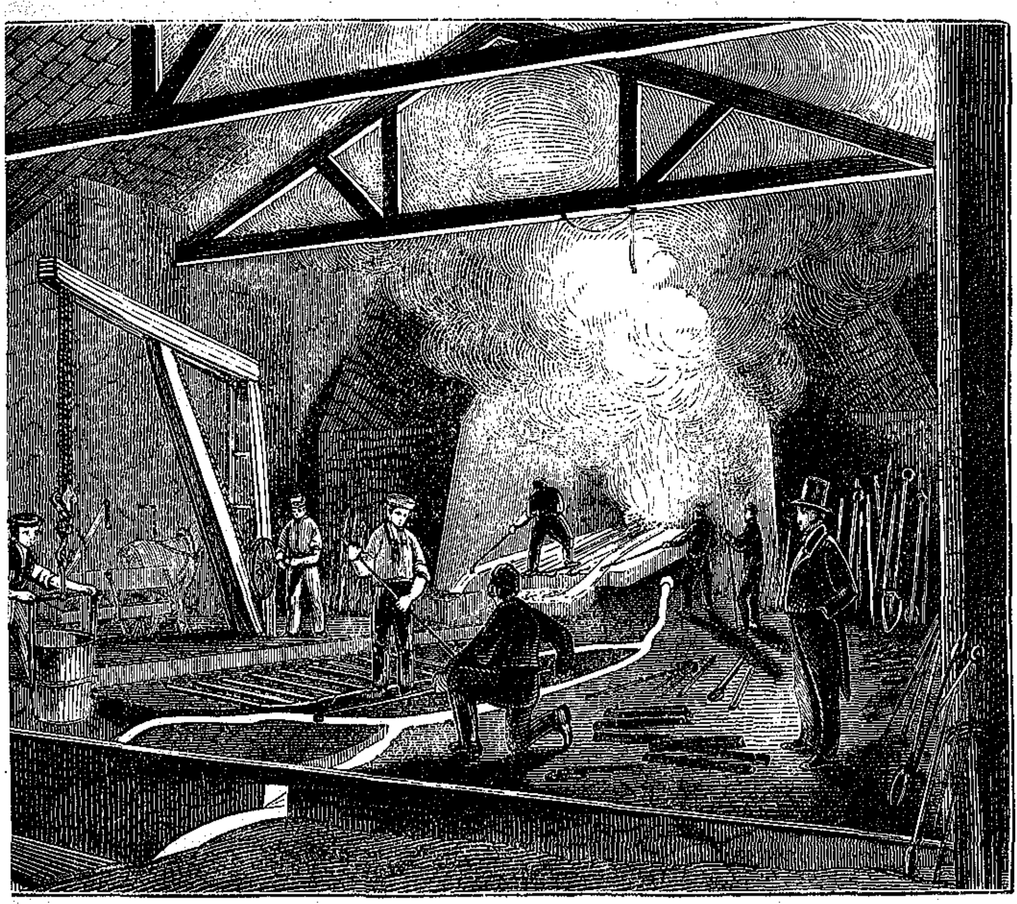
Productivity growth is even more important in accounting for the improvement in real output per person, a rough measure of the average level of living. Over the 30-year period, the hours worked per person in the U.S. declined. As a result, the entire growth in real output per person reflects the improvement in real output per hour—that is, productivity.

Economic growth has meant a better life, not only in terms of greater amounts of goods and services per person, but in their variety. And although such economic progress is sometimes associated by those critical of the consumer-oriented economy with the loss of environmental amenities, increased productive efficiency often yields savings per unit of output in scarce resources of land and water. Greater productivity is also a means to generate income that can be directed to controlling and even reversing environmental pollution, without sacrificing other economic goals.

Most important, increased productivity and economic growth could provide a basis for reducing poverty, by creating the opportunity to share in a larger real output, instead of taking income away from one group to give to another. In an expanding economy, productivity gains that are more equitably shared would contribute to a climate of industrial and social peace.

Finally, as more and more people are able to meet their material wants, they place greater value on leisure, education, health, and recreation. Historically, U.S. citizens have shared productivity gains not only by increasing the per capita consumption of good and services, but by experiencing, without loss of pay, shorter workdays, shorter workweeks, and more vacations and holidays. The reduction in labor time per unit of output has also led to extended years of schooling and a shortened worklife through pensioned retirement. A person born in 1900 could have expected to spend only 16 years doing something other than

The iron and steel industry as it existed in the 1840s at the English Butterley Iron-Works. The scene shown is taking place in the iron works foundry—or, as it was then called, the cast-house.



PRODUCTIVITY I

Defining the game and the players

Who's worried about productivity? We all should be, if we're to believe IEEE Fellows J. Fred Bucy (p. 45), Jacob Rabinow (p. 48), and Jordan Baruch (p. 47). These three men operate in vastly different environments with equally diverse concerns. Dr. Bucy, as president of Texas Instruments, is a "captain of industry"; Dr. Rabinow, chief research engineer at the National Engineering Laboratory for the U.S. National Bureau of Standards, is one of the great, independent inventors; Dr. Baruch, Assistant Secretary of Commerce for Science and Technology, has much to do with the development of governmental technology policy. But all three agree that the future of innovation is in peril.

How does this relate to productivity? Innovation and productivity form a closed loop. Without innovation, productivity growth cannot occur; without productivity growth, the capital necessary to spur innovation will not exist. And without both innovation and productivity increases, according to these men, the very quality of our lives must decline!

The following 19 pages of this special *Spectrum* issue on productivity provide a forum for expert authors to define the issues—to tell us what productivity is, how it's measured, what its growth trends have been and are likely to be, and what all this means should the trends continue without any special effort to affect them.

For the most part, this section depicts a gloomy scenario, but, in the interest of a full debate, one group of contributions (p. 40) by expert authors takes issue with the assumptions and conclusions upon which the bulk of this special issue is based—those that revolve around current fears that productivity is on the decline.

For the full effect, *Spectrum*'s editors suggest that you read the articles that follow in their order of presentation.

A call for focusing on productivity: It directly affects inflation, cost of living, job stability—and the quality of life

Edgar Weinberg
U.S. Department of Labor

In a little noticed sentence in the 1978 Economic Report of the President of the United States, the U.S. Council of Economic Advisors states that the slowdown in productivity growth in the United States is "one of the most significant economic problems of recent years." The slowdown affects almost every major issue facing U.S. citizens—the U.S. trade balance, the expansion of inflation, the number of jobs available, the very quality of life. And yet, this phenomenon has attracted insufficient attention among the nation's policy makers.

The slowdown has been underway since the late 1960s. After World War II, for the first two decades the rate of increase of output per employee-hour in the private economy averaged 3.2 percent per year; then, in 1967–77 that rate dropped by half, to 1.6 percent. The latter period did include the 1974–75 recession—the most serious of the postwar period—when production declined measurably. However, the Council of Economic Advisors and the Council on Wage and Price Stability have concluded that even when rates are corrected statistically for business cycle fluctuations, productivity growth rates for the past decade were significantly lower than they had been at any other time since the end of World War II.

Also, the slowdown was fairly widespread among industries. Approximately two thirds of the 62 industries for which the U.S. Bureau of Labor Statistics (BLS) reports data showed declines in rates of productivity growth during 1966–76. There was an absolute decline in productivity in mining of copper and coal, indicating increasing real costs (inflation corrected) of obtaining the raw materials essential to industrial progress. After two decades of rapid improvement averaging 6.8 percent a year, output per hour in coal mining during the last decade declined at a rate of 3.6 percent a year; copper mining declined at about 0.2 percent a year.

The story has been rather different in industries employing substantial numbers of electrical engineers. Output per employee-hour continued to rise at above-average rates in electric utilities, which averaged an annual increase of 3.6 percent over the 1966–76 decade. However, even this was down from the 7.2-percent annual rate for the 1947–66 period. Telephone communications recorded a 5.6-percent annual rate of increase from 1966–76; this compared with 7.2-percent growth over the 1951–66 period.

Perhaps the most often cited example of decreasing industrial productivity is provided by the plight of the U.S. steel industry. Improvement in output per hour has lagged, averaging only a 1.8-percent annual gain over the 1966–76 period, whereas European and Japanese competitors have improved productivity at a rate several times greater. By 1976, Japanese steel producers had actually exceeded the U.S. steel productivity level, and the competitive position of their U.S. counterpart has so deteriorated that Federal intervention has become necessary.

Even the fact that the U.S. is currently in a postrecession expansion does not alter the view of those experts who predict trouble ahead. As capacity utilization rates improve in the early stages of a business expansion, substantial advances in productivity can be expected. The rate of productivity growth then levels off in the later stages to the extent that the U.S. comes up against capacity constraints. So far, during this expansion, the early advances have taken place at a slower rate than during previous expansions. Further, the pro-

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"Jobs are at stake," some say. "Our very quality of life is in jeopardy." The speakers are no mere prophets of doom; their growing ranks include leaders of government, industry, and academia as well as social and physical scientists and, last but not least, engineers. The common target of their concern is productivity.

Throughout the industrialized world, productivity as measured by conventional formulas has been tailing off. It's not that the U.S., Japan, Europe, and the U.S.S.R. are reporting absolute declines, but, during the last few years, post-World War II productivity growth trends have not held up.

In the U.S., for example, productivity growth over the last ten years has been half of what it was over the previous two decades. Further, the U.S. industrial leadership position relative to that of other industrialized nations (particularly Japan and West Germany) has clearly eroded. In steel, Japan has surpassed the U.S. in productivity measured in output per employee-hour. In consumer electronics, the vast portion of subassembly work by U.S. color TV makers has shifted to such countries as Taiwan and Mexico. And even in computers—long the domain of U.S. industry—Japan is making major strides toward sales competitiveness.

Ellis Rubinstein Senior Associate Editor

But Japan itself has seen its previously unrivaled productivity growth rate founder of late and, for the first time in decades, the Japanese corporate giants have found it difficult to guarantee lifetime jobs to their employees. Similarly, the powerful West German economic machine has begun to falter. The question all this raises is: Are we merely seeing in these productivity setbacks the effects of the recent worldwide recession, or are we seeing a grander pattern based on a decline in technological innovation, a lack of farsighted economic policies, or a combination of factors?

Acknowledging the importance of the problem, *Spectrum* has devoted this entire issue to the topic of productivity. Beginning on page 34, we have attempted to define the issues—what is meant by "productivity," what evidence exists that traditional growth trends are imperiled if not already "by the board," and what key elements (social, fiscal, governmental, and, of course, technological) have an impact on productivity growth rates.

As elsewhere throughout the issue, this first section—which essentially answers the question

Scanning the Institute

Deadline is set for 1980 Fellow nominations

April 30, 1979, is the last date for nominating candidates for election to IEEE's Fellow grade for 1980. Forms for nominations, together with the "Guide for IEEE Fellow Grade Nominations," are available from IEEE Headquarters in New York City.

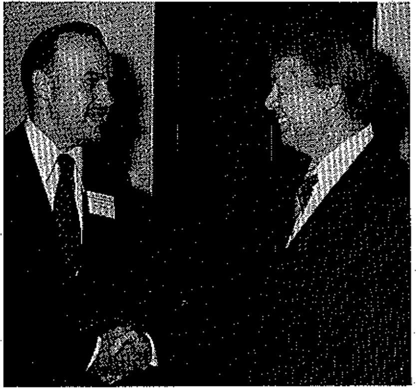
The IEEE Bylaws define the Fellow grade as one of unusual professional distinction, to be conferred only by invitation of the Board of Directors upon a person of outstanding and extraordinary qualifications and experience in the field of electrical engineering, or the related arts and sciences, who has made important individual contributions to one or more of these fields. A nominee must be a Senior Member of the Institute, and have been a member in any grade for at least five years prior to January 1 of the year of consideration.

In the Fellow Committee processing, candidates' dossiers are evaluated on a basis of nine criteria: (1) individual innovative technical contributions; (2) evaluations by an IEEE Group(s) or Society(ies); (3) team contributions resulting from leadership and management clearly identified with the nominee; (4) publications and patents, and/or other visible evidence of technical accomplishments; (5) opinions of five references (special arrangements apply to Regions 8, 9, and 10); (6) service to IEEE; (7) service to other organizations; (8) opinions of other endorsers; (9) total years in the profession.

Selections, based on the consensus of committee judgments, are submitted to the Board of Directors for consideration and election. Fellows elected for 1979 will be announced in December 1978.

The number of nominations received each year exceeds the number of new Fellows permitted by Institute Bylaws, and thus favorable action on all candidates in a given year is not possible. Such election frequently occurs in a subsequent year, however, reconsideration requires resubmission of a new nomination form. References are acceptable for two successive years.

The President discusses productivity



President Carter responded to questions by *Spectrum* Editor Christiansen regarding innovation and productivity, the subject of this special issue, at a recent meeting at the White House. The President's responses are summarized in *Spectral lines*, page 31.

Competition now open in four fellowship programs

The National Science Foundation (NSF) plans to award approximately 640 fellowships in the spring of 1979 for advanced study to help meet the need for trained scientific personnel. Application materials are now available for all four programs: NSF Graduate Fellowships (due November 3); NSF Minority Graduate Fellowships (due December 12); NSF National Needs Postdoctoral Fellowships (due November 3); and the North Atlantic Treaty Organization (NATO) Postdoctoral Fellowships in Science (due November 3).

The competition for the four programs is open to all citizens and nationals of the United States who meet the eligibility requirements. Awards are made on the basis of merit and in all fields of science, including interdisciplinary and multidisciplinary areas. The NATO fellowships are awarded for scientific study or work outside the U.S. in a country that is a member of, or cooperates with, NATO.

For copies of the announcements and application materials for the NSF fellowships, write to: Fellowship Office, National Research Council, 2101 Constitution Avenue, N.W., Washington, D.C. 20418. For the NATO fellowship announcement and application forms, contact: NATO Fellowships Program, Division of Scientific Personnel Improvement, National Science Foundation, Washington, D.C. 20550; telephone (202) 282-7154.

Views are invited on 'applying for a patent'

Recognizing that a patent application can represent technical writing at its most demanding level, the *IEEE Transactions on Professional Communication* will devote its June 1979 issue to the patent area.

In issue no. 2 next year, the editors will be looking at such topics as the concept of creativity and inventiveness, the requirements for claiming invention, and the documentation of inventions. Discussions also will cover patents as technical literature and an introduction to the Patent and Trademark Office.

Original contributions on these subjects and suggestions for others are welcome. Further information can be obtained from the editor: Dr. R. J. Joenk, IBM Corporation, P.O. Box 1900, Boulder, Colo. 80302.

Coming in Spectrum

Fuel-cell power plant. The prototype of a new electric power option, a 4.8-MW fuel-cell module, is scheduled for installation and operation on the Consolidated Edison Company of New York electric system as part of a joint government/electric utility program. It will be the first effort to apply the fuel-cell concept in a utility environment. This article describes in depth the technology behind this significant project.

Microcomputers in traffic control. Automated systems for urban traffic control have gained prominence over the past 25 years. During this period, many different types of systems and methods of implementation have been tried. This article examines one of the latest methods of implementing urban traffic control—the use of microcomputers in a multilevel distributed control system. It consists of a hierarchy of local intersection controllers, master controllers, and network processors.

Remote sensing and the Nimbus satellites. October 23 is the next available date for launch of the last of the Nimbus satellites, Nimbus 7. This article gives a comprehensive review of the accomplishments of the first six satellites in the series and what is hoped to be accomplished with Nimbus 7.

Electric quackery in medicine. Despite legitimate machines for electrical treatments in medicine, electricity for medical use is often associated with quackery. This article discusses how this bad reputation came about and gives examples of quack machines.

EE equipment in college labs. Engineering undergraduate labs across the U.S. are facing severe budgetary problems—partly due to severe inflation. As a result, engineering students, in many cases, are learning on obsolete vacuum-tube equipment with limited capabilities, or the engineering labs are shrinking. This special report presents the results of a survey of 20 top schools and a survey of industry labs for comparison.

Circle No. 35 →

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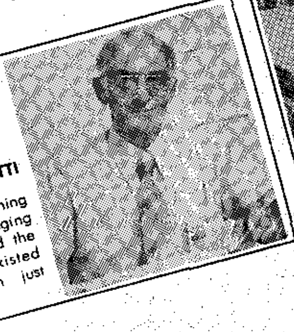

MITCH MICHELETTI

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LAURA SMITH

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EEs' Tools & Toys

Std 488 gets some fine tuning

After 3½ years of use by industry and implementation in approximately 500 products throughout the world, IEEE Std 488 is about to get a slightly new look. Experience with the digital interface standard for programmable instrumentation has shown that portions of the written text could be more clearly stated and that other minor elaborations could further improve the standard's usefulness. None of the changes in IEEE Std 488-1978—due out this month—invalidate present applications or contradict the technical concepts of the original standard published in 1975.

Exemplifying a technical change, one that broadens rather than narrows the original specification, is the increase of the driver low-state output voltage from 0.4 to 0.5 volt dc. The increased margin permits incorporation of Schottky-transistor-transistor-logic components, which were not as readily available when the original standard was published as they are now.

Exemplifying a clarification of wording is the stipulation that an END message be sent on its signal line concurrently with a data byte. The original document contained clauses that might have given the impression that an END message could be sent at other times.

In addition, the revised standard closes a minor loophole in the 1975 publication. In rare cases, it was possible for attention (ATN) and data valid (DAV) messages to coexist temporarily, with the result that an idle device could conceivably misinterpret a data byte as a command. The present standard inserts an optional term in the accept or handshake (AH) interface function as an interim standard. A final solution, involving a minor addition to the controller (C) interface function, is under consideration by an IEEE subcommittee.

The revised document costs $10 to nonmembers and 10 percent less to members, plus $2 per order (regardless of the number of purchases involved) for shipping charges. To order, write to the IEEE Service Center, 445 Hoes Lane, Piscataway, N.J. 08854.

Mammoth handbook spans entire EE field

Within its 2146 pages, *Electronics Engineers' Handbook* (McGraw-Hill, $49.50) brings together the essential principles, data, and design techniques of all the specialties that make up the field of modern electronics engineering.

Written by a corps of experts, the handbook includes practical data from many diverse books and papers along with previously unpublished information, and it covers such topics as components, circuits, equipment, assemblies, and systems. The book also contains more than 2000 illustrations.

The volume was edited by Donald Fink, a Fellow of both the IEEE and IEE (London) and former Executive Director and General Manager of IEEE. The assisting editor in this work was Alexander A. McKenzie, a Contributing Editor for *IEEE Spectrum*.

Thermal equipment program runs on printing calculator

As many energy-conscious designers have discovered, insulating thermal equipment like pipes, boilers, and heaters can be costly. The challenge is to find a balance between heat loss and insulation prices—a feat that typically requires dealing with complex equations or the use of computers.

Now there is an easier way. Consultant Marvin Dodson and Michael Wilkinson, a professor, have developed a series of programs for computing economic insulation thicknesses without the difficulty of hand calculation or the expense of a full-size computer. Designed for nearly all insulation applications, the program series is based upon the HP-97 portable printing calculator. The programs were developed from equations and data generated by the U.S. Federal Energy Administration.

For more information, or to obtain the Dodson and Wilkinson packet, including seven program cards and a descriptive booklet, contact Labor Management, Inc., P.O. Box 1172, El Dorado, Ark. 71730.

Microprocessor course offers take-home micro

Enroll in IEEE's three-day intensive workshop on microprocessor programming when it comes to your area and you can take home a working microcomputer complete with power supply at the end of the course. Designed for practicing engineers, engineering managers, and programmers, the workshop has been held at various sites throughout the U.S., and its travels have by no means exhausted its popularity.

During the first day of a workshop, the basics of microprocessors and elementary programming are covered. On the second day, indexing, tables, controllers, and numerical processing are among the topics. The third day focuses on higher-level languages and product development. Laboratory exercises are part of the schedule on each of the three days.

Each registrant receives his or her own Motorola MEK6800D2 evaluation kit, plus a preassembled and tested power supply. During the workshop, a student may select those exercises of particular interest.

Class size is limited to the first 50 registrants. Fees are $475 for IEEE members and $525 for nonmembers. (The difference between member and nonmember registration fees can be applied to IEEE membership, provided the nonmember registrant applies for membership before the end of the workshop.) The fee includes all course material, lecture notes, and manuals.

For more information, or to find out when the course will be given in your vicinity, call Vincent Giardina at the IEEE Service Center, (201) 981-0060, ext. 174/175.

New York gets the Computer Flea

Hobby computer enthusiasts in the New York area can now look forward to a monthly show and market. Beginning Sunday, October 15, the New York Computer Flea gets underway at Manhattan's Doral Inn, Lexington Avenue and 49th Street.

Intended for both the experienced hobbiest and the neophyte owner of, say, Commodore's Personal Electronic Transactor (better known as PET), the computer show will have exhibitors running the gamut from manufacturers to computer stores and sellers of used or surplus equipment. Organizers of the show expect that vendors with new hardware or software may want to use the facility as a vehicle to test the marketability of their wares.

An estimated attendance of 1000 has been predicted for the first day of the show. The admission fee is only $1; hours are 11 a.m. to 5 p.m. Subsequent shows will be held on the third Sunday of every month. For more information, write to: Robert Schwartz, 375 Riverside Drive, New York, N.Y. 10025.

Loyal employee: 45 years with one company

The saga of how giant, multinational Philips developed from a modest maker of light bulbs to its present prestigious leadership in electronics and electrotechnology is told by the chairman of the board of governors of its holding company, Frederik Philips, the only son of founder Anton Frederik Philips. The vehicle for the telling is an autobiographical account, *45 Years With Philips*, just published in English by Blandford Press.

The 280-page, hard-cover volume contains some 48 pages of photographs, many of them recording personal events in the life of the author. The volume is hardly a recipe for building an industrial empire, although Dr. Philips is clearly a firm believer in capitalism and free enterprise as he acquaints the reader with the problems Philips has encountered in technology, labor relations, pricing, and marketing. More important, one gains insight into Frederik Philips—engineer, cartoonist, antique collector, family man, and last, but far from least, "company man."

Data Corporation as an example of microprogrammed emulation—the AYK-14 emulating the YUK-20.

The YUK-20 referred to is, in fact, the Sperry Univac UYK-20—which also uses microprogrammed emulation. It emulates the Univac 1616 and, in addition, provides many new functions.

K. E. Warhol
Univac Field Service
Subic Bay, Philippines

Review corrected

In the review of the book, *Future Developments in Telecommunications* (Sept., p. 78), the words "geostationary" and "geosynchronous" were inserted in error in the last sentence of the fifth paragraph by the *Spectrum* staff. The paragraph should have read as follows:

The first is his statement that "There are many frequency allocations ... for geosynchronous (fixed) communications satellites ..." This statement can be confusing or misleading to the unwary reader since it implies that the allocations are only for those satellites that are fixed with respect to the earth. Actually, the allocations can be used both by satellites that move with respect to the earth (e.g., the Russian Molniya satellites) and those in geostationary orbit. The use of the word "fixed" in the allocation table that Mr. Martin is discussing refers to the earth stations that are at fixed locations as contrasted with mobile earth stations.

Patent rights

The articles on inventors' rights and patent legislation (Mar., pp. 54-59 and 60-64) are the most complete I have seen in any IEEE publication, and they also have the merit of looking somewhat beyond U.S. frontiers.

For anyone seeking patent rights in other countries, the International Patent Research Office (Stuyvesant Straat 120, The Hague, Netherlands) supplies comprehensive information on the procedure for patent registration in almost any country in the world.

Giorgio G. Muller
Sao Paulo, Brazil

High achievers

Heavy readers are high achievers, wrote Hans Jenny in the September issue (p. 66). He based this conclusion on the results of an RCA survey of its engineers and their supervisors. Constructed for the survey was an achievement index designed to produce a distribution of respondents ranging from high achievers to low achievers. It was this distribution that enabled Mr. Jenny and RCA to conclude that the two extremes had statistically different reading habits.

For lack of space in that article, *Spectrum* was unable to include Mr. Jenny's caveat regarding the achievement index. He writes:

"The achievement index constructed

another question. Mr. Bachelet will doubtless *leave that to the railway engineers* to settle." (emphasis added)

Perhaps this will add some historical perspective to the consideration of a 64-year-old "new technology."

A note on the source: The *Annual* is an omnibus edition of the *Boys' Own Paper*, a somewhat jingoistic British youth journal that ceased publication in the 1960s. My copy of the 1914 edition (a gift from an uncle) is now in London, England. It contains stories by Jules Verne, such as the original, serialized versions of "Master of the World" and "Robur the Conqueror"; and instructions on how to build a crystal set, including the "condenser" of sheet metal.

Ray W. Nettleton
Purdue University
West Lafayette, Ind.

Simple SSB

Bruce Lusignan's "Single-sideband transmission for land mobile radio" (July, pp. 33-37) shows what can be done with relatively simple equipment. The results, although preliminary, do indicate the practical possibilities of spectrum conservation and signal-to-noise ratio enhancement using bilateral speech-processing techniques.

Of particular note is that relatively inexpensive equipment, designed for use on the Amateur Radio Service, was used for this survey. Indeed, the 2-meter (144-148-MHz) Amateur Radio Band was utilized for on-the-air tests. This demonstrates once again the usefulness of the Amateur Radio Service for experimentation and is consistent with its history of furthering the communications art. I hate to think what the costs of these tests would have been using custom-made equipment, not to mention the additional bureaucratic red tape that would be involved in securing special authorizations from the Federal Communications Commission.

Then too, how many EEs got their start in electronics, sometimes at a tender age, at the Morse key!

John F. Sehring
WB2EQG
Oradell N.J.

Unfunded testing

An item in "Best bits" (July, p. 23) describing work on neurobehavioral testing at Vanderbilt University erroneously attributed funding to the National Cooperative Dialysis Study, when, in fact, this work was largely unfunded. Partial funding came from NIAMDD for development of a Sternberg test system last year.

John R. Bourne
Professor of Electrical and Biomedical Engineering
Vanderbilt University
Nashville, Tenn.

Emulation

The article on "Computers: consolidating gains" (Jan., pp. 26-30) cites the AYK-14 developed by the Control

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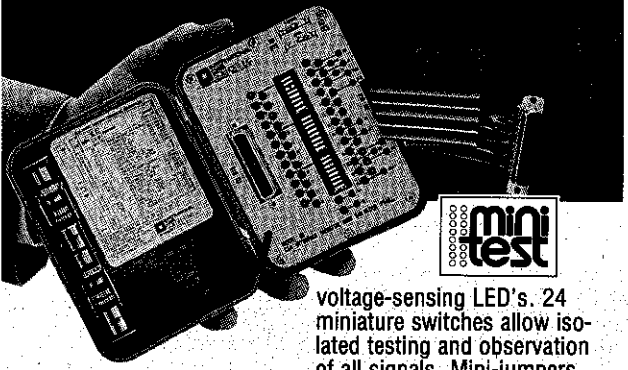

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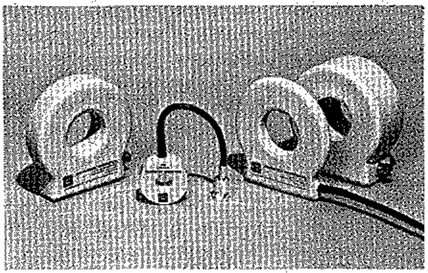

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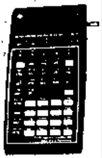

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Forum

Readers are invited to comment in this department on material previously published in IEEE *Spectrum*; on the policies and operations of the IEEE; and on technical, economic, or social matters of interest to the electrical and electronics engineering profession. Short, concise letters are preferred. The Editor reserves the right to limit debate on controversial issues.

AM stereo: pro Kahn

As suggested in the article on AM stereo systems (June, pp. 24-31), I wish to indicate my preference among the five competing options described. My vote goes to the Kahn/Hazeltine ISB system.

Based on my long experience in the development of FM multiplex systems, including the first FM stereo broadcast system in 1950, and as a proponent of one of the five FM stereo systems tested and evaluated in the early 1960s, later adopted by the Federal Communications Commission (FCC), I feel that there are good reasons for selecting this system for public broadcast service.

My choice stems partly from the fact that I have often heard AM stereo programs broadcast by XETRA, a 50-kW station in Tijuana, Mexico, that has been using the Kahn system for a number of years. In driving between Los Angeles and my home in Woodland Hills, Calif., about 30 miles west of the city, as well as in driving from Woodland Hills to Santa Barbara, about 50 miles in a northwesterly direction from my home, I have noted that the stereo broadcast signals from XETRA as received by my monophonic receiving equipment have an outstanding audio quality and are, in my opinion, superior to program signals from any of the AM-type stations in Los Angeles. And when I use a low-cost portable AM receiver to supplement my AM car radio and home receivers...the stereo separation of the XETRA signals is very effective and greatly adds to the overall program quality.

One of the main reasons, however, for my preference for the Kahn system is that at the outer limits of the receiving locations I have described, averaging about 150 airline miles from XETRA, the use of two single sidebands as employed by that system avoids the serious fading and distortion problems that can occur between sundown and the night hours in the transition from ground-wave to sky-wave modes of radio signal transmission. During those hours, I have noticed no adverse effects on stereo broadcasts from XETRA. Stereo signal quality also is described as excellent in reports on the performance of the Kahn AM stereo system at very long distances, as between Tijuana and Alaska, during nighttime hours.

It is unfortunate that Mr. Kahn did not participate officially in the proceedings of the National AM Stereophonic Radio Committee. I know, as a result of my own experience with the National Stereophonic Radio Committee (NSRC), how costly and time consuming these proceedings can be, especially for small firms like Mr. Kahn's. My firm, Multiplex Development Corporation, was also very small. Such problems were not a factor for General Electric and Zenith, whose FM stereo systems were proposed during the NSRC proceedings. Mr. Kahn rightfully states that his AM stereo system has been in successful public operation for many years, and the FCC has a large quantity of test and measurement data in its files as a result of experience with his system.

William S. Halstead
Telecommunications Consultant
Woodland Hills, Calif.

A matter of degree

The "Spectral lines" entitled "So you're an engineer. But what do you do?" (June, p. 23) hits me where it formerly hurt. It begins with the assumption that the reader is an engineer. How has this been determined? A common definition is the possession of at least a B.S. degree in some field of engineering, in addition to several years of work experience.

For 25 years I held a position described by my employer as "electrical engineer." I obtained this job on the basis of experience and skill in the fields of radio and electronics, which I was able to translate into industrial electronics work. I did not have a B.S. degree of any kind and my compensation reflected this deficiency, which was my own fault. When the state of California started to register electrical engineers, I applied under the "grandfather" clause, but was not accepted. Since I was qualified to do so by my experience, I took—and passed—the written examinations and was registered as a professional engineer.

I soon discovered that registration was not considered an acceptable substitute for a B.S. degree. This was true, I believe, because many expert and well-qualified electricians were able to obtain registration as professional electrical engineers under the grandfather clause. As for a happy ending: I resigned from my job, returned to college on a full-time basis, and in three years earned an M.S.E.E. degree. I then was able to obtain a position suited both to my knowledge and experience.

John P. Isaacs
Long Beach, Calif.

Engineers and public policy

Although I am a mechanical engineer, I read *Spectrum* regularly. It inevitably contains articles of technical and professional interest to all engineers, such as that by Myron Tribus on "The engineer and public policy-making" (Apr., pp. 48-51). Dr. Tribus makes many perceptive and accurate observations, and his material is well written, with humor and logic properly blended.

Engineers do have much to contribute beyond the mere performance of their daily jobs. They are not unique saviors of society nor are they wiser than other groups, but in a world built upon technology and needing a bit of rational thinking amid the emotional turmoil, engineers are conspicuously absent from society's decision-making processes.

I've heard one definition of the word "expert" as a person who can give all the reasons why something cannot be done. Who ever came up with that definition must have been thinking of engineers. Engineers tend to gripe among themselves about how badly they are treated, how they are unrecognized second-class professionals how the country is going to the dogs, and so on. Yet few of them demonstrate any initiative to go out and do something—anything. They prefer to remain private little "experts."

With the increasing recognition, ponderously slow though it may be, of these views by the engineering societies, and some small growth in the engineers' interest in society and in engineering professionalism, things may improve. If they can stop being smug, living room experts, and overcome some laudable but overdone attitudes that have become weaknesses, engineers can use their strengths to benefit both themselves and society. I have some honest doubts that this will come about, but I can hope.

Brian G. Boden
Madison, N.J.

Maglev circa 1914

The recent correspondence (Feb., p. 10; July, p. 8) concerning magnetic levitation (Maglev) transportation systems has, in general, tended to imply that the idea is new. However, there is evidence that the concept (including working models) is actually at least 64 years old.

An article from the *Boys' Own Annual*, published in England in the winter of 1914, asserts that the "levitated railway," using electromagnetic energy for both levitation and traction, was invented by an Emile Bachelet, and describes a public demonstration of a working model. From the photographs, it is clear that Mr. Bachelet's "railway" is none other than the currently proposed "new technology" turned inside out; the levitating and propulsive coils are part of the guide, leaving the vehicle as the passive element.

The most piquant part of the article, viewed in retrospect, is the following quote: "The 'levitated railway' is said to be *so far perfected* that a mile of line, on which cars capable of carrying 100 pounds of mail matter might be run at 300 miles an hour, could be built *within three months.* Whether this wonderful invention can be developed so as to become commercially feasible for a service of passenger or goods trains is

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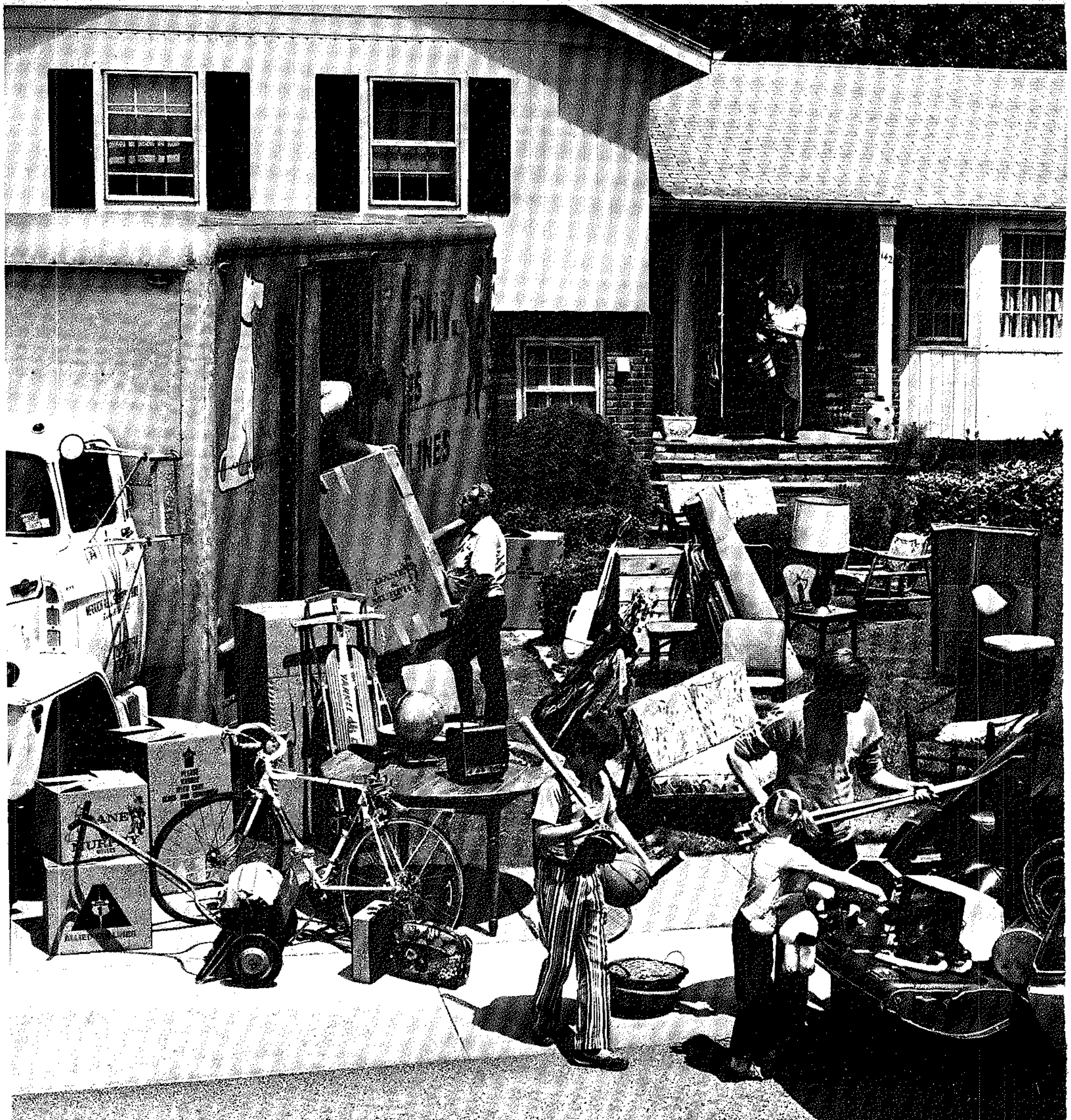

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Energy report

The authorization bill for the U.S. Department of Energy, which covers the coming fiscal year, is being held up in the Congress. The bill is awaiting resolution of the natural-gas part of the energy bill that was developed by Congress as a result of the President's energy plan. Two other portions of the energy plan involving utility rate reform and energy conservation are expected to pass without difficulty. The energy bill in its entirety was not expected to reach the U.S. Senate before some time this month, and it is questionable as to whether either bill will be acted on this year.

A new transmission line now interconnects the power systems of Con Edison (New York City) and the Long Island Lighting Company. Spanning some 28 km underground and underwater between the LILCO substation at Glenwood Landing in Nassau County, N.Y., and Con Edison's Dunwoodie substation in Yonkers, the line comprises a 345-kV cable, with a power-carrying capacity of 900 000 kilowatts. The new intertie is expected to increase the reliability of electric power supply for both companies' customers--close to four million people. It is also expected to result in some savings to both the companies and their customers by facilitating purchases of cheaper power from other utilities in the New York Power Pool. The total cost of the project, which was started in 1974, was $75 million.

The British success in electric load management--the process of altering the pattern of electricity use--can benefit other utilities and customers, as well as manufacturers of appliances. That was the tenor of a seminar given last month in four major cities in the U.S. by the British Electrical and Allied Manufacturers Association, in conjunction with the Electricity Council of London, U.K. That success is primarily attributed to 20 years of successful marketing in Britain of space and water heating systems that have thermal storage and use "off-peak" electric power at reduced rates. More than 2.3 million storage-heating systems are now installed in Britain, and the use of off-peak power in that country has increased from 0.3 GW in 1956-57, to 17 GW in 1976-77. That led to the improvement of the load factor of the power system in Britain from 48 to 57 percent during the same period. (Load factor is defined as the ratio of the average load on the power generating equipment over a designated period of time to the peak load occurring in that period.)

Combustion tests with synthetic liquid fuel derived from coal--a potential alternative to conventional petroleum--took place last month at the Con Edison generating station on 74th Street in Manhattan. Sponsored by the Electric Power Research Institute, the tests involved burning the fuel continuously for periods of up to ten hours over a five-day period. Data were taken on emission parameters such as NO_x, particulates, opacity of smoke, carbon monoxide, and oxygen. In addition, the combustion was qualitatively examined via television cameras. The data will facilitate a comparison between the synthetic fuel and conventional petroleum, from combustion and emission viewpoints.

A new installation for research in nuclear fusion was dedicated last month at the General Atomic Company in San Diego, Calif. Sponsored, in part, by DOE and EPRI, the facility is based on the principle of confining hot plasma by magnetic fields. It employs a vacuum chamber with a peanut-shaped rather than circular cross section, a configuration that is expected to reduce the power requirements of future reactors.

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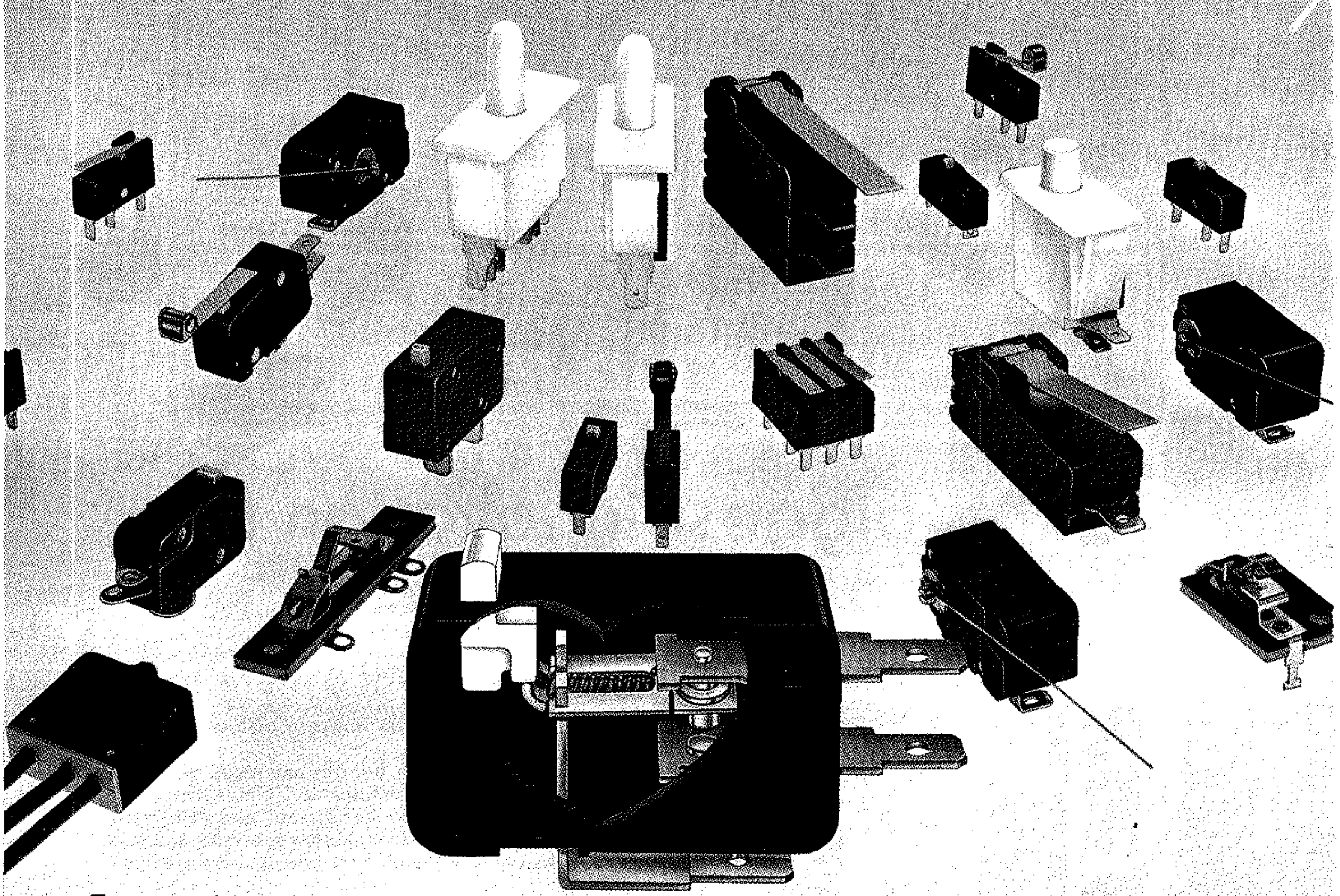

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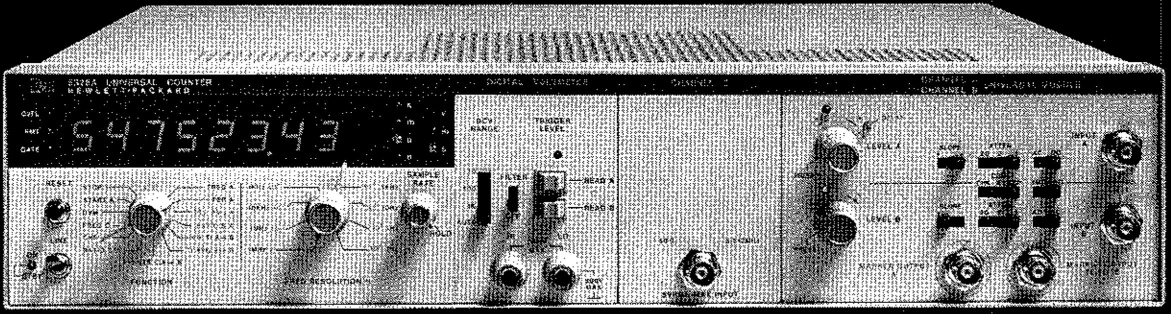

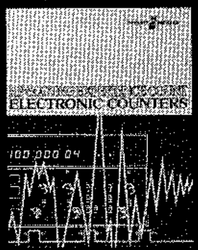
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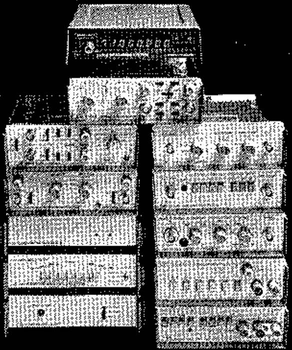

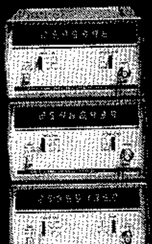

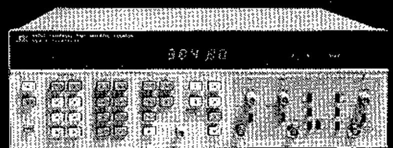

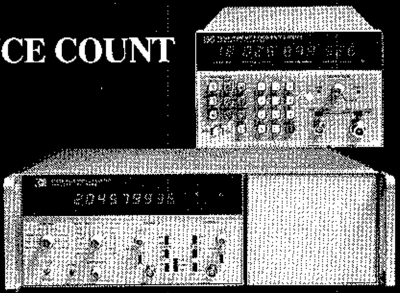

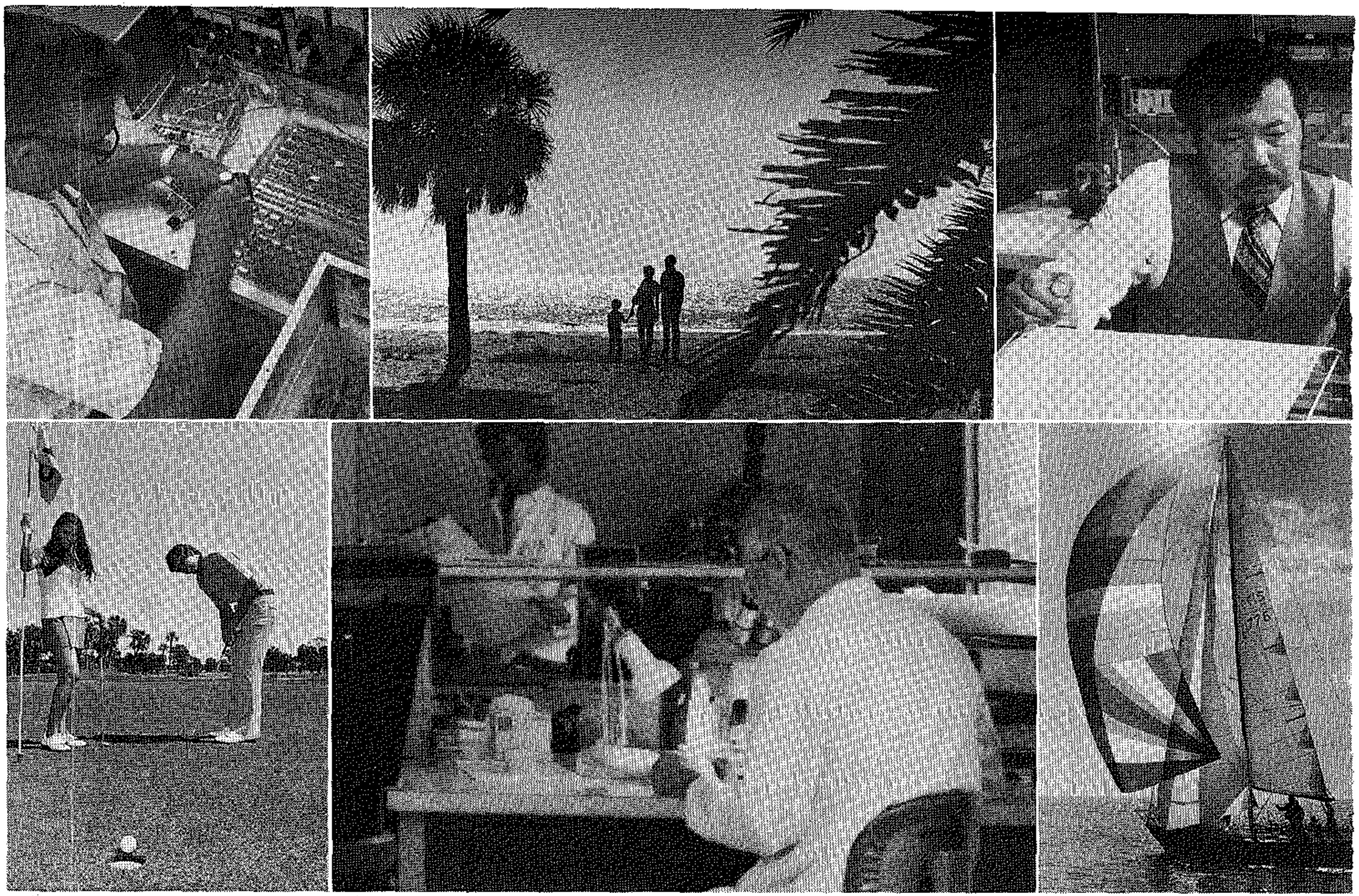

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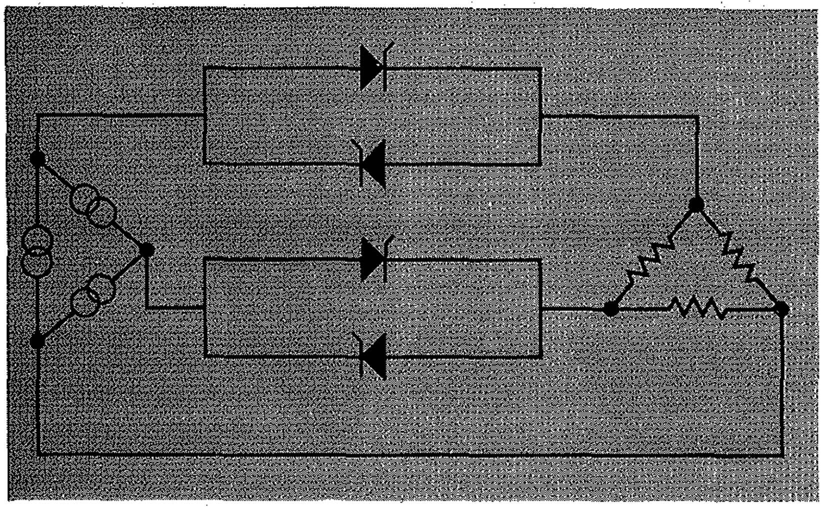

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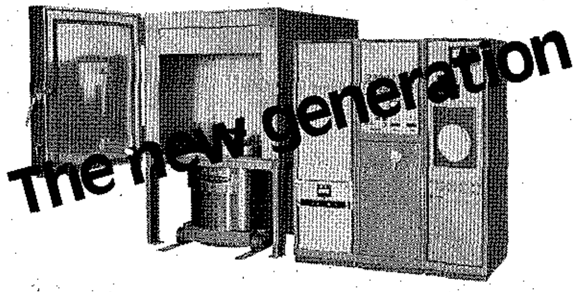

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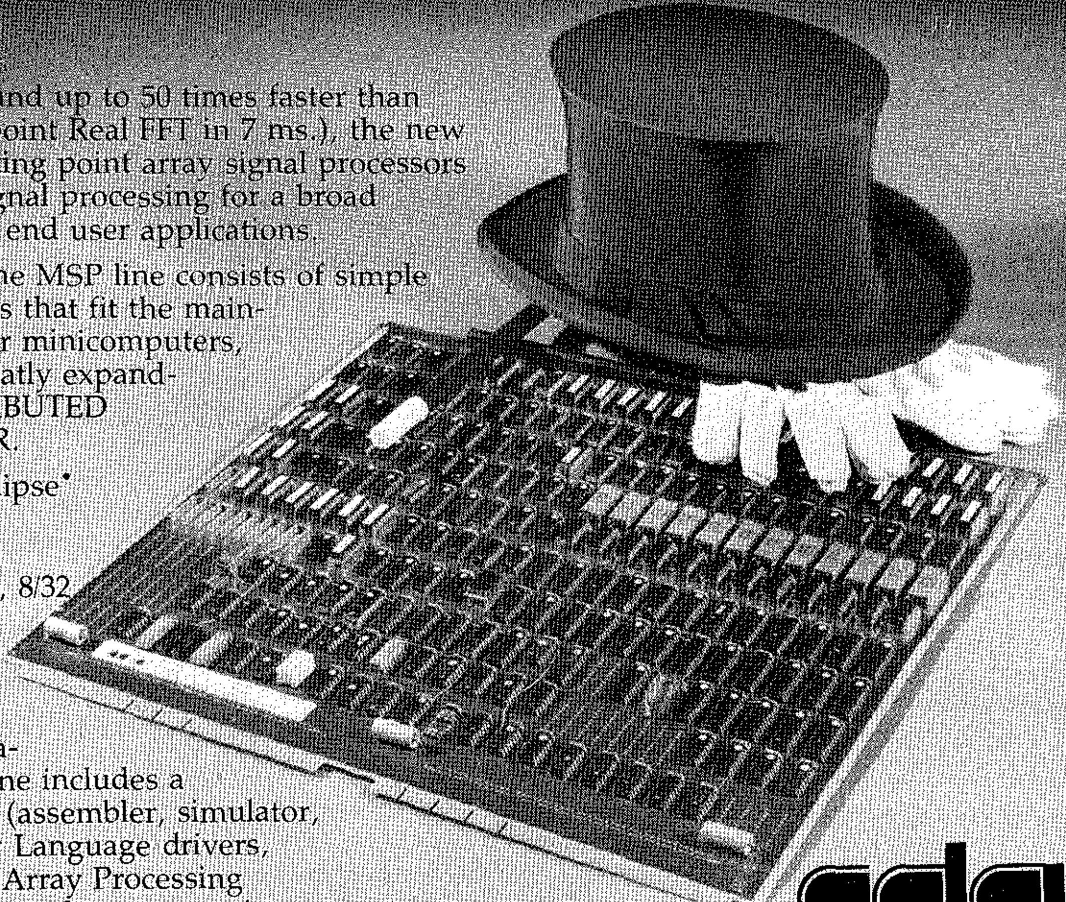

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