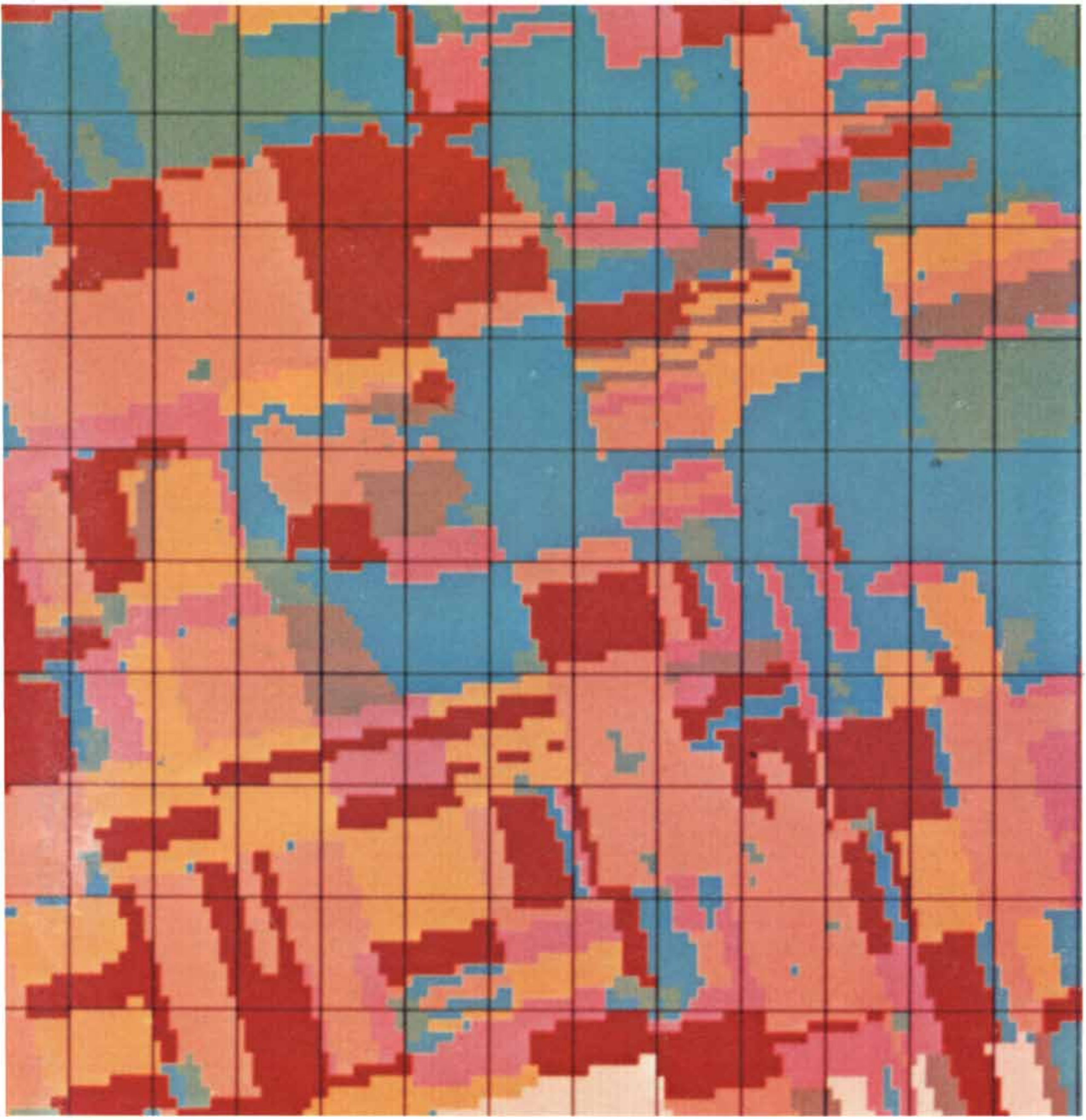
SCIENTIFIC AMERICAN



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September 1980

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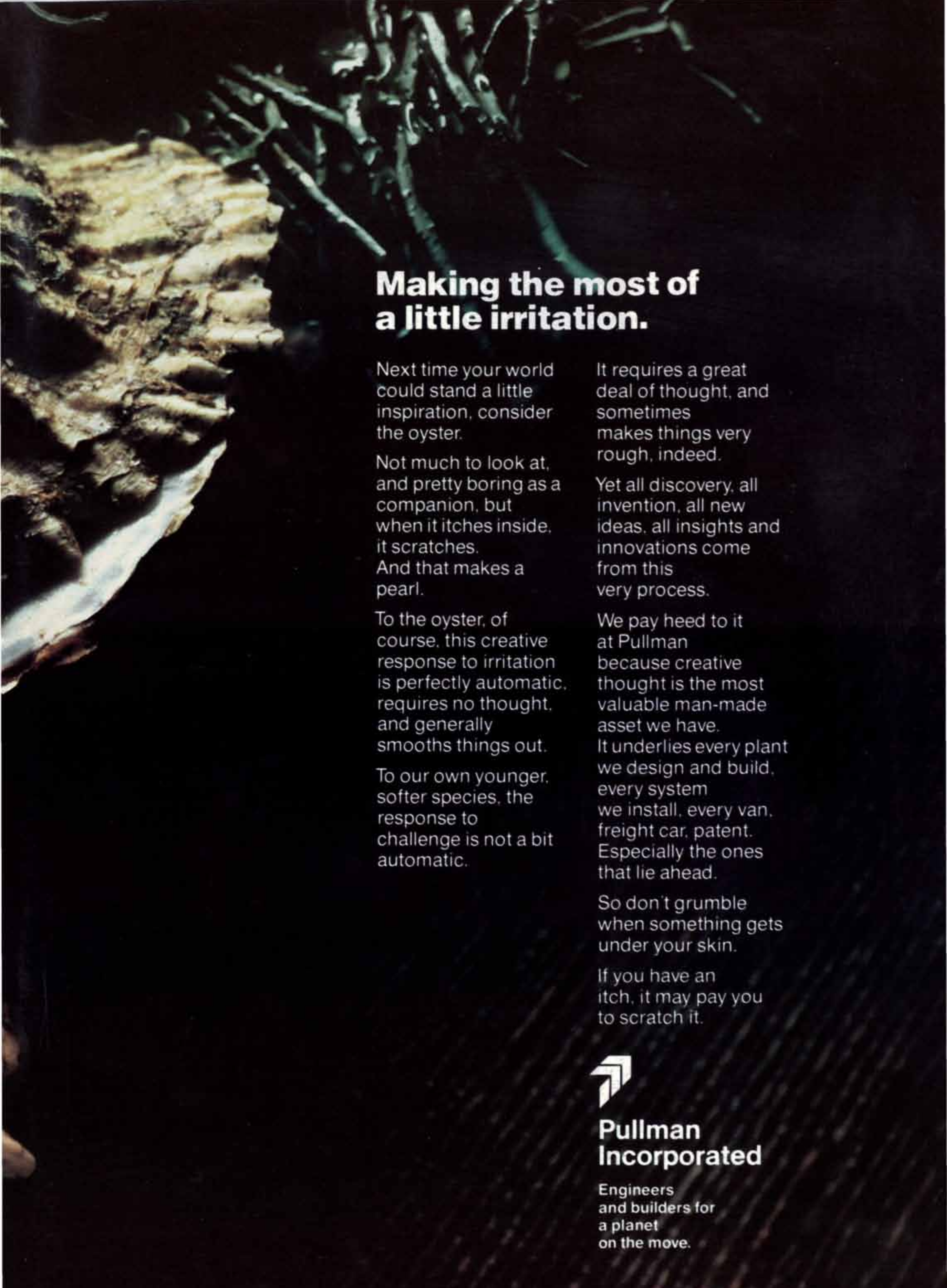
Making the most of a little irritation.
Next time your world could stand a little inspiration, consider the oyster.
Not much to look at, and pretty boring as a companion, but when it itches inside, it scratches. And that makes a pearl.
To the oyster, of course, this creative response to irritation is perfectly automatic, requires no thought, and generally smooths things out.
To our own younger, softer species, the response to challenge is not a bit automatic.
It requires a great deal of thought, and sometimes makes things very rough, indeed.
Yet all discovery, all invention, all new ideas, all insights and innovations come from this very process.
We pay heed to it at Pullman because creative thought is the most valuable man-made asset we have. It underlies every plant we design and build, every system we install, every van, freight car, patent. Especially the ones that lie ahead.
So don't grumble when something gets under your skin.
If you have an itch, it may pay you to scratch it.
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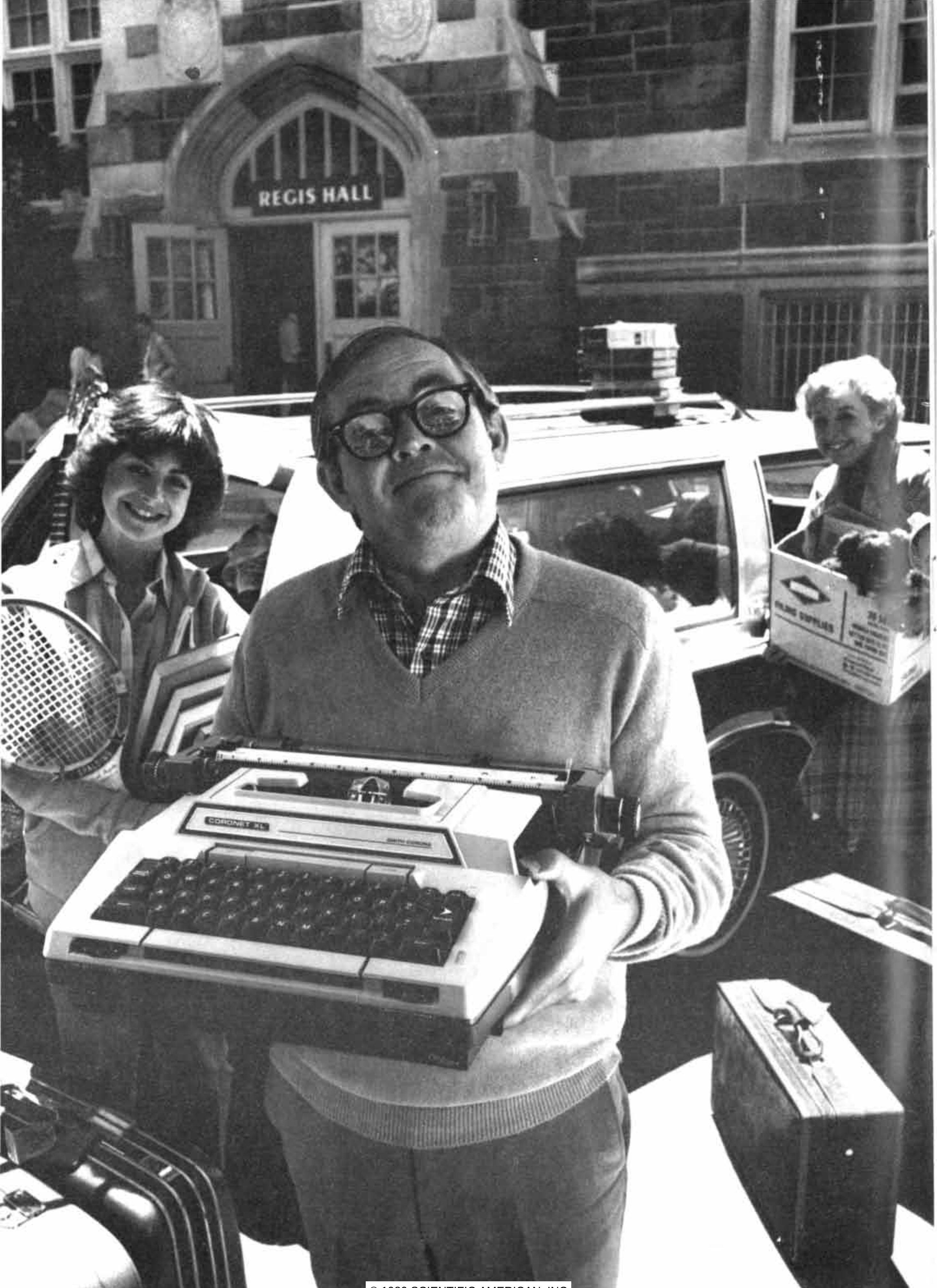
Established 1845 **SCIENTIFIC AMERICAN** September 1980 Volume 243 Number 3

ARTICLES

DEPARTMENTS


REGIS HALL
CORONET XL

Protect your investment with a Smith-Corona.

You can't believe your child is finally off to college. But she is. And you can't believe how much the cost of college has gone up since you were there. But it has. And how!

Now, more than ever before, it makes all kinds of sense to invest in a Smith-Corona® electric portable.

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We really want you to compare it with any other portable. First, *listen.* A Smith-Corona sounds solid and professional, because it is.

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When you consider what four years of college costs, a Smith-Corona is one of the least expensive forms of insurance you can buy.

Smith-Corona. It will make her words sing.

Patented Correction Cartridge

Smith-Corona

THE COVER

The seemingly abstract pattern on the cover symbolizes the theme of this issue of SCIENTIFIC AMERICAN: the harnessing of human ingenuity to help solve the problems of economic development. The pattern is actually a specially processed false-color enlargement of a test segment selected from a satellite image of croplands on the northern Great Plains of the U.S. The original image was acquired by the *Landsat 2* earth-resources satellite from an altitude of some 570 miles in the month of August; the segment covers a region of rectangular strip fields in Wilkin County, Minn. The boundaries of the fields come directly from the original Landsat image, which is made up of many of the tiny picture elements called pixels; that is what accounts for the jaggedness of the diagonal lines in this enlargement. The colors were assigned arbitrarily on the basis of a ground inspection of the crops growing in the fields at the time the picture was made. The object of the test was to assess the accuracy of computer-assisted crop-classification schemes being developed to analyze such Landsat images directly, without recourse to ground information. The test pattern was made in the course of the Large Area Crop Inventory Experiment, a joint project of the National Aeronautics and Space Administration, the Department of Agriculture and the National Oceanic and Atmospheric Administration that was designed to explore the feasibility of remote sensing in global crop forecasting.

THE ILLUSTRATIONS

Cover picture courtesy of National Aeronautics and Space Administration

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The man, the wi

ng and the Apple.

If you could talk to Orville Wright, he'd tell you the problems he faced as a turn-of-the-century engineer. You could tell him all about the technological solutions available to today's engineer and scientist... particularly a 20th century phenomenon that tests assumptions and defines models before a project gets off the ground. The Apple personal computer.

Computation, calculation, analysis...the power to pilot your projects.

With a highly-integrated system from the extensive Apple personal computer family, Orville and brother Wilbur would have increased their productivity. Perhaps even launched the Kitty Hawk Flyer well before 1903.

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Apple's existing software library includes a program that plots the shape of an airfoil, given its parameters.

that's unparalleled for analyzing alternative paths of design and modeling a wide variety of physical processes.

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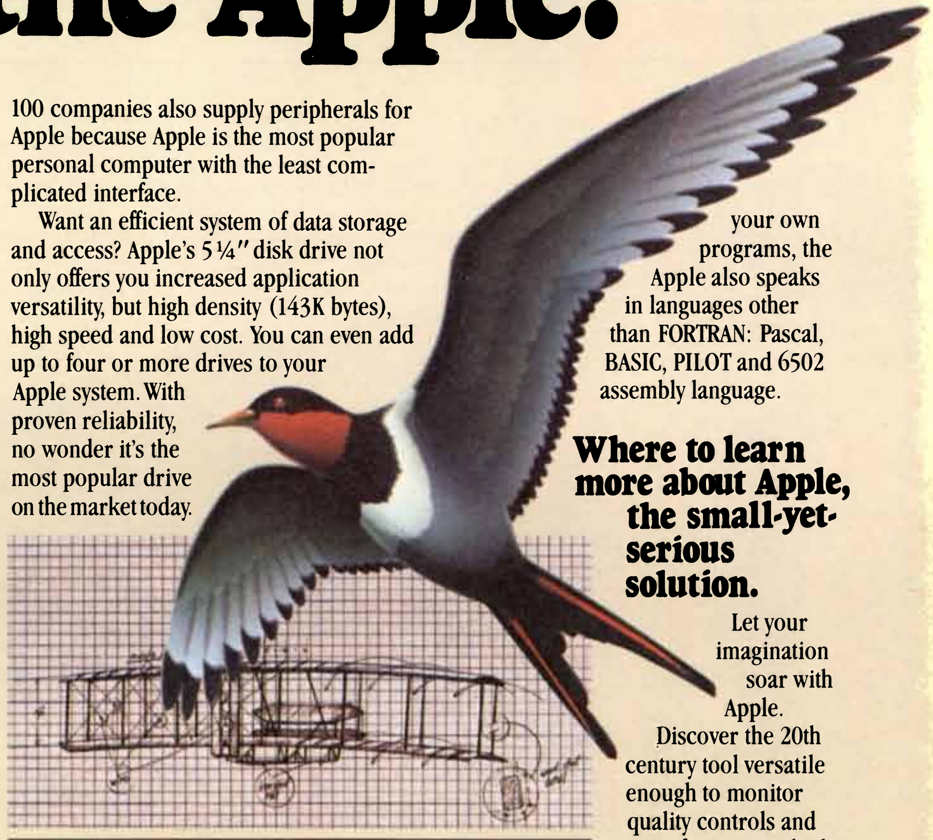

Wilbur determined that birds didn't have to constantly flap their wings to fly. With an Apple, he could've determined the fixed-wing design of the Kitty Hawk Flyer much faster.

FORTRAN that helped to design a 20th century flying machine.

Fluent in the same language that helped to design the 747, Apple FORTRAN lets you tackle differential equations at the touch of a key. And since more the 170 companies also offer software for the Apple family, you can have one of the most impressive program libraries ever...including vast subroutine libraries for math, science, engineering and statistics. When you write your own programs, the Apple also speaks in languages other than FORTRAN: Pascal, BASIC, PILOT and 6502 assembly language.

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Let the Apple dealer show you how, by putting the system of your choice through its paces. He'll tell you about our extended warranty, support and service. And he'll prove that a personal computer is not just a flight of fancy but a serious solution. Don't let history pass you by. Visit your nearest Apple dealer, or call 800-538-9696. In California, 800-662-9238.

apple computer

Consumer Orientation
No. 5 in a Series of Technical Papers

5

Subject:
Optimization of Vehicle Aerodynamic Form

Porsche 924

Porsche + Audi
Nothing Even Comes Close

Air resists the movement of a vehicle passing through it. Resistance increases with the square of the vehicle's speed: twice the speed produces 4 times the resistance. The engine power required to overcome this drag increases with the cube of the vehicle's speed: twice the speed requires 8 times higher power. Thus, even a small reduction in drag can result in a large increase in fuel economy. Dr. Ferdinand Porsche was among the first to reduce drag through body design. The Porsche 924 benefits from 70 years of Porsche aerodynamic development. Its drag coefficient is a low 0.36. And it requires only 15 hp to cruise at 55 mph.

Air does not impact uniformly on a moving vehicle. In fact, air-flow creates zones of high and low pressure on a vehicle's surface. The 924 is designed to take advantage of this phenomenon. (See diagram below and corresponding numbers on car above.)

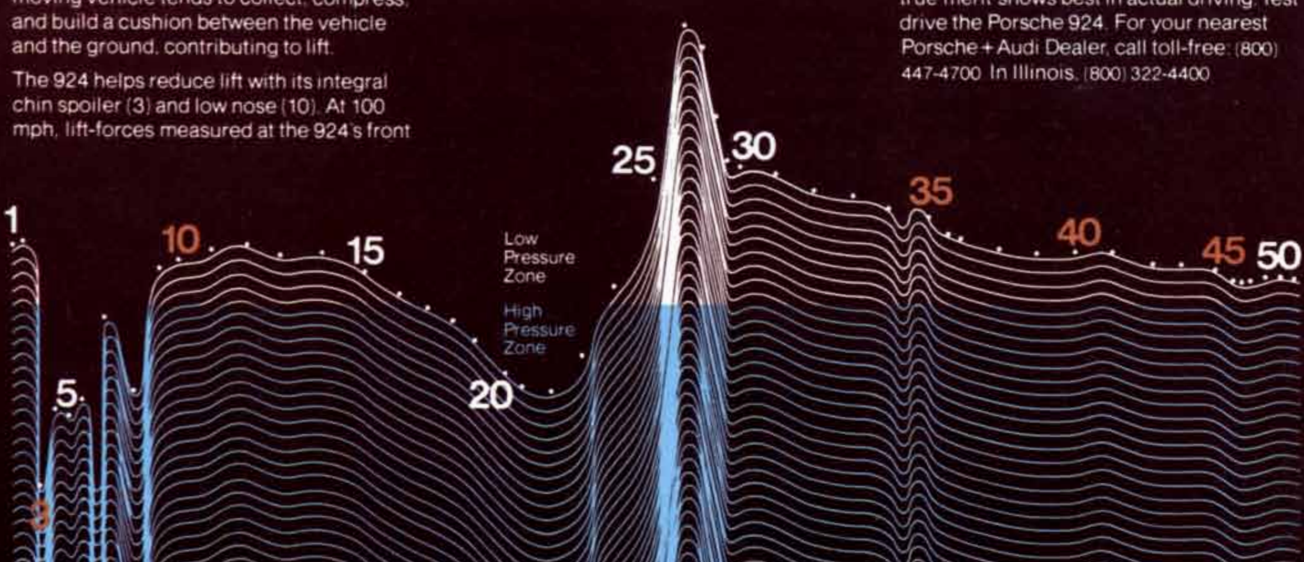
For example, the air that passes beneath a moving vehicle tends to collect, compress, and build a cushion between the vehicle and the ground, contributing to lift.

The 924 helps reduce lift with its integral chin spoiler (3) and low nose (10). At 100 mph, lift-forces measured at the 924's front and rear wheels are only 46 and 105 lbs., respectively.

Crosswinds can affect a vehicle's directional control at high speeds. Reaction to crosswinds is determined largely by the relative location of the vehicle's center of aerodynamic pressure to its center of gravity.

The elevated rear deck (35-45) places the 924's center of aerodynamic pressure slightly behind its center of gravity. Thus, sidewinds tend to bring the 924's nose into the wind, in a self-correcting motion.

Many of the 924's aerodynamic features are apparent in its clean styling. But their true merit shows best in actual driving. Test drive the Porsche 924. For your nearest Porsche + Audi Dealer, call toll-free: (800) 447-4700. In Illinois, (800) 322-4400.



LETTERS

Sirs:

After being in the dark about the Three Mile Island accident for a long time, I received the first hint of what had happened from "The Safety of Fission Reactors," by Harold W. Lewis [SCIENTIFIC AMERICAN, March]. Newspapers reported the first of the two points he mentions: that there was apparently no checklist such as is used on an aircraft before a takeoff, and there was no supervisor to recheck. That was why the block valves of the emergency feedwater pumps were inadvertently left closed. Much more important was the failure of the relief valve and the absence of signal lights to indicate its position; the only light merely showed whether or not the relay was in position to open or close the valve, not whether it had succeeded in doing so.

This defect was particularly serious because judging by the drawings in Professor Lewis' article the valve also had a grave defect of design that would have precluded its use for water and steam. The valve disk (in this case a plug) slides in a bore, much as a drawer slides in a desk. If the drawer is wider than it is long, it has a tendency to cant (to lock itself by friction if it is not guided carefully). The diameter of the Three Mile Island valve plug appears to be almost 1.3 times its guided length; it had a great tendency to cant, particularly because it was backed by a helical spring notorious for its tendency to exert excentric pressure. The valve was probably all right for a dairy, since the butter globules in the milk would lubricate it; water and steam, however, have an antilubricating effect that is felt when a wet finger is pushed over a piece of glass. In addition the rubbing surfaces were probably somewhat corroded and roughened. Professor Lewis writes that the valve was to have been exchanged because it was leaking; this in itself was probably not serious, but it was an ominous sign of the plug's sticking and not seating itself correctly, and of the imminence of failure because of canting and jamming.

In view of this the probabilistic treatment of nuclear-plant safety by "event tree" and "fault tree" analysis seems about as relevant as the calculation of the probability of size 7 shoes not hurting feet size 10. Professor Lewis writes that "the report of the President's Commission on the Three Mile Island accident, headed by John G. Kemeny of Dartmouth College, had little to say about improving the design or construction of light-water reactors. Instead it contained a blistering denunciation of everyone connected with the assurance of reactor safety" and "asserted that a change in 'mind-set,' or mental attitude, was essential." The drawings suggest that much more essential would have been a competent expert engineer, with a knowledge of valves and of friction, at the critical stages of design and perhaps also on the committees dealing with reactor safety and Three Mile Island. As things are, I am reminded of a conversation I had with the late Sir James Chadwick soon after his return to England from Los Alamos and Washington; he asked me if I, having studied engineering, could explain why everything went well at Los Alamos if it was done by physicists, and all the troubles occurred where engineering was involved.

EGON OROWAN

Belmont, Mass.

Sirs:

The "sea of radiation" in which all of us live referred to by Professor Lewis includes radiation dosages other than those he mentioned. Although many Americans are exposed to an average of 150 millirems per year from cosmic, terrestrial, medical and dental sources, this amount does not include the much larger dosages that millions are unwittingly receiving from such little-known sources as tobacco and porcelain dentures.

According to the National Council of Radiation Protection ("Radiation Exposure from Consumer Products and Miscellaneous Sources," NCRP Report 56, 1977), cigarettes expose 50 million Americans to annual dose equivalents of as much as 8,000 millirems per person through accumulations of polonium 210 at bifurcations of segmented bronchi in the lungs (assuming a consumption of 30 cigarettes per day), and dental prostheses containing uranium porcelains (rather than the newer acrylics) expose 45 million Americans to an annual average of as much as 60,000 millirems per person. Still other unexpected radiation sources are liquid-crystal-display wristwatches and pocket-carried calculators that were granted Nuclear Regulatory Commission exemption to contain up to 200 microcuries of tritium.

It is interesting to compare the tobacco- and denture-radiation exposure amounts with the Environmental Protection Agency's suggested maximum annual exposure of 170 millirems per person from all manmade radiation sources other than medical and dental ones. Although cigarette smokers may not be deterred by the knowledge that they may be exposing themselves to 47 times the EPA's suggested radiation maximum, the presence of polonium 210 in tobacco is still another reason for having nonsmoking sections in areas of public assembly.

JULIAN KANE

GEORGE COX

Garden City Senior High School
Garden City, N.Y.

Sirs:

I think Professor Lewis has done an excellent job of providing a balanced perspective on the subject. There is, however, one important aspect of the situation that I believe needs to be further explained to the public and its representatives in government. I refer to the fact that the vast majority of the putative victims of a putative uncontained nuclear meltdown will have received excess radiological exposures no severer than those many members of the public are already receiving from the excess accumulation of highly radioactive radon decay products that is being measured in many energy-efficient homes. (The radon is released by the decay of the trace amounts of radium in building materials and in the ground. Its concentration in energy-efficient homes is increased because the heated or cooled air in such homes is recycled instead of being expelled and replaced by fresh air.)

It is clear from the scientific literature on the public perception of risks that the specter of large catastrophic accidents looms large in the public mind. The American Physical Society study of 1975 reinforced this public percep-

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tion of uncontained nuclear meltdowns as unprecedented catastrophes by adding more than 10,000 casualties to the estimate made in the draft "Rasmussen report" (the Nuclear Regulatory Commission's study WASH-1400). The estimate was that the hypothetical reference accident would cause between a few hundred early fatalities and none. The figure of more than 10,000 additional casualties was arrived at by including putative victims with an average excess lifetime cancer risk of .1 percent (on the basis of the linear hypothesis of low-level-radiation risk). Although Wolfgang Panofsky of the American Physical Society study took pains to emphasize that these additional casualties were "in a different context" from the early fatalities estimated in WASH-1400, I doubt that the public has realized, either then or now, that the .1 percent risk to the average exposed individual would be equivalent to the risk from living in certain energy-efficient homes for less than a year. According to EPA linear-hypothesis estimates (published in the *Federal Register* for April 22, 1980), this increment in risk could result from lifetime residence in homes with only a modest reduction in air exchange.

There is at present considerable interest in the subject of indoor air pollution, but so far no systematic attempt has been made to alert the public to the possible need for mitigative action. Perhaps this relatively relaxed approach is justified by the fact that the number of people now living in energy-efficient homes is small. On the other hand, it is not unreasonable to expect as a result of the government-encouraged trend toward energy-efficient homes that within a few years millions of people will have incurred an added .1 percent risk from radon decay products.

I do not wish to imply by this line of reasoning that the absence of urgent action with respect to the home-radon problem justifies failure to take all reasonable steps to further reduce the probability of an uncontained nuclear-reactor meltdown. I nonetheless think there should be some limitation to the degree to which society insists on going into a regime of diminishing returns to avoid one hazard that is no more severe than similar hazards that remain largely uncontrolled. This is particularly the case when some of the measures adopted in regard to the former hazard introduce dangers of their own.

HENRY HURWITZ, JR.

Schenectady, N.Y.

Sirs:

The letters elicited by my article span the usual range from outrage to praise. There were a few recurrent themes that deserve comment.

A number of readers took me to task for having declared that reactors are "safe," even though I tried hard to make the point that such declarations are meaningless. In view of the fact that nothing is totally safe, how safe is "safe"? It is unfortunately a fact of the great nuclear debate that the juices it maketh to flow often block the reception of information. This has been true on both sides.

A number of engineers expressed various forms of astonishment and dismay that critical parameters of a reactor such as valve positions and water levels are often not directly known to the control-room operator. The point is a valid one, except that one does not want to put *everything* on the control panel, and the selection of which parameters to display is one of the things that has to be done through rational risk assessment. All too often the layout of a control panel is determined more by the requirements of normal operation than by those of an operator in upset conditions, and if there is one lesson that comes through loud and clear from the Three Mile Island experience, it is that in the course of an accident operators will intervene. Unfortunately we may be moving in the direction of providing exactly those indicators that were called for during the Three Mile Island accident and not those that will be required for the next accident.

Another class of letters dealt with the effects of low levels of radiation. Messrs. Kane and Cox refer to irradiation through cigarette smoking; Dr. Hurwitz describes some recent work on radon concentration in energy-efficient homes. The latter is a particularly sensitive point for antinuclear proponents of energy conservation, because calculations of cancer mortality in energy-efficient homes, using exactly the same methods we use to make equivalent calculations for reactors, lead to estimates of many thousands of cancer deaths per year as a consequence of mass conversion to domestic energy efficiency. Our mothers were right when they told us that fresh air was good for us. Interestingly enough, the trend in the community of radiobiology experts (as will be borne out if the National Academy of Sciences ever releases its new report on the subject) is to reduce the realistic estimates of the effects of radiation for the kinds of radiation that are associated with nuclear reactors but not for the kinds that are responsible for the exposures from cigarettes and in homes.

HAROLD W. LEWIS

Department of Physics
University of California
Santa Barbara, Calif.

50 AND 100 YEARS AGO

SCIENTIFIC AMERICAN

SEPTEMBER, 1930: "*Sinanthropus* turns out to be the most impressive and significant discovery in the entire history of human paleontology. The revelation of the nature of the brain case of Early Pleistocene man displayed in photographs affords ample corroboration of the claim that the discovery provides a new basis for the study of human evolution. The photographs were made in Peking immediately after Professor Davidson Black had successfully accomplished his long and exacting task of clearing away the hard matrix of travertine in which the base and left side of the skull were embedded when it was found on December 2 by Mr. W. C. Pei. They reveal the individuality of the new genus. Although the skull has the prominent eyebrow ridges of *Pithecanthropus,* the brain case is much fuller than the Java skull. Father Teilhard de Chardin and Dr. C. C. Young have given a preliminary report on the fossiliferous deposits at Chou Kou Tien, which establishes the fact that all the remains are later than the Pliocene and earlier than the Loess—in other words, they are Lower Pleistocene."

"On the Housatonic River near New Milford, Conn., the Rocky River hydroelectric plant of the Connecticut Light and Power Company pumps a river uphill in order to store a sufficient head of water to run its own generators. It is the first plant in America to pump water for power generation. In general the pumping is done when there is a surplus of power at other hydro-electric plants in the system. This water supply is used for generation when there is a peak load on the system."

"The big news of the recent meeting of the American Chemical Society in Atlanta was the announcement of a new refrigerant, non-inflammable and nontoxic, by Thomas Midgley, Jr. He is the chemist who discovered the anti-knock properties of tetra-ethyl lead. Now he has perfected a refrigerating medium that can be used in household electric refrigerators without the remotest risk of danger from leaky coils. His discovery of the suitability of dichlorodifluoromethane gives promise of the early use of refrigeration for air cooling in homes and theaters and other public gathering places where refrigerating engineers have hesitated to risk accidents with refrigerants that are poisonous or explosive."

"The blame for unemployment has often been placed on machinery, and in times past labor has fought the introduction of machines into industries where hand work has been the rule. Even now there are pessimists who deprecate the increasing use of machinery and lugubriously assert that it is a Frankenstein monster. Their memory is short. Thirty years ago 200 unskilled workers were required to do the work now done by one steam shovel. In the glass industry one machine takes the place of 600 skilled glassblowers of a few years ago. From these figures it would seem the pessimists' assumptions are correct. They are not. The number of wage-earners increased 3 per cent during the eight years between 1919 and 1927, but our production increased 50 per cent! Working hours have been cut down, first from a 12-hour day to a 10-hour day, then down to an eight-hour day. The working man's week was cut down from six to five and a half days, and it is now proposed to cut it to five. Better pay and more leisure in which to enjoy the fruits of his work—these are the dividends of machinery to the American wage-earner."

SCIENTIFIC AMERICAN

SEPTEMBER, 1880: "During June alone 72,567 immigrants arrived at the 10 principal United States ports, and during the year ending with June, 1880, the total number was 263,726. Immigration is therefore two and a half times greater this year than last. A very interesting feature of the available facts in regard to the immigration this year is the internal distribution of those who come and the states or territories where they finally settle. For the six months ending with June it is estimated that 116,000 immigrants passed through Chicago, the Chicago and Northwestern Railroad and the Milwaukee and St. Paul Road taking 31,500 to destinations northwestward, chiefly to Minnesota and Dakota. The Rockland and Alton Road took 35,000 to Iowa and beyond, and the Burlington Road 17,000 in the same direction, with the small number of 8,000 going southward along the line of the Illinois Central. The same authority estimates the receipt by states as follows: Kansas, 15,000; the Pacific states, 15,000; Iowa, 14,000; Minnesota and Colorado, each 12,000; Wisconsin, Nebraska and Dakota, each 11,000; Michigan, 3,000. The real movement is westward from Chicago."

"The boilers of the Russian mail steamer *Cesarewitch* are heated by petroleum refuse instead of coal, a system


By age 30, you should know the best way to finance your retirement.
The years come and go. And investment fads with them. But New York Life's convertible term insurance remains an ideal way for young people to start a long-range financial security program.
Because it is term insurance, it gives your family maximum protection now for a given outlay.
Yet, as your income grows, you can convert it to whole life insurance that builds cash value— cash value that can guarantee a lifetime income later, when you retire.
Talk to your New York Life Agent before you blow out another candle. And your chance for a more comfortable retirement.
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that effects an enormous saving of expense and labor, the heating apparatus being as thoroughly under control as a gas jet and requiring but one man to manipulate it. It consists of two tubes about an inch in diameter, terminating at the same point in a small oblong brass box. Through one of these tubes the black residual naphtha (*astatki*) drips slowly, being blown into spray by a jet of steam from the boiler, conveyed to the second tube. This spray, when ignited, forms a great sheet of flame that is projected into the hollow of the boiler. The system has the immense advantage of requiring no stoking, as no ashes are produced, and by turning down the flame to the required degree the steam can always be kept up to the pressure required for immediate starting without the tedious and more or less wasteful process of 'banking' the fires."

"When the excitement in this country and Europe that attended the laying of the first Atlantic cable and the doubt, delays and misfortunes of that great enterprise are contrasted with similar operations at the present time, we are enabled to realize the progress that has been made in telegraphy within less than a quarter of a century. The Anglo-American Telegraph Company has just completed the work of laying a new cable from Valentia to Heart's Content, and so much a matter of course has such work become that it attracts scarcely any public attention. These slender cords buried in the depths of the sea now connect every country of the earth, and the history of the preceding day at the Antipodes appears in the morning papers as regularly as the incidents occurring in the immediate vicinity of their publication. The electric telegraph has bound together the most widely separated sections of the earth and has revolutionized the business and social systems of the world."

"Biological chemistry is yet in its infancy and has few to tenderly care for it. Most chemists prefer to take on easier subjects, but interest in it is increasing. In fermentation, putrefaction, vitrification and zymotic diseases life may intervene, but how much we do not yet know. There is much in the training of the chemist to foster a wholesome skepticism and just intolerance, intolerance of human pride and skepticism of airy theories. The chemist soon learns that exact truthfulness in others and rigid honesty in himself lie at the very foundation of science and real knowledge, and he looks on laxity in experiment or statement as the unpardonable sin. No other subject is so well calculated to impress one with the idea that theories are but the changeable dress of science. We all wonder what will become of the atomic theory itself when its centennial comes around 27 years hence."

THE AUTHORS

K. K. S. DADZIE ("Economic Development") has been Director General for Development and International Economic Cooperation for the United Nations since 1978. Born in Ghana, he studied in its university system and then received an honors degree in economics at the University of Cambridge. He has since held several diplomatic positions in the Ghanaian government, including Permanent Representative to the UN in Geneva. Dadzie's career at the UN includes serving as Director for External Relations and Inter-Agency Affairs, as president of the Trade and Development Board and as chairman of the Ad Hoc Committee on the Restructuring of the Economic and Social Sectors of the United Nations System, a position he held until shortly before he took up his present one.

HALFDAN MAHLER ("People") is in his second term as Director General of the World Health Organization, an institution in which he has been active since 1951. A native of Denmark, he obtained his medical degree at the University of Copenhagen in 1948. He began his WHO career as Senior Officer in the National Tuberculosis Program of India. Mahler has since occupied the WHO positions of chief of the Tuberculosis Unit, director of Project Systems Analysis and Assistant Director General for the divisions of Family Health and of Strengthening of Health Services; he became Director General in 1973.

NEVIN S. SCRIMSHAW and LANCE TAYLOR ("Food") are professors in the International Nutrition Planning Program at the Massachusetts Institute of Technology. Scrimshaw's early professional training was in anatomy and gynecology, including postgraduate degrees in biology and physiology from Harvard University and an M.D. from the University of Rochester School of Medicine and Dentistry. His 1948 field research on nutrition and pregnancy in Panama led him to the Institute of Nutrition of Central America and Panama, where he became director in 1949. In 1961 he joined M.I.T. as head of the Department of Nutrition and Food Science, a position he retained until 1979. Currently Institute Professor at M.I.T., he directs the university's interdepartmental and interdisciplinary Food and Nutrition Policy Program and guides the formation of the World Hunger Program at the new United Nations University in Tokyo. In this capacity and as president of the International Union of Nutritional Sciences, Scrimshaw travels widely in developing countries. Taylor, who holds a joint appointment in the economics and nutrition departments at M.I.T., was graduated in mathematics from the California Institute of Technology in 1962 and received his Ph.D. in economics at Harvard in 1968. In pursuing his main interests of food policy and the economics of developing countries, Taylor has done field work in Egypt, Brazil, India, Pakistan and Chile.

ROBERT P. AMBROGGI ("Water") was senior adviser to the United Nations Food and Agriculture Organization from 1961 through 1979, acting concurrently as consultant to the UN Development and Environment Programs and to the World Bank. A French citizen born in Corsica, he was graduated from the University of Nancy in 1939 and completed his doctorate at the University of Paris (the Sorbonne). As director of the Water Resources Department of Morocco, in 1942 Ambroggi began studying ground-water hydrology and has since served as special adviser to the King of Morocco and senior adviser to the International Training Center for Water Resource Management, which is on the French Riviera.

WOLFGANG SASSIN ("Energy") has been working for five years at the International Institute for Applied Systems Analysis near Vienna as a member of its Energy Systems Program. He received a degree in technical physics from the Technical University in Munich in 1964 and his doctorate in solid-state physics from the Technical University in Aachen. From 1964 to 1973 he worked at the Nuclear Research Establishment in Jülich on radiation damage, low-temperature electricity transmission and systems analysis in the fields of energy and the environment.

丁忱 (DING CHEN) ("The Economic Development of China") is vice-president and secretary general of the Shanghai Federation of Industry and Commerce. He earned his B.A. degree at Shanghai Chiao Tung University in 1939 before attending the University of Pennsylvania and then going to Harvard University, where in 1946 he obtained his Ph.D. in economics. Ding, who has served as vice-president of the Shanghai World Economics Society and as a national-committee member of the Chinese People's Political Consultative Conference, visited the U.S. last year on a lecture tour sponsored by the National Academy of Sciences.

RAJ KRISHNA ("The Economic Development of India") has been professor of economics at the University of Delhi since 1976. He completed his Ph.D. in economics at the University of Chicago in 1961, and after working as senior economist and adviser at the World Bank in Washington he became a member of the Indian government's Planning Commission in New Delhi. There he prepared much of the draft Sixth Five-Year Plan revised last year.

ROBERT B. MABELE, WILLIAM M. LYAKURWA, BENO J. NDULU and SAMUEL M. WANGWE ("The Economic Development of Tanzania") teach economics at the University of Dar es Salaam in Tanzania. Mabele, director of the university's Economic Research Bureau and senior research fellow, received his master's degree in agricultural economics at the University of Tennessee in 1973. Wangwe, who got his master's at the University of Dar es Salaam the same year, now heads the university's department of economics and is senior lecturer in the department. Lyakurwa and Ndulu, both lecturers at the university, got their Ph.D.'s in economics respectively from Cornell University in 1978 and from Northwestern University in 1979.

PABLO GONZALEZ CASANOVA ("The Economic Development of Mexico") is a leading Mexican scholar on the history of political and economic movements in his country. Born in Toluca, he attended the College of Mexico and the National School of Anthropology. He received his master's degree at the National Autonomous University of Mexico in 1947, and he was president of the university from 1970 to 1972. Gonzalez' work has taken him to the University of Paris, where he completed his Ph.D. in 1950, and to Britain, where he was visiting professor at the University of Oxford in 1974. In October he will be visiting professor at the University of Cambridge. Currently senior professor at the Institute of Social Research at the University of Mexico, he has been working on several histories of Latin-American intellectual and labor movements.

WASSILY W. LEONTIEF ("The World Economy of the Year 2000") retired from Harvard University in 1975 after more than 40 years in the department of economics. A native of Russia, he received his education at the University of Leningrad and completed his Ph.D. at the University of Berlin in 1928. In 1973 he received the Nobel prize in economic science. He has served as an economic adviser to China, the U.S. and the UN; he has also been a consultant for disarmament and environmental protection. The author of numerous essays and books, the most recent of which is *The Future of the World Economy* (1977), Leontief currently directs the Institute for Economic Analysis at New York University, where he has been professor of economics since 1975.

MATHEMATICAL GAMES

Dr. Matrix, like Mr. Holmes, comes to an untimely and mysterious end

by Martin Gardner

The sons of the prophet are brave
men and bold,
And quite unaccustomed to fear,
But the bravest by far in the ranks
of the Shah
Was Abdul Abulbul Amir.
—ANONYMOUS BALLAD

Going through my files on Dr. Irving Joshua Matrix, the greatest numerologist in the world, I find notes on many escapades that I have not yet written about in his peripatetic career. There was the year he spent in Tübingen as founder and director of the Institute of General Eclectics, a philosophical school maintaining that all metaphysical and religious systems are in substantial agreement. (Hans Küng taught there for several months.) And I have never told about Dr. Matrix' revival in Bombay of phrenology, which he cleverly combined with the ancient Hindu technique of acupuncture (a method quite different from that of the Chinese). Nor have I disclosed details about his notorious Parisian brothel for dogs and cats, where the madam was a large red-haired chow from Hong Kong, and pets were given free numerological readings on Saturdays.

Perhaps someday I shall recount these odd episodes, but this month I must with a heavy heart speak of my visit with the wily old charlatan last April in Istanbul. I had been in Budapest attending an international magic convention at the Duna Inter-Continental Hotel, where I had a comfortable room with a breathtaking view of the Danube. Dr. Matrix' half-Japanese daughter Iva somehow learned I was there, and one day while I was out she telephoned, leaving the cryptic message "Jeremiah 33:3," followed by an Istanbul phone number.

The Gideon Bible in my room provided the verse: "Call unto me, and I will answer thee, and shew thee great and mighty things, which thou knowest not." Iva answered the phone when I called. Had I ever, she wanted to know, been to Istanbul? I told her I had not. She and her father would be there for a week, she said, staying at the Hilton Hotel on Taksim Square, on the European side of the ancient city, and they would be glad of my company.

I flew to Istanbul early the next morning, taking a room at the Santral Hotel, which is near the Hilton but considerably cheaper. When Iva came by for me at half-past ten, driving a rented American car, I was surprised to find her clad in a traditional burka of bright orange that covered everything except her hands and feet and her dark, enigmatic eyes. I was to call her Fatima, she said. Her father was in Istanbul on a top-secret mission for the U.S. Government, the nature of which she could not disclose. He had assumed the identity of a Muslim from Teheran and was using the name Abdul Abulbul Amir. Because he would not be free to meet us until late that afternoon she suggested that we explore the city.

We drove south down Istaklal in bumper-to-bumper traffic to the accompaniment of wildly honking horns. Iva zigzagged adroitly through incomprehensible traffic lights, navigating by way of the old Jewish quarter, past the cone-capped Galata Tower and across the Galata Bridge. The murky water on each side—the Bosporus to the east and the Golden Horn inlet to the west—heaved with flotsam. The stench of sewage diminished only slightly as we moved deeper into Istanbul's Asian sector and parked near the Great Bazaar.

What bedlam! The rubbishy streets lined with tiny shops throbbed and jangled with swarms of people in every imaginable mode of dress. The more traditional of the women wore long coats and head scarfs, but some were in smart European clothes and a few even wore shorts. All of them stared at Iva in her burka as if she had been transported by time machine from the days of Ali Baba. As we pushed our way through the crowds scrawny cats darted between our legs, and it seemed that everywhere we turned there were young boys either shining shoes on luridly decorated boxes or hawking black-market Marlboro cigarettes with shouts of "Mah-buh-ro." A strong scent of spices almost masked the smells wafting from the surrounding waters.

Iva paused at a table of costume jewelry and after lengthy haggling bought four inexpensive trinkets at four different prices. One item, a pair of scarlet earrings, cost $1 in U.S. currency. When the young shopkeeper, pretending to be angry at the low settlement, added the four prices on his pocket calculator, I noticed that he hit the multiplication button three times instead of the addition button. When I pointed this out in a whisper to Iva, she nodded but gave the man the $6.75 that showed on the calculator's display.

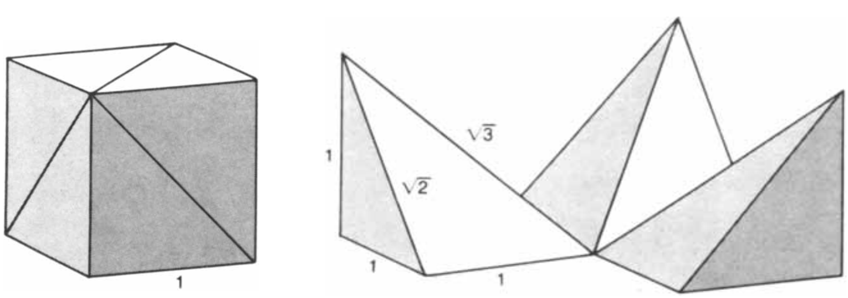
"Why didn't you protest?" I asked as we elbowed our way to another shop.

"Because," she replied, "I added the prices in my head and they came to the same amount."

I did some scribbling on the back of an envelope. "By the beard of the prophet!" I said. "You're right!"

Even more surprising, I later discovered that only one set of four different prices that includes $1 has $6.75 as both its product and its sum. Next month I shall give the solution to this pleasant little problem in Diophantine analysis.

We lunched at the Havuzlu restaurant, near the post office, and for the next four hours Iva took me around the city. We visited the Blue Mosque and the Topkapi Palace. We drove past the old Byzantine walls west of the city. It was distressing to see how many of the beautiful mosques are decaying. Some are used now for storing soft drinks; others house squatters. Once-elegant mosaic walls are pockmarked with gaps where the tiles have fallen. Even the domes and spires are stained brown



Dr. Matrix' cube (left) *cut to form three identical skew pyramids* (right) from pollution, and it was difficult to see them through the thick daytime haze.

When we finally arrived at the Hilton, Dr. Matrix was in his suite waiting for us, wearing a striped blue suit with a small emerald crescent in his lapel. His hair was closely cropped. I assumed that his gray beard and mustache were authentic, but his piercing green eyes had been turned black by contact lenses.

"You've not been in Afghanistan, I perceive," he said as we shook hands.

"No, thank Allah," I said with a smile, recognizing Dr. Matrix' parody of Sherlock Holmes's first remark to Watson. "How on earth did you know that?"

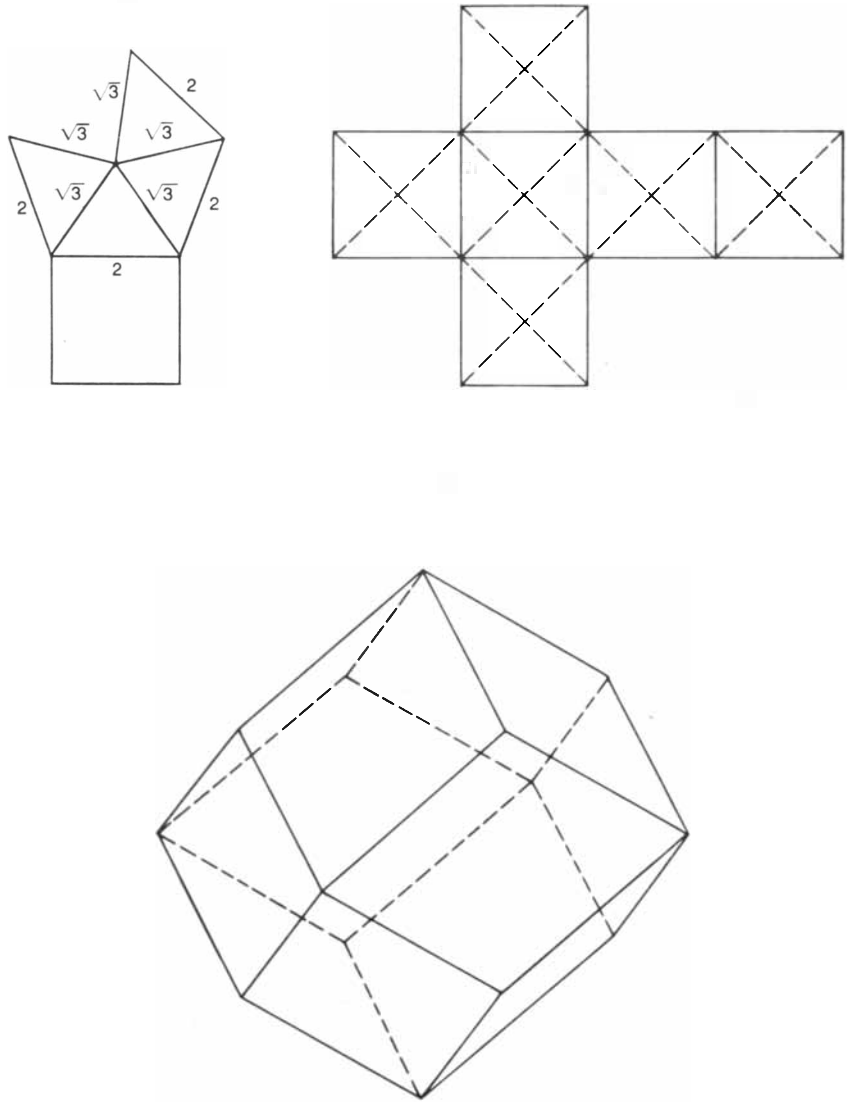
Dr. Matrix shrugged. "My daughter keeps good track of you."

Iva excused herself to change to less cumbersome attire, and Dr. Matrix and I seated ourselves in the bedroom he was also using as an office. On his desk was a large ivory cube that had been sliced in two places and hinged so that it opened to form three four-sided skew pyramids, each with a square base (as is shown in the illustration on the opposite page).

"The three pyramids are congruent," said Dr. Matrix. "If the square base has a side of 1, two adjacent faces are isosceles right triangles with sides of 1 and a hypotenuse that is $\sqrt{2}$. The other two sides are scalene right triangles with sides of 1 and $\sqrt{2}$ and a hypotenuse that is $\sqrt{3}$. The pyramids are easy to make with cardboard, but you would be surprised how many people have trouble putting them together to form a cube. The dissection goes back to ancient China. The pyramids were called yangmas. You might ask your readers if they can discover a completely different way to cut a cube into three identical solid forms."

Dr. Matrix picked up the hinged yangmas and folded them back until their square bases were mutually perpendicular. "Fit eight of these triplets over the eight corners of a cube of side 2," he continued, "and you create a rhombic dodecahedron. This construction provides an easy way to calculate the volume of such a solid. If the central cube has a side of 2, the rhombic dodecahedron has a volume of 8 + (24/3), or 16. Moreover, if you make four identical yangmas, they will fit together to form a pyramid that resembles the Great Pyramid of Egypt, with a 2-by-2 square base and four congruent isosceles triangles as sides."

The skeleton of a rhombic dodecahedron with its 12 identical diamond faces is shown at the bottom of the illustration on this page. The unfolded pyramid that can be made with four yangmas is shown at the top left in the illustration, and a fascinating toy can be created by gluing six of these pyramids at their bases to six square cells marked on a cross made of tape as is shown at the top right. Paint the bottom of the tape red and the sides of the pyramids blue.



Plans **(top)** *for a toy that forms both a rhombic dodecahedron* **(bottom)** *and a cube*

Folding the pyramids inward creates a solid red cube. Folding them outward, on the other hand, creates a blue rhombic dodecahedron with a cubic interior hole. With two such models it is possible to display a blue rhombic dodecahedron, remove its "shell" to disclose an interior red cube and fold the shell to make another red cube of the same size. Each cube can then be opened into two identical blue rhombic dodecahedrons.

Each corner of Dr. Matrix' ivory cube was marked with a different digit from the set 0, 1, 2, 3, 4, 5, 6, 7. The digits were cleverly placed, he told me, so that the sum of the two digits at the ends of each edge would be a prime number. (The primes are not necessarily different.) Can the reader find the only arrangement of the eight digits with this property before I give it next month?

"By the way," said Dr. Matrix as I jotted down the cube's number pattern, "are you aware that every cube has a volume equal to its surface area?"

He seemed mildly amused by the astonishment on my face. "Take any cube," he said, "and divide its edge into six equal parts. Call each part a hexling. A face obviously has an area of 36 square hexlings, and so since there are six faces, the total area is 6 × 36, or 216, square hexlings. The volume is of course 6^3, or 216, cubic hexlings. In the same way you can show that the area of any square is equal to its perimeter by dividing the side of the square into four equal quadlings. The paradox is related to a confusing proof that the surface-to-volume ratios of a sphere and a cube are the same."

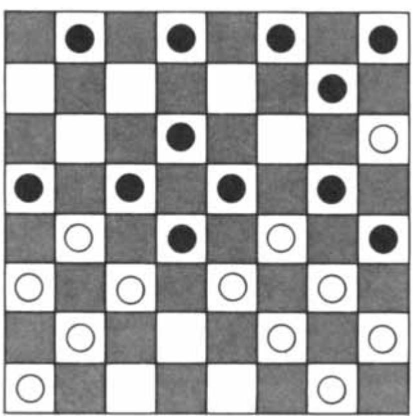
"But isn't it well known that of all solids the sphere has the smallest such ratio? That's the reason soap bubbles are spherical."

"That's true," said Dr. Matrix, "but hear me out." He explained the "proof" as follows. If d is the diameter of a sphere, its surface is πd^2 and its volume is $\frac{1}{6}\pi d^3$. The surface-to-volume ratio, then, reduces to $6/d$. Now let d be the edge of a cube. Here the surface-to-volume ratio is $6d^2/d^3$, which also reduces to $6/d$. Obviously something is wrong, but what is it?

"Enough of geometry," I said, my head spinning. "Have you encountered any number oddities since you came to Istanbul?"

Instead of replying, Dr. Matrix tossed over to me a 60-page booklet in English titled *Number 19: A Numerical Miracle in the Koran.* I later discovered that the author of this monograph, Rashad Khalifa, is an Egyptian who received a doctorate in biochemistry from an American university, where he also taught for a time. His booklet was published privately in the U.S. in 1972.

The number 19, Dr. Matrix pointed out, is as inscrutable to Muslims as 666, the Number of the Beast, is to Christians. Verses 27 through 31 of Sura 74 in the Koran tell how hell is guarded by 19 angels and explain that this number is intended to be an enigma for unbelievers. Dr. Khalifa's monograph attempts to show that 19 appears throughout the Koran too often to be there by chance. The number of suras in the Koran is 114, a multiple of 19. A famous verse called the *Basmala* ("In the name of Allah, most gracious, most merciful"), which opens every sura but one, has 19 letters. Its first word (*ism*) appears 19 times in the Koran. The second word (*Allah*) is found 2,698, or 142 × 19, times. The number of times the third word (*al-Rahman*) appears is 57, which is also a multiple of 19, as is the number of times the fourth word (*al-Raheem*) appears, 114.



FINAL POSITION

	RED	WHITE
1.	12-16	22-17
2.	16-20	23-19
3.	11-15	19-16
4.	9-14	16-12
5.	14-18	26-22
6.	5-9	31-26
7.	9-14	26-23
8.	6-9	23-19
9.	9-13	30-26
10.	7-11	26-23
11.	11-16	

The shortest no-capture checkers game known

"It's an ingenious study of the Koran," said Dr. Matrix, "but it could have been more impressive if Khalifa had consulted me before he wrote it. Nineteen is an unusual prime. For example, it's the sum of the first powers of 9 and 10 and the difference between the second powers of 9 and 10. Do you know what an emirp is?"

I shook my head.

"Well, *emirp* is *prime* backward, and it's the name my friend Jeremiah P. Farrell uses for any prime that is not a palindrome but that yields a different prime when its digits are reversed. For example, the last emirpal year was 1949, and the next will be 3011. Unfortunately both dates include duplicate digits, and to a numerologist emirps in which no two digits are alike are far more interesting. I call those numbers no-rep emirps, and their sequence is 13, 17, 31, 37, 71, 73, 79, 97, 107.... No one knows if the set of no-rep emirps is infinite. In fact, no one knows if there is a highest emirp or a highest palindromic prime."

"Is there any connection between emirps and Istanbul?" I asked.

"I'm coming to that," Dr. Matrix said. "As you know, Istanbul was once the great city of Constantinople. Its name was changed to Istanbul in 1930. Note the 19 and the 30. Nineteen is the mysterious Koran prime, and 30 is the largest integer n with the property that every smaller integer relatively prime to n is itself a prime. As you know, two integers are relatively prime if they have no common divisors, and Paul Erdös recently showed that 70 is the largest integer such that any smaller integer relatively prime to it is either a prime or a power of a prime." (See "A Property of 70," by Paul Erdös, in *Mathematics Magazine,* Vol. 51, No. 4, pages 238–240; September, 1978.)

"But I digress too far," Dr. Matrix said. "The most important date in the history of Constantinople is of course 1453, the year the city was conquered by the Turks. Now, 1,453 is not merely an emirp but also a no-rep emirp. Observe too that its digits add up to 13, which is the smallest emirp."

"Have there been many no-rep-emirp years since 1453?"

"There have been 11. The last was 1879 and the next will be 3019," Dr. Matrix said. "My good friend Leslie E. Card is the world authority on emirps, which he calls reversible primes. It's easy to determine that there are four pairs of two-digit emirps and 13 pairs of three-digit emirps. Card tells me there are 102 four-digit pairs and 684 five-digit pairs. He has a computer listing of all the no-rep emirps under 10,000,000. The breakdown by pairs is four with two digits, 11 with three, 42 with four, 193 with five, 612 with six and 1,790 with seven."

Card also discovered, Dr. Matrix told me, that only one six-digit emirp is cyclic, in the sense that if the first digit in the number is shifted repeatedly to the other end, each of the resulting permutations is an emirp. This unique number is 193,939. In other words, if this number is written with its digits in a circle, one can begin at any digit and go around in either direction to get a six-digit prime. The only cyclic emirp with five digits is 11,939. There are no cyclic emirps with three, four or seven digits.

Card has entertained himself, Dr. Matrix said, by constructing emirp squares of digits with the property that every row, column and main diagonal is a different emirp. Thus a square of n-by-n digits would contain $4(n+1)$ distinct primes. There is no such square of order 2 or 3. Examples for orders 4 and 5 are as follows:

```
9 1 3 3      1 3 9 3 3
1 5 8 3      1 3 4 5 7
7 5 2 9      7 6 4 0 3
3 9 1 1      7 4 8 9 7
             7 1 3 9 9
```

There are many other order-5 squares, but the order-4 square is truly extraordinary: ignoring rotations and reflections, it is the only possible square of this type.

Can similar squares be made with no-rep emirps? No, because all primes except 2 and 5 end in 1, 3, 7 or 9: only those four digits can border an emirp square, and so if the square is of an order higher than 4, no outside prime will be free of repetitions.

I wish I had space for more of Dr. Matrix' comments about primes. He also pointed out that the squares of the first seven primes add up to 666, and he mentioned the even more astounding fact that if the English names for primes are alphabetized, the first number on the list is 8,018,018,851. Is the last prime on this list also determinable? Dr. Matrix thought it was, but he suggested that a computer would be needed to find it.

At this point Iva, now dressed in gray silk pants and a yellow blouse, came in with a tray holding three martinis. We chatted about nonmathematical topics until the towers and domes of Istanbul became black silhouettes against a flaming gold-red sky. It was a vision straight out of *The Arabian Nights.* Sunsets, Iva pointed out, were the only admirable by-product of the city's dirty air. Through the open windows floated the wailing of a muezzin, his call to twilight prayer amplified by loudspeakers as he stood on a minaret not far away. (Mohammed disliked bells.) Dr. Matrix unrolled an intricately tessellated prayer rug and placed it on the floor with the point in its pattern directed southeast. After removing his shoes he recited the *Fatiha,* the Koran's first sura, in a loud voice and knelt on the rug and prostrated himself toward Mecca while Iva

sat sipping her martini with a bemused smile.

I spent several delightful days in Istanbul, and when I left, I fancied I could see tears in Dr. Matrix' eyes. Did he have a premonition about his kismet? His last words to me were "*Gulegule, Mashalla Hanim effendi*": "Good luck and Allah bless you."

"*Salaam,*" said Iva.

Three weeks later, back in New York, I was shattered by a story in *The New York Times.* It was datelined Bucharest. A Muslim known as Abdul Abulbul Amir, said to have been on a secret mission for the CIA, had met in Bucharest with a Russian agent, Ivan Skavinsky Skavar. The two had gone to a desolate spot on the delta of the Danube, outside the Ukrainian city of Izmail near the Romanian border. What happened there was unclear. Apparently the two men had fired revolvers simultaneously and both had died instantly. A peasant who witnessed the scene from a nearby hilltop reported hearing the taller man cry "*Allah Akbar!*" as he fell.

A few words may suffice to tell the little that remains. Amir's only surviving relative, a daughter named Fatima, had arranged for her father's burial in a tomb on the bank of the Danube near the spot where he had died. It was rumored, said the *Times,* that a group of Russians had taken Skavar's body aboard a ship and disposed of it in the Black Sea. No doubt I will learn more details if and when I see Iva again. With these sad words I close my final account of him whom I shall ever regard as the strangest and the wisest man I have ever known.

Here is how Ross Honsberger, who wrote last month's column, answers the three exercises given in his discussion of the pigeonhole principle:

1. To show that one of the line segments connecting five lattice points must pass through some lattice point in the coordinate plane, note that there are four "parity" classes for the coordinates of a lattice point: odd, odd; odd, even; even, odd, and even, even. On the pigeonhole principle some two of five lattice points, say (x_1, y_1) and (x_2, y_2), must belong to the same class. This implies that $x_1 + x_2$ and $y_1 + y_2$ are both even numbers, making the midpoint of the segment joining the points, namely $[(x_1 + x_2)/2, (y_1 + y_2)/2]$, a lattice point.

2. To prove that six circles arranged in the plane so that none of them contains the center of another cannot have a point in common, assume the converse is true, namely, that there is a point O common to six such circles. Now suppose O is joined to each of the six centers. No two centers can be colinear with O because no circle contains the center of another circle and all the circles contain O. Therefore the six lines all fan out from O. Let OA and OB be consecutive segments in the fan. Since O belongs to each circle, the segments OA and OB are not larger than the radii of the circles in which they lie. But since neither circle contains the other center, AB must be larger than either of these radii. Thus AB is longer than the other two sides of triangle AOB, which implies that angle AOB opposite AB is larger than either of the other angles in the triangle. Hence angle AOB must exceed 60 degrees. If this is so, however, there is not room in the 360-degree sweep around O for six angles such as AOB, which establishes the conclusion by contradiction.

3. To prove that in any row of $mn + 1$ distinct real numbers there is either an increasing sub-sequence of length $m + 1$ or a decreasing sub-sequence of length $n + 1$ let "coordinates" (x, y) be assigned as in example 7 given last month. The conclusion holds either if x is greater than m or if y is greater than n. Now, when x is less than or equal to m and y is less than or equal to n, there are only mn different pairs (x, y). On the pigeonhole principle two of the pairs assigned to the $mn + 1$ numbers in the row must be the same, and as was shown last month a contradiction follows.

Last June I reported that Alan Beckerson, a London expert on checkers problems, had found 28 final positions for a 24-move game in which no checkers are captured. For more than half a century the minimum number of moves for a no-capture game was thought to be 24, but that is not the case. Beckerson has now found several no-capture games that end after the 21st move. One such game is shown in the illustration on page 22.

For the material discussed this month I am indebted to many sources. The problem of the four prices is given in *Crux Mathematicorum* (Vol. 4, No. 4, pages 164–167; June, 1978). For the dissections of the cube see *Mathematical Models,* by H. Martyn Cundy and A. P. Rollett (Oxford University Press, second edition, 1961, page 122), and letters in *The Mathematical Gazette* (Vol. 57, No. 399, pages 66–67, February, 1973, and Vol. 57, No. 401, page 211, October, 1973). The problem of the numbers on the cube is from a personal letter from Garry Goodman, and the paradox of the cube's surface area and volume was sent in by Harlan L. Umansky.

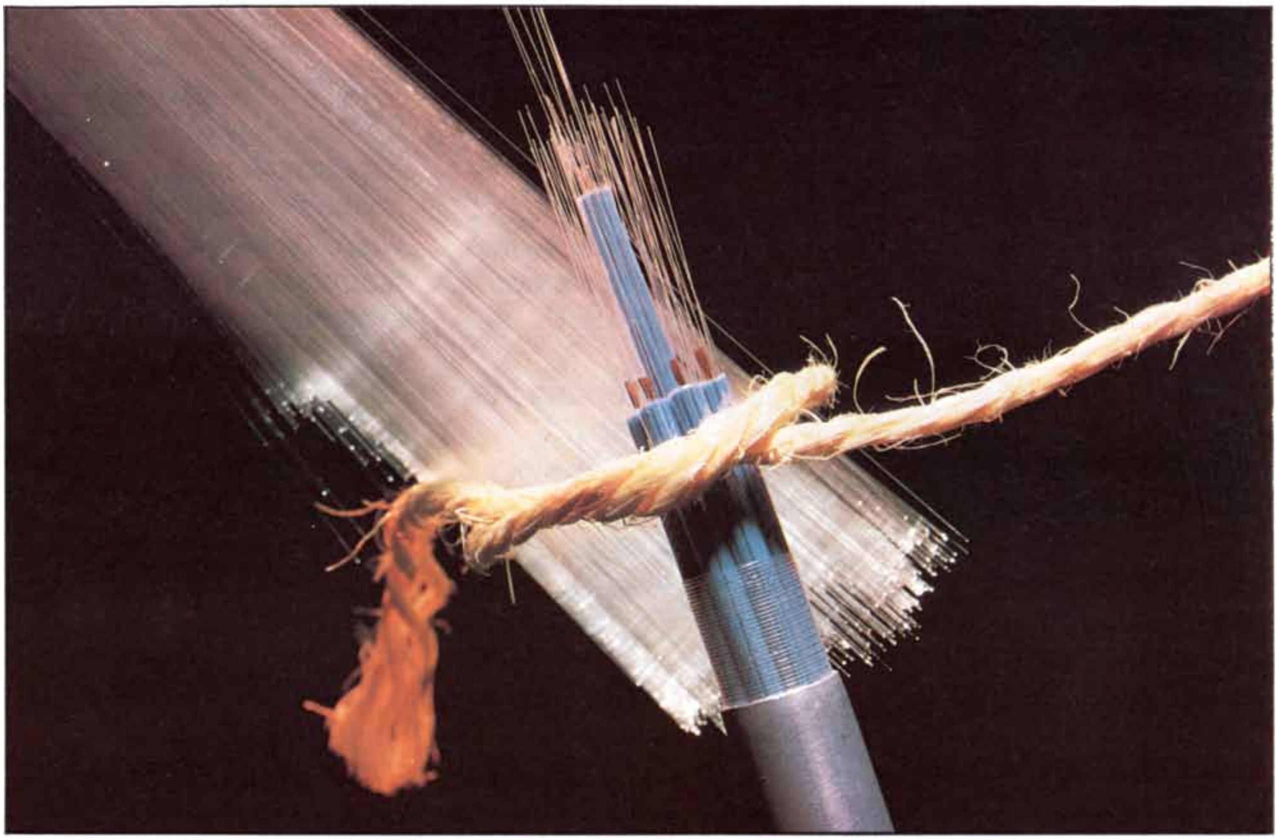
Lam Garvin of the sheikhdom of Qatar called Khalifa's booklet to my attention by sending in clippings about it from this year's January 13 and January 20 issues of the weekly *Gulf Times,* which is published in Doha, the capital city. The 666 curiosity is a recent discovery made by Elvin J. Lee. The prime-alphabetization tasks are from Edward R. Wolpow's article "Alphabetizing the Integers," in *Word Ways* (Vol. 13, No. 1, pages 55–56; February, 1980).

FRENCH TELECOMMUNICATIONS:

DIGITAL TECHNOLOGY AND THE TELEMATIQUE PROGRAM

This special report on recent advances and future innovations in French telecommunications was written by Joel Stratte-McClure, a Paris-based technical and financial writer.

Photograph courtesy of CNET.



Fiber optical cables play an important role in French telecommunications by transmitting more information in less space. The town of Biarritz in southwestern France will be equipped with a complete fiber optic transmission system.

France spearheaded a technological revolution in telecommunications in 1970 when the world's first electronic time division multiplexing (tdm) switching center was put into operation in Perros-Guirec, a rustic coastal village in Brittany. Since then the French have moved swiftly forward to develop an integrated telecommunications system which utilizes sophisticated digital technology and makes the telephone network the fundamental component of a comprehensive information-based society.

To attain this goal the French have substantially developed their domestic telephone system and launched a far-reaching télématique program which marries the capabilities of telecommunications and data processing (known as *informatique* in French). The télématique program incorporates telephones, television, facsimiles, computer terminals and other media into an harmonious network which permits data and other forms of information to be transferred speedily using advanced digital transmission techniques and tdm switching.

During the next few years a diverse range of consumer products and services will transform the telephone line into a multi-functional tool which will perform a variety of communication requirements.

"The development of the French telecommunications network springs from the radically new concept of telecommunications in which speech transmission is only one aspect of the network which will transmit information in all forms – oral, visual and written," explains Gérard Théry, Director General of Telecommunications (DGT) for the French Ministry of Postes, Télécommunications et Télédiffusion (PTT), the government body which oversees development of France's domestic telephone network.

"The integrated services digital network must be able to meet all communication needs by use of a single line. The subscriber will only need to adapt his terminal equipment to his immediate purpose and the telephone network will be able to provide the requested service."

Competitive Productivity

A visitor to France today is immediately struck by the amount and diversity of activity in the telecommunications sector. At first glance the entire country resembles a research and development (R&D) laboratory for a wide range of telecommunications equipment and télématique-oriented products.

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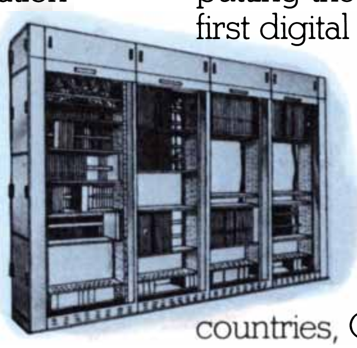

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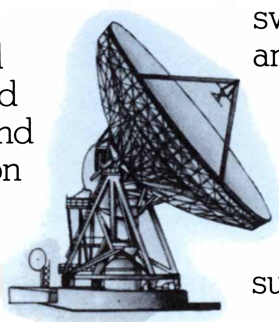

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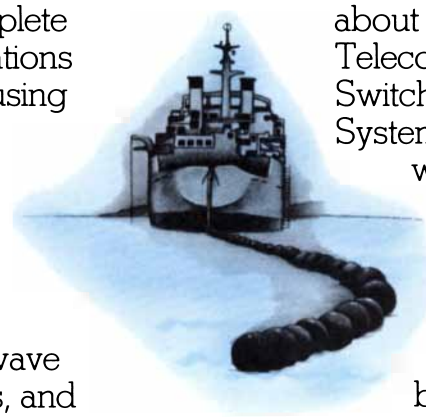

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The manufactured output ranges from large-capacity tdm switching systems developed by the two giants of the French telecommunications industry, CIT-Alcatel and Thomson-CSF Telephone, to the invention of a springless alphanumeric keyboard by Edouard Serras-Paulet, president of the rapidly growing Sigma Industries.

Large and small companies, from Lille in the north to Marseilles in the south, from Brest in the west to Strasbourg in the east, have developed and produced modems and multiplexers, home terminals and consumer facsimiles, connectors and fiber optical cables and an overwhelming range of compatible but competitive peripheral telephone equipment.

There is an immediate sense of vitality and youth in the French telecommunications industry due to the fact that half of the nation's manufacturing plants are less than a decade old.

New industrial parks, like Vélizy, southwest of Paris, have literally sprung up to enable companies like ITT's subsidiary Compagnie Générale de Constructions Téléphoniques (CGCT) to assist in the development of a new generation of tdm switching equipment. The town of Lannion, an hour's flight from Paris, houses two government R&D laboratories and private companies conducting their own R&D activities. In Grenoble, a new research center earmarked for the development of rapid high-density integrated circuit technology is the first step towards making that part of France a Silicon Valley in the Alps.

Companies dot the entire country manufacturing telecommunications products for domestic and international consumption. Somfy-Tec produces telephone exchange protection systems in the Alpine village of Cluses. Tekelec's range of testing and measuring equipment is designed and assembled in Bordeaux. The Matra group is working on France's first domestic telecommunication satellite in Toulouse and Barphone is producing automatic diallers and intercom systems in Saumur on the Loire River.

Cables are manufactured in Lyon, software is being developed for the télématique program in Rennes and a *télé-boutique* in Orleans, a chic shop promoting and selling telephone-related goods, gives Frenchmen a glimpse of the latest product advances.

Domestic Development

France's telecommunications industry received a major boost in 1975 when President Valéry Giscard d'Estaing and his government decided the top priority of the country's seventh five-year plan would be the development and modernization of the telephone network. The government gave the PTT the go ahead to raise funds publicly and spend a hefty $30 billion to improve the internal telecommunications network.

The purpose of such a vast expenditure was not only to usher in revolutionary switching and transmission techniques, create a national packet data transmission network, produce the télématique program and develop a prosperous industry, but in the first instance to increase the number of available subscriber lines and give everyone access to a telephone.

The numerical results, which form the backbone of future progress in the télématique program, are impressive.

The number of subscriber lines in France, a country of 53 million people, will have increased from 6.2 million in 1974 to 16 million at the end of this year. In 1987, there will be 28 million subscriber lines with 34 million lines projected for 1992.

To provide some perspective, during the past eight years France will have installed more than twice the number of telephone lines put into operation during the previous 100 years. In fact, one out of eight telephone subscribers being hooked up to a telephone anywhere in the world today is French.

Technical Choices

Naturally the decision to invest this amount of money in the country's telecommunications future was not taken lightly. The planning, from the early option to develop electronic tdm switching to the philosophical and technological thrust of the télématique program, was largely the result of lengthy studies conducted by the DGT's research arm – the Centre National d'Etudes des Télécommunications, or CNET.

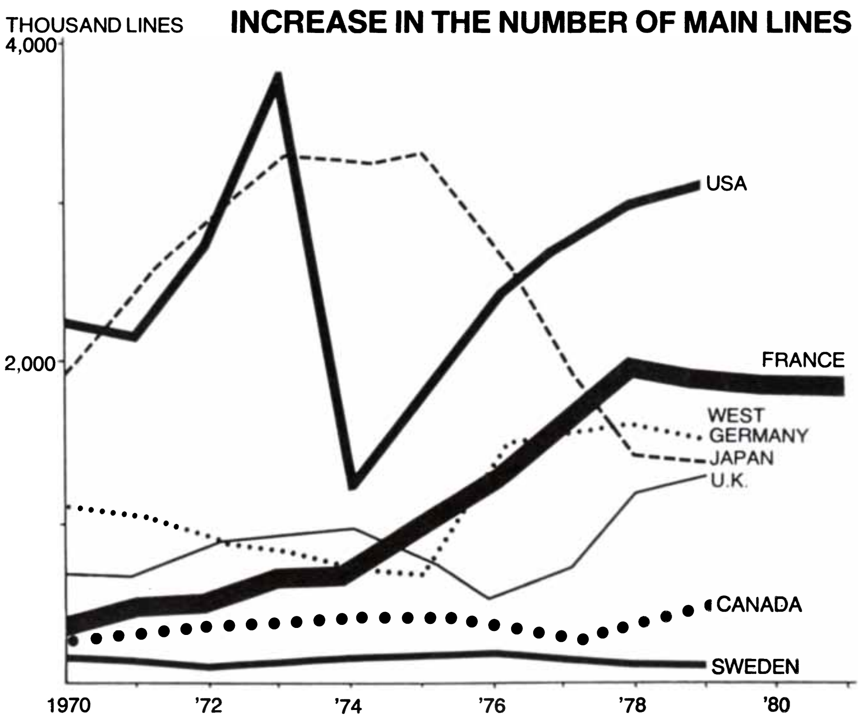
The CNET can be compared to some degree to Bell Telephone Laboratories in the United States. Its R&D activities, undertaken with a medium and long range view, have a considerable impact on the direction and activity of the telecommunications and electronics industries.

It was research first conducted by the CNET in the early 1960s, for example, which prompted CIT-Alcatel to develop its E 10 series of tdm switching centers. In 1972, the CNET produced studies which resulted in the creation of TRANSPAC, France's domestic data packet transmission network. And in the late 1970s the CNET defined the télématique program.

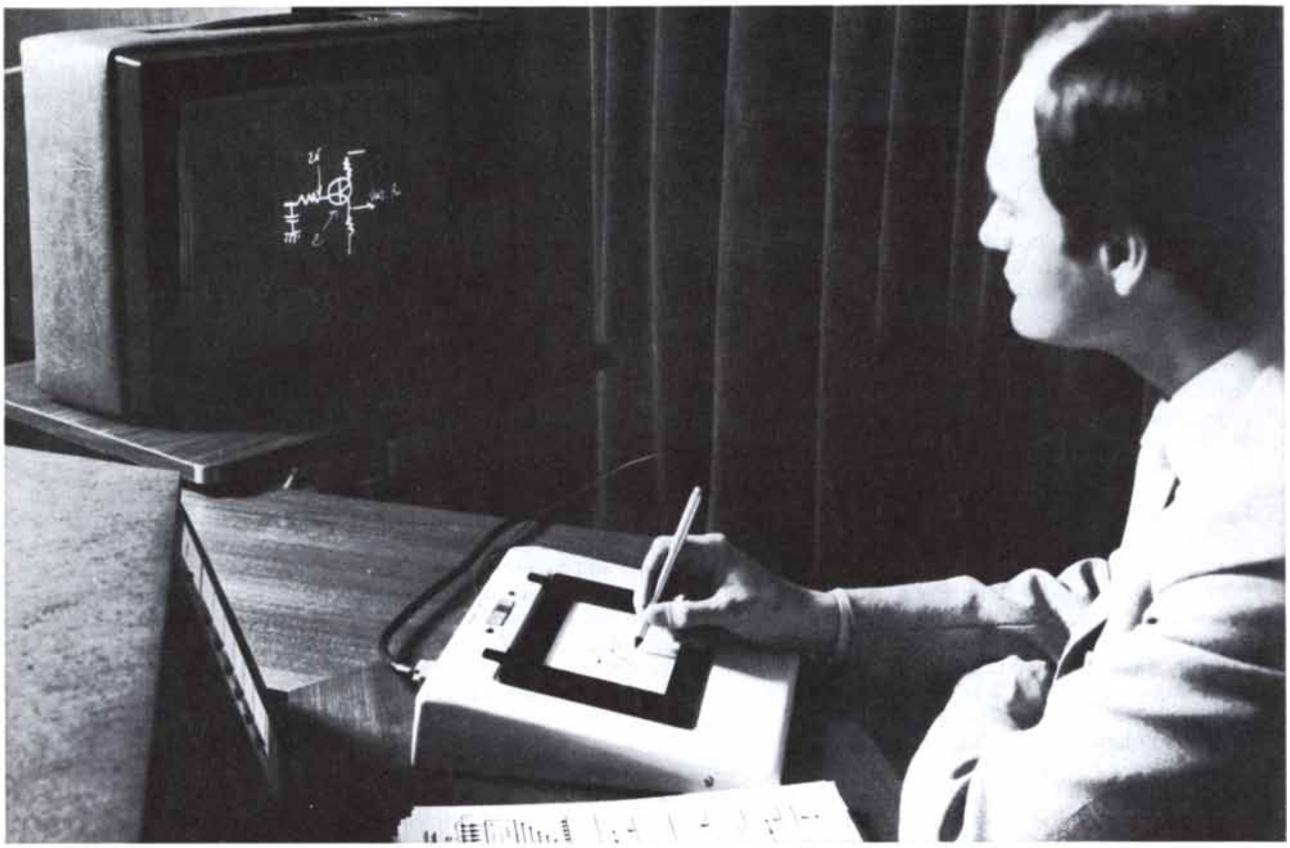
"The CNET put the creative carrot before the entire telecommunications industry in France," says Henri Sulzer, corporate development manager of Matra's télématique division, which has developed a number of products, including a video telephone, in collaboration with the CNET. "Much of the progress in French industry, from digital transmission to the télématique program, would not have occurred if it weren't for the CNET's foresight."

CNET: The 70s and 80s

Any overall look at French telecommunications begins at CNET's six research centers. Here the organization introduces new materials, products and patent applications which will eventually be developed by two or more French industrial



Photograph courtesy of CNET.



The CNET, the French government's research and development organization, has spearheaded a number of advances in the country's telecommunications industry. This telewriter uses multiplexing techniques which permit the simultaneous transmission of written material.

companies. It prepares general and technical specifications, an important role in determining how French-made products can be adapted for use in other countries.

"We are a catalyst for French industry as far as product development and general direction are concerned," says Maurice Bernard, director of the CNET. "Because we're a state organization we have the luxury of taking the long view in our planning and R&D."

Bernard believes there are five primary areas in which the CNET and French industry broke new ground in telecommunications during the past ten years.

"The first is obviously electronic tdm switching," he says. "The second is digital transmission, the third is satellite communications in which two satellites proved the feasibility of various digital transmission facilities, the fourth is optical communication systems and the fifth is the new services, including the data transmission network, which have moved out of the laboratory."

During the 1980s a number of CNET-developed products will be commercialized by French industry including intelligent telephone sets, low cost consumer facsimiles and systems based on man-computer dialogue.

"Our current R&D efforts will be even more important than ever before because of the continuous cost reduction in microelectronics," Bernard predicts during an interview at his Paris office. "Image and graphics will be at the core of our work and during the next ten years the CNET will concentrate on six major R&D areas: silicon microelectronics; optoelectronics; intelligent terminals and networks; optical and satellite communication systems; computer and microprocessor assistance to all network functions and new communication concepts."

With télématique products leaving the laboratory for the consumer market, Bernard admits he is very concerned with mass consumption.

"We are getting the citizen involved and to a degree we are becoming sociologists," he says. "It will be interesting to see how the man in the street reacts to the possibility of having data processing capabilities in his living room."

Tdm Switching

The foundation of the overall plan for the evolution of the telephone network was the revolutionary decision to rapidly adopt French-developed electronic tdm switching and digital transmission techniques. In 1980, over 70 per cent of the equipment ordered for the French telephone network is of the electronic tdm type (the remainder is space division and electromechanical) while 75 per cent of the orders in transmission are for digital pulse code modulation (pcm) equipment. During the next few years all orders for new equipment will consist of tdm switching units and compatible digital transmission systems.

When the French first pioneered the movement into electronic tdm switching, which is now globally applauded, it must be recalled that their decision was met with considerable scepticism. In the 1960s, digital technology was contrary to accepted trends and considered a great risk.

Most telecommunications professionals agreed there would ultimately be a digital revolution in the field, but felt the French were moving into commercialization at too early a stage. In addition, telecommunications specialists felt digital technology was applicable only in transit switching centers and many were astounded when the French began the digital movement by applying these techniques to their rural subscriber networks.

However, by using remote subscriber units to equip rural zones in France, the electronic tdm era began and has subsequently enabled the French to equip their entire network with tdm switching exchanges of various capacities.

A telecommunications network predicated on tdm switching and digital pcm transmission became feasible when computers were introduced to perform data processing services in switching centers – including call processing, circuit control and fault-finding. The French techniques generally allow technological progress in electronics and data processing to be applied to switching and transmission.

Rather than using outmoded analog "voice frequency" transmission, the digital system samples, codes, multiplexes and routes the electric signal transmitted by the subscriber. The result is a network which functions much more efficiently and with less interface equipment than that of the analog variety.

Digital technology in telecommunications first attracted the interest of the French because of a number of operational advantages which are worth noting briefly. Tdm switching and pcm transmission increase productivity due to the use of integrated components which continue to decrease in price; there is a much greater flexibility in engineering and operation; the 2 mbit/sec standardized channels eliminate interfaces and decrease network installation costs; and the quality of subscriber service is improved by the non-blocking networks. The modular design of the system and the overall use of plug-in cards results in several months reduction in installation time, much less surface space requirements and greater reliability.

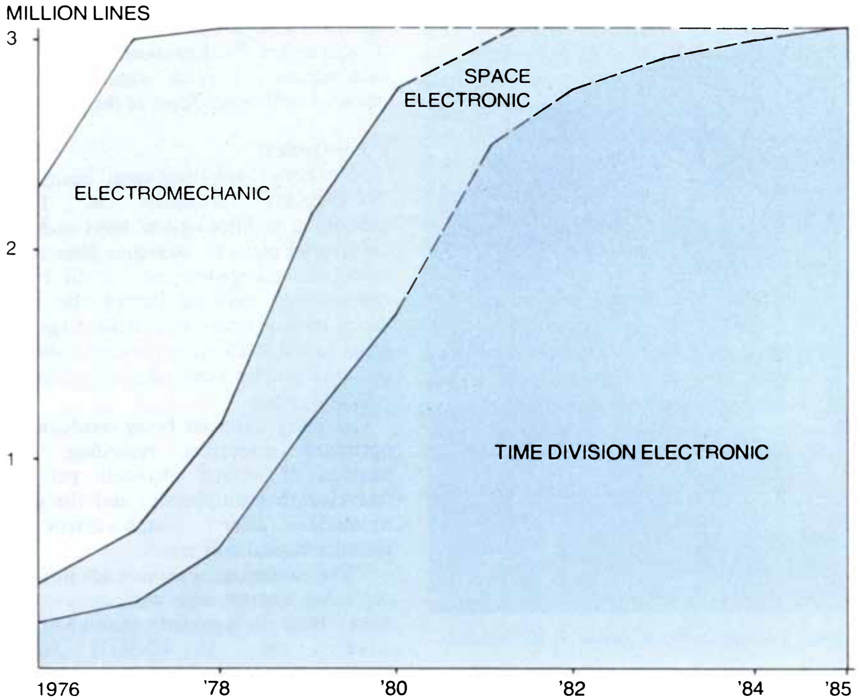
More importantly, tdm switching and pcm transmission provide networks with increased flexibility permitting the connection of multiple terminals and the possibility of dialogue from terminal to terminal, or with a computer, without costly interfaces.

"The advantages of time division multiplexing switching and digital transmission techniques enable us to integrate future télématique services into an economic and efficient network," explains Gérard Théry. "In the process there is increased productivity, a decrease in network costs and a less complicated operation at the level of maintenance and management."

The first tdm system developed for the French network was manufactured by CIT-Alcatel, a company with 40 per cent of France's switching market, 42 per cent of the multiplex market and 40 per cent of the private automatic branch exchange (pabx) sector.

"We started studying tdm switching in 1960 in collaboration with the CNET," recalls Ambroise Roux, chairman of the CGE group which controls CIT-Alcatel. "Our intention was to combine tdm switching and digital transmission to

DEVELOPMENT OF SWITCHING EQUIPMENT ORDERS



Although the first member of this American-oriented digital family, the TSS-5, does not use specific hardware or software from the E 10 system it follows the overall philosophy of combining decentralized distributed switching and control with centralized maintenance and administration.

"Small capacity US subscribers are moving into this range of digital equipment," says Jacques Blanché, head of CIT-Alcatel's public switching division. "This new unit allows us to take digital technology to the market for small-to-medium range requirements."

CIT-Alcatel received its first order for the TSS-5 from an American client last May and will make delivery in 1981.

France's other large telecommunications company, Thomson-CSF Telephone, an affiliate of the large professional electronics company Thomson-CSF, has also moved into the tdm switching field. Their MT range of tdm exchanges has been on the market for two years and over 2 million lines have been ordered in 16 countries.

Thomson-CSF Telephone currently has four models of the MT system available: the MT 20 transit center which is suitable for integration into urban, national or international grids; the high capacity MT 25 (65,000 subscribers) subscriber exchange; the medium capacity MT 30 (8,000 subscribers); and the MT 35 with a capacity of 200 to 1,000 subscribers.

The MT 20 range consists of a unit time-multiplexing the pcm channels connected to it, local or remote interfacing units for all types of trunk lines, and signalling units which process lines and register signalling data.

Between them, CIT-Alcatel and Thomson-CSF account for over 60 per cent of all tdm switching lines in service or on order in any part of the world today.

A third French company has also developed a tdm system for public telephone networks and will be competing with CIT-Alcatel and Thomson-CSF Telephone for domestic and international orders.

Jeumont-Schneider's JISCOS 80 has a flexible architecture capable of handling up to 20,000 subscribers.

In addition to the these companies, ITT's French subsidiary CGCT is also moving into tdm switching for all sizes of public and private networks. Although their main switching strength in the past has been the Metaconta space division switching system, one CGCT affiliate, the Laboratoire Central de Télécommunications (LCT) in Vélizy, is currently working in collaboration with other ITT laboratories to develop the System 12 range of tdm switching products.

"We realize the importance of tdm technology in public switching especially in view of the growth of the télématique program and other services using the public network," says Robert Bonami, manager of System 12 engineering at LCT. "The French pushed other companies into this area with their first tdm systems and the movement has now gained global acceptance. We think our later entry into the market gives us a more sophisticated generation of equipment but that will become clearer when prototypes are available in January."

Digital Transmission

Accompanying the introduction of tdm switching is the corresponding pcm digital transmission supporting environment, which is necessary for a complete electronic network. The French, particularly at the local and regional levels, are rapidly converting their transmission system from analog to digital techniques which use hierarchial operational channels (2, 8, 34 and 140 mbit/sec digital paths) to transmit over coaxial cable, microwave, radio relay and optical fibers.

The development of digital transmission, which was first initiated in 1965 when pcm was used over a 20 kilometer link in a suburb of Paris, is related to the comparative low cost of the multiplexed channel and the possibility of using existing low frequency cables without installing a totally new network. Today 21 per cent of French circuits use digital techniques and an entire generation of digital terminal and line equipment has been developed.

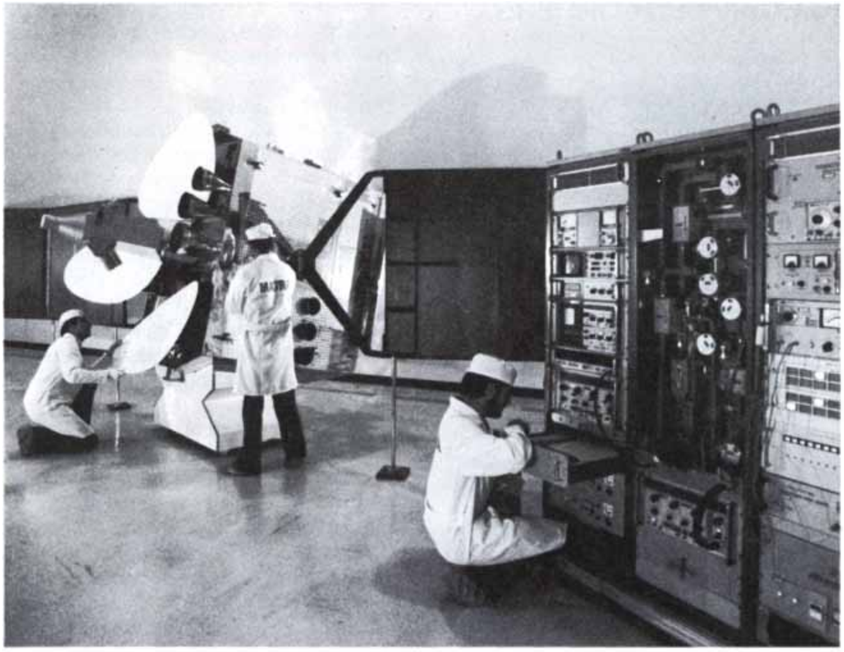
Although the French network will ultimately be completely equipped with digital transmission facilities, the administration is determining the introduction of this equipment on a case-by-case basis according to cost considerations. The first areas employing digital techniques are the urban and local networks where existing cables have been modified for digital transmission without the installation of new lines.

In addition, between 1970 and 1979 over 300 2 mbit/sec microwave links and 400 8 mbit/sec microwave links were put into service. The result is that today 340,000 of 1.6 million circuits are digital and the existing analog network will be progressively replaced by digital links. Orders for digital equipment have increased from 31 per cent in 1976 to 64 per cent in 1979 and to 75 per cent this year.

Again, as in the area of tdm switching, the French took an early gamble when they opted to equip their network with pcm transmission links, but the continuing decrease in costs of electronic components and integrated circuits has made digital transmission a highly economic solution.

Digital transmission techniques, in combination with tdm switching, have a number of cost-saving benefits: they reduce the required amount of coding and multiplexing equipment, more circuits can be established on existing cables than by employing analog techniques, and they can also be used for telex and other transmission services.

The most profound future plans in the pcm transmission area concern the full-scale introduction of these techniques on



The French domestic telecommunication satellite, Telecom 1, is being manufactured under the auspices of the Matra group at their Toulouse facilities.

long-distance trunk networks. In 1982, 4 x 140 mbit/sec systems will be manufactured using 2.8/10.2 coaxial pairs with aluminium external conductors. In addition, French companies are in the process of developing coder-decoder integrated circuits (CODEC) which will allow the placement of digital techniques up to the subscriber's telephone set.

A variety of French firms, including SAT (Société Anonyme de Télécommunications) and TRT (Télécommunications Radioélectriques et Téléphoniques), produce transmission equipment ranging from cables to digital multiplexing terminals adaptable to any transmission medium.

Thomson-CSF has thirteen production plants in the transmission field and is capable of designing, manufacturing and installing complete telephone transmission networks using cable, microwave or satellite. The company's new series of microwave transmission, for example, features digital transmission with speeds of 2 x 140 mbit/sec using microwave modulation (20 GHz).

CIT-Alcatel has developed a large number of pcm systems employing metallic cables, optical fibers and microwave links for subscriber and trunk lines. These systems provide inexpensive connections to switching equipment forming a complete integrated network.

"The future for everyone in the pcm area," says CIT-Alcatel's technical director Jacques Eldin, "is to increase circuit capacity which, of course, decreases the price per line."

Telecom 1

Satellites and fiber optical cables – which accelerate the introduction of digital transmission techniques and form the physical connections for the télématique program – both play a substantial role in future French transmission plans. France is expected to put its own domestic satellite, Telecom 1, into service in 1983 while fiber optical cables will gradually be installed during the next decade.

Telecom 1 will provide an "intracompany" link with high speed digital wide band communications between separate branches of a subscriber's organization. It will link France and its external territories for telephone and television traffic between strictly localized geographical points and facilitate the development of new applications in large bandwidths – including video teleconferences, high speed facsimile and the rapid transfer of data between computers.

The system – two satellites in geostationary orbit above the Gulf of Guinea in the Atlantic Ocean – will carry a communications package in the 12 and 14 GHz bands with a gross capacity of 150 mbit/sec and a transmitting power of 20 W. Subscribers will have access to Telecom 1 through a tdm system using earth stations.

A number of French companies will be involved in the construction of Telecom 1. The Matra group, which will oversee development at its Toulouse site, is the prime contractor and Thomson-CSF has been awarded a design contract for the payload including telecommunications repeaters and antennas adapted to different coverage areas. Thomson-CSF and CIT-Alcatel, through their 50-50 partnership in Telspace, are the European leaders in the construction of earth stations and will jointly handle that aspect of the project.

Fiber Optics

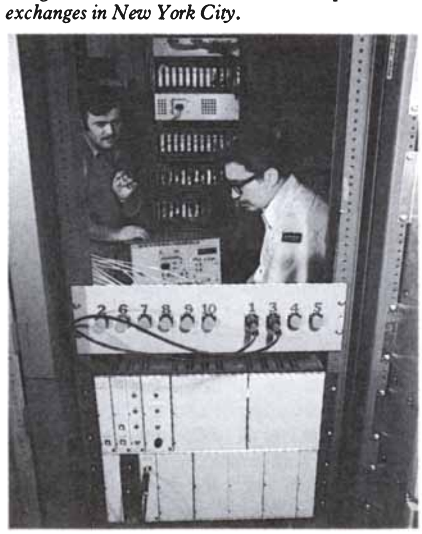
There have been long-term design and development programs in France pertaining to fiber optical links and there are overall plans to introduce fiber optical cable into numerous parts of the French transmission network during the 1980s. These include inter-urban links, large-band links to subscribers, submarine cable and optical fibers for video telephone and video teleconferences.

Currently, tests are being conducted for optimum resolution regarding transmission of several channels per fiber (wavelength multiplexing) and the use of unimode fiber (improvement of distance/digital flow ratio).

"The numerous economic advantages of replacing copper wire with optical fibers have been recognized throughout the world," says the CNET's Maurice Bernard. "They provide the transmission of more information in a smaller space."

The CNET laboratory in Lannion has conducted design and experimental work using several different cable structures including the conventional one where fibers are individually protected in a cable; a grooved cylindrical structure with fibers inserted in spiral grooves on the outside of a cylindrical core sheathed by protective tapes; and a tape structure where fibers are rolled out in parallel between two sheets of plastic material to form a tape and then placed on top of each other. Experimental optoelectronic systems were established on 0.85 and 1.3μm to illustrate the feasibility of links.

A CIT-Alcatel fiber optic communications system is being used to link two Western Union telephone exchanges in New York City.



This month Thomson-CSF's subsidiary, Lignes Télégraphiques et Téléphoniques (LTT), is installing a seven kilometer link between two urban exchanges in Paris using a grooved structure cable (34 mbit/sec) containing 70 fibers. The company is also placing a 10 kilometer fiber link along two stations on Paris' express subway line to permit two-way transmission between digital terminals at the rate of 2 mbit/sec.

LTT, which produces about 100 kilometers of fiber cable a month, is installing another fiber optic system in the Loire Atlantique region of France which connects a television camera to a surveillance monitor over a distance of five kilometers.

"Our strength in the fiber optic area is that we're one of the few companies in the world capable of producing all the components for a complete fiber optic transmission system — lasers, cable, connectors, splicing equipment and so on," says Thomson-CSF's technical director Michel Carpentier.

CIT-Alcatel is also active in fiber optics and has delivered equipment for an experimental fiber optic link in New York City which began operating in January between two Western Union exchanges. The system has a 45 mbit/sec capacity and extends over a distance of four miles without repeaters. CIT-Alcatel has also installed an experimental link in Berne, Switzerland, and its affiliate Câbles de Lyon is in the process of equipping a microwave link in Dijon with fiber optic transmission. Another subsidiary, Calais-based Submarcom, which is the world's second largest producer of submarine transmission systems, is experimenting with underwater fiber optical systems between Corsica and France.

Although fiber optical techniques will ultimately be introduced throughout the French transmission system, the most ambitious project is the installation of a complete fiber optic transmission network in Biarritz, a town of 30,000 people in southwestern France.

The Télématique Program

Electronic tdm switching, pcm transmission and TRANSPAC – the French public data packet transmission network which permits the processing equipment of one subscriber to communicate with that of any other subscriber by presenting data in a prescribed manner to the national network – combine to form the foundation for the télématique program. Industrial companies and government officials react with enthusiasm when discussing the product and service potential associated with télématique and the term has become a buzzword throughout the French telecommunications industry.

The phrase was created in the late 1970s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when two French telecommunications specialists, Simon Nora and Alain Minc, used it in their lengthy report on a computerized society. "Simply stated," says Simon Nora, "télématique is the result of the growing interconnection between telecommunications and data processing and will, sooner or later, lead to radical changes of life in all countries."

A key feature of the télématique program in France is an emphasis on mass markets and the corresponding low cost of products and services. The end result will be a multi-service telecommunications network offering unlimited and tailor-made services producing a considerable reduction in communications costs.

"The multi-service network answers all telephone, data transmission and facsimile needs including the interrogation of data bases," explains the DGT's Gérard Théry. "The collective and general network will also substantially reduce costs."

France, unlike most other countries, has created a télématique program supported by a unified national policy which calls for the integration of numerous compatible products and services. The government's stated intention is to provide the public with access to a wide range of new and complementary methods of communication which facilitate dialogue and create a more democratic, equitable society.

"Mass computerization will take hold," predicted Nora and Minc in *The Computerization of Society*, "becoming as indispensable to society as electricity."

The possibilities of the télématique program, using uniform terminals and improved transmission techniques, are vast: written messages and electronic mail can be transmitted between individual subscribers; information may be obtained using a simple keyboard through a unidirectional teletext system; data processing may be conducted on a compatible interactive videotex system; and a standard terminal can be used to obtain telephone numbers.

The télématique program, using the telephone and television as building blocks, permits the simple connection of every telephone subscriber to virtually any information source. During the past few years, research branches of the PTT have been conducting studies to determine which services should be offered to subscribers and how they should be physically transported and presented.

The result is a logical and coherent plan for the transmission and reception of information using the fewest number of commands to request, and to receive the greatest amount of data.

As it gets underway the télématique program has created a number of advantages for French manufacturers.

At the terminal level, for example, specifications have been standardized to provide complete compatibility which allows terminals to be used for a large number of services. Terminals being manufactured for the télématique program have a unified base which adapts to all network standards and consequently may be employed for a variety of tasks. Broadcast functions operate separately from display functions which greatly expands usage and uniform graphics and character definition – up to 16 different alphabets displayed on a single page – allow production and editing of material for different services.

In addition, because the French are in the forefront of the move into the télématique era, their equipment is being developed in conjunction with international organizations resulting in the establishment of international norms.

France's lead in télématique allows them to experiment with systems which will probably be adopted in other countries. In the area of billing, for example, the French have developed a magnetic credit card with a microprocessor which will be inserted into the terminal with each use to determine the cost for the specific service.

The overall thrust of the French télématique program is the result of a unified concept which provides exceptional flexibility. Products and services are geared to integrate and interfunction so that the ultimate possibilities of the télématique program depend upon consumer demand and imagination. New services may be added without substantially altering transmission techniques or terminals.

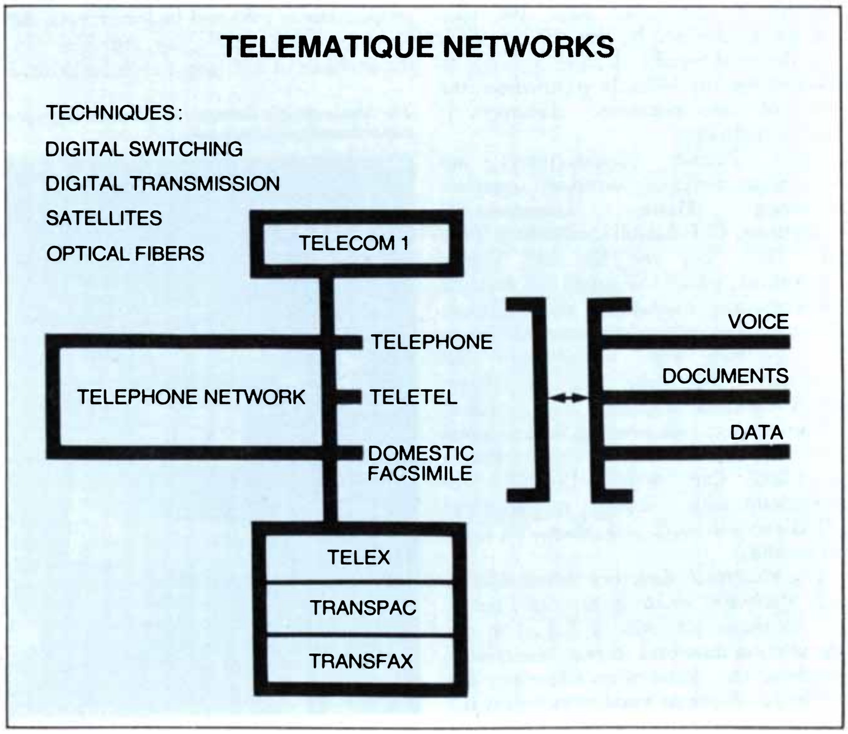
To obtain an idea of the initial application of the télématique program simply imagine yourself in a French living room in 1982. Naturally you will have a telephone and television but a number of new products, all using the telephone network, will be at your fingertips. An electronic directory will enable you to find a telephone number without the traditional telephone book. A facsimile will permit you to send a letter instantaneously. You can use the television to book an airplane flight.

"Your living room becomes an office which can handle all of your communication requirements," says Hervé Nora, head of the DGT's new products and services division. "And it will be as easy as picking up the telephone."

Electronic Directory

The first step in the télématique program, which could potentially be a major problem, is selling the concept to the consumer. There is no market research which indicates there would be an immediate rush to purchase terminals and other equipment simply because it is on the market.

But the French have side-stepped this dilemma with the decision to provide free alphanumeric terminals to replace the current paper telephone directories. 250,000 telephone subscribers in the Ille and Vilaine region of western France will be the first to get the terminals in 1981 and during the decade the units, which permit consultation of daily updated telephone subscriber lists, will be progressively introduced in other parts of the country.



France's télématique program will use the telephone line to bring facsimiles, electronic telephone directories, videotex and other sevices into the consumer's living room.

"We expect to see the complete abolition of printed directories in France by 1995," says Gérard Théry.

Théry expects that the terminals can be produced at less than $100 per unit for the mass market in France and contends they will not only inaugurate the télématique program but solve the problem of high paper costs and quickly outdated printed telephone directories.

Says Jean Syrota, head of the Industrial and International Affairs Division (DAII) of the DGT, "In 1979, it took 30,000 tons of paper to produce the printed directory in France. Each year, because of our increased number of subscriber lines, the total volume is increased by two million names and the total weight of paper will rise to 100,000 tons by 1985. In comparison, the cost of an electronic directory is substantially less."

Four French manufacturers are developing electronic directory terminals including Matra, Thomson-CSF Telephone, CIT-Alcatel's subsidiary Télic and TRT. For the Ille and Vilaine experiment, which will gauge and evaluate the consumer reaction to the electronic directory, two industrial groups will create the software and manufacture the terminals. CIT-Alcatel and its affiliate SESA (Société d'Etudes des Systèmes d'Automation) will produce one terminal and consultation system while software specialists Cap Sogeti Logiciel will collaborate with computer manufacturer CII-Honeywell Bull and Matra-TRT for the second.

The electronic directory terminal, a 9-inch black and white screen connected to the telephone set, will be linked to the consultation data base through the regular telephone line. Subscribers will obtain the requested telephone number by typing the required name on the keyboard to enter the system. The number will then appear on the display screen.

"Substituting an electronic directory for a paper one solves the problem of getting a terminal to the consumer," says Matra's Henri Sulzer. "With the entire French population as a captive market we can produce these terminals in larger quantity and at low cost – which gives us an edge in markets outside France."

Jean Syrota expects the electronic directory to have applications beyond the French borders. He predicts that "between 30-50 per cent of the electronic directory production in 1985 will be for exports. All developed and developing countries face the problem of high paper costs for printed directories and will see the electronic directory as a practical and simple solution."

Videotex

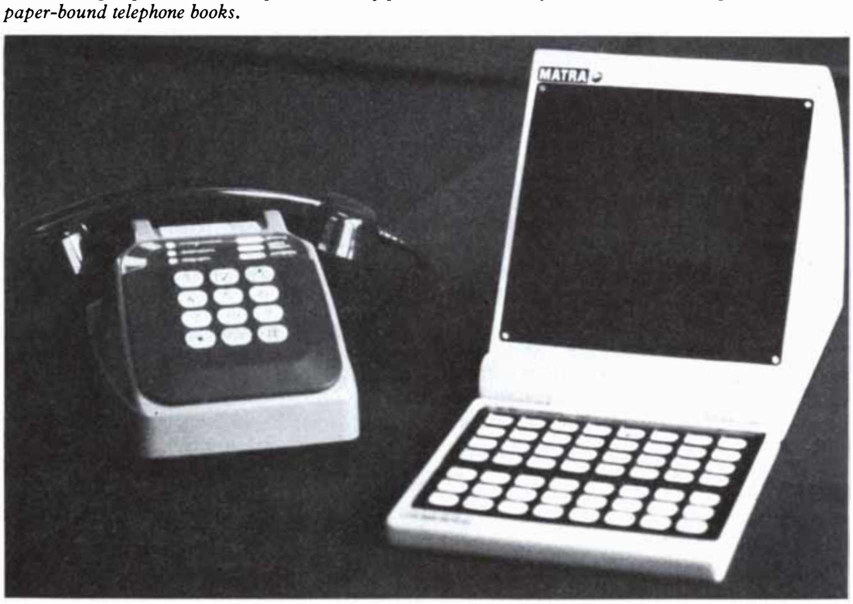
The terminal for the electronic directory is compatible with developments in the videotex area and can also be used to request information which will appear on the television screen. A French videotex service will be inaugurated on a test basis in 3,000 households in the Vélizy area this autumn and is the key to two-way data processing. The French program involves two services based on a common standard:

- Antiope is the direct one-way broadcast of radio signals through the radio network. The user selects required data for display on the screen using the numeric keys on the terminal keyboard. Television broadcasting of digital data making up the Antiope pages is based on the DIDON system of data broadcasting. For transmission, the DIDON multiplexer divides the continuous flow of coded data into 32-octet packets; for reception, the DIDON demodulator performs the symmetrical function. The result is a fully transparent system.
- Télétel (derived from the words telephone and television) is connected directly to information stored in data bases through the telephone network. It creates an interactive dialogue with the data processing centers using the alphanumeric keyboard to request information.

"Télétel is a video telephone with a keyboard," explains Gérard Théry. "It is the ideal tool for domestic computer communications."

Télétel enables both professional and home users to consult a wide range of data banks – timetables, news or stock quotations, for example – or conduct

The Matra group's electronic telephone directory provides access to information without using the traditional paper-bound telephone books.



THIS IS MATRA

The means of achievement

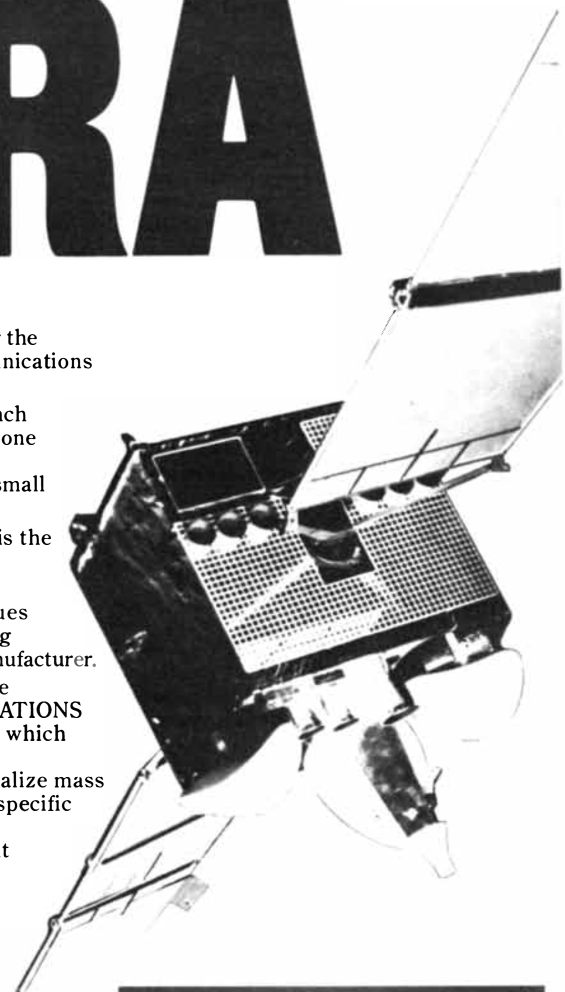
MATRA has set up a communications and telematics division which develops and distributes systems and terminals for business communication and new consumer services.
It possesses specialised electronics laboratories and major programming resources. The use of mini and micro-computers and exploitation of the facilities offered by micro-electronics endow MATRA systems and equipment with a high degree of adaptability and extendibility.
This Division benefits from the technological support and complementary nature of the Group's abilities: mechanics, electro-mechanics optics, components, manufacture and marketing.
These resources comprise a rational industrial group facilitating the development of the Communications and Telematic activities.

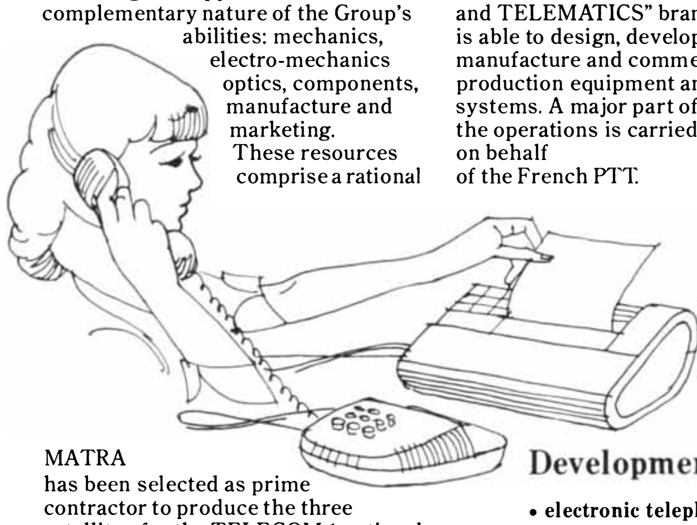
PERITEL Co leads the French market in peripheral telephone systems, mobile radiocommunications and small switching systems.

PICART LEBAS Co (TPL) is the leading French Keysystem manufacturer.

"Constructions Telephoniques DEPAEPE" Co is the leading European telephone set manufacturer.

Now, MATRA Group has the facilities of a "COMMUNICATIONS and TELEMATICS" branch which is able to design, develop, manufacture and commercialize mass production equipment and specific systems. A major part of the operations is carried out on behalf of the French PTT.





MATRA
has been selected as prime contractor to produce the three satellites for the TELECOM 1 national telecommunications system to be put into operation by the French Telecommunications Authority in July 1983.
MATRA has been selected for the new Telematics projects of the French PTT: "Teletel Velizy", "Terminal annuaire", "Utility facsimile".
Efficiency, fast response, and top performance have turned MATRA into a regular challenger of the biggest companies in international competition.

challenge us
MATRA BP 1 - F 78140 VELIZY

Development areas

- **electronic telephones and peripherals**
- **keysystems - PABX**
- **facsimile**
- **videotex**
- **land mobile radio**

MATRA
SERVING PROGRESS
WORLD WIDE

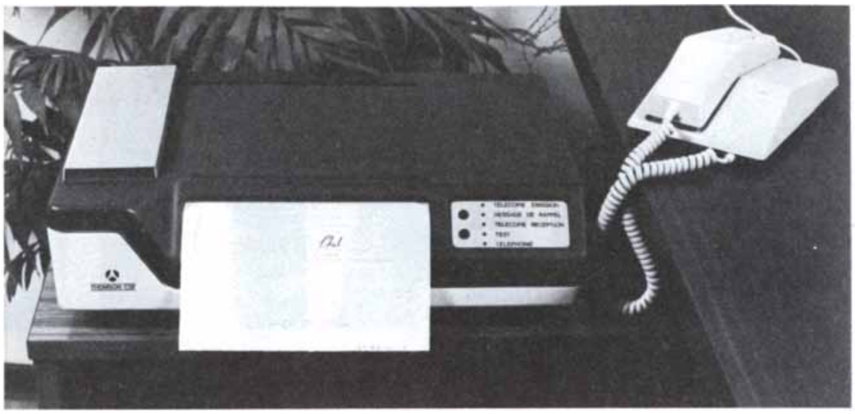
multiple transactions – such as banking operations, booking flights or ordering goods. To date, over 200 companies have contracted to hook up with the system. For the Vélizy experiment, for example, the French railways will provide a home booking system.

"The possibilities of Télétel are limitless," says Hervé Nora. "We have developed a software and hardware system which could be adapted in any other country. One of the primary advantages is that there is no central computer system involved. Participating companies are interfaced with the network and have complete control over their software."

A separate Télétel terminal, being developed by Thomson-CSF Telephone, consists of a decoder, modem and alphanumeric keyboard which can either be assembled as an external adaptor connected to a television receiver, or integrated into a television set at the time of manufacture. The Télétel user will reach local hosts on the normal telephone network but will employ the TRANSPAC network for longer distances.

Mass Fax

Another product in the télématique program is a low cost (about $500 per unit according to current estimates) consumer facsimile transceiver which will permit transmission of a page of paper through the existing telephone network. This equipment, scheduled for delivery next March, will be automatic for the receipt of documents up to 21 x 20.7 cm and can also be operated as a simple photocopier. Transmission will take between 40 seconds and two minutes.



Thomson-CSF Telephone has entered into agreement with an American company for worldwide distribution rights for its facsimile transceiver. The desktop facsimile is capable of transmitting a standard page of paper in two minutes over the telephone line.

The consumer facsimile, or mass fax, complements the Telefax service launched for business offices and government agencies in November 1978, based on Group Two machines, and a number of firms are developing units aimed at small businesses and private homes.

"The facsimile represents a communications medium with the ability to transmit any written material within a significantly short period of time," says Théry. "It is the natural complement of the telephone and gives users the advantages of hard copy and data communication."

Théry believes that between 10-15 million telephone lines in France will be equipped with facsimile units by the early 1990s and contends future prices will be even lower than current estimates when the mass market is adequately developed. He also feels the facsimile will be used to make copies of material received through the videotex network.

French companies involved in the production of consumer facsimiles acknowledge that a large market is required to achieve a unit price of $500 but are convinced the télématique program will give them a realistic shot at that figure.

"You need a large scale market for the consumer facsimile to produce components at a reasonable price," says Thomson-CSF's Carpentier. "The télématique program will provide a domestic market which will also give French producers an opportunity to sell mass fax abroad at very competitive prices."

Thomson-CSF has already entered into an agreement with 3M in the United States for worldwide distribution rights to its desktop facsimile which is capable of transmitting a page of paper over the telephone network in 2 minutes. The reproduction device is by means of an oscillating strip of 576 points on thermo-sensitive paper and the reading device is an analysis of each line with a light-sensitive strip of 1,728 points.

Matra has developed the Matrafax G3 telecopy machine which uses coming and going carriages supporting a photo-sensor ensuring the simultaneous reading of 16 lines for both reading and reproduction on light-sensitive paper. The company has a technology exchange agreement with Olivetti.

SAGEM (Société d'Applications Générales d'Electricité et de Mécanique), a company with a long and successful history in the production of teleprinters, has

This home terminal was developed by Thomson-CSF Telephone for the French videotex network which becomes operational in the Paris suburb of Vélizy later this year. It is connected directly through the telephone network to information stored in data bases.

manufactured a consumer facsimile with coming and going carriages supporting a photo-sensor ensuring the simultaneous reading of eight lines.

Telewriter

A fourth product which will be associated with the initial stages of télématique program is a telewriter which permits the simultaneous transmission of written material. The system uses multiplexing techniques which allow input from a pressure sensitive graphic tablet - manuscript or sketch – to be conveyed in the segment of the speech bandwidth between 1550 and 1950 Hz. Both ends of the telewriter are identically equipped with a specially modified screen to display local and received copy. The same image is presented to both users who are each able to transmit at the same time.

French manufacturers and government officials stress that the télématique program will expand into many other areas, such as electronic banking, once it gets off the ground.

"Virtually any type of communication can be handled when télématique gets going," says Hervé Nora.

In addition, manufacturers point out that télématique products and services are not confined to national programs. Most companies envisage the adaptation of télématique-oriented services to a variety of different applications.

"We're setting up a replica of the télématique program – with electronic directories, consumer facsimiles, télétel – within our company," says Thomson-CSF's Carpentier. "Services like the electronic directory can be employed for a company, a city or an entire country."

Private Telephony

The progress the French have made in modernizing the country's internal network has had a formidable impact throughout the entire telecommunications industry. In fact, there is not a single area in which French manufacturers have not made considerable developments.

A competitive private telephony sector, for example, has produced a varied product range which rivals that available in any other country.

- CIT-Alcatel has a full range of private branch exchange (pabx) units available which meet international standards and can be connected to all telecommunications networks. The exchanges, manufactured and marketed by the company's subsidiary Télic, are entirely electronic, have microprocessor stored program control, thyristor crosspoint speech matrix and removable slide-in printed circuit boards.

"Our overall product development has enabled us to move into this end of the electronic switching market," says Jean-Yves Leclerc, a Télic director. "Our US subsidiary has just installed a 600 line Télic 2505 exchange at a hospital in Indiana."

- Thomson-CSF Telephone has also created its own range of pabx equipment, the P series, with a stored program electronic system catering to capacities from 6-300 network lines.

"Our P series is really a télématique product in itself," says Carpentier. "In the future it will play the role of a computer which coincidentally serves as a switching system."

- SAT has entered the electronic switching arena with transit switching systems and subscriber automatic exchanges. The latter, the Telecom series, features digital tdm switching and stored program control techniques.
- Jeumont-Schneider has an entire range of pabx's using tdm switching, pcm coding and third generation microprocessors. Their TLC 10 was the first pabx to use tdm technology and can be employed with video telephones and high speed data transmission units.
- Peritel, the peripheral telecommunications arm of the Matra group, has licensed its Peritel III pabx with Digital Telephone Systems in San Francisco.

A Télic electronic private automatic branch exchange (pabx) is being used by a New York bank.

Which of these things do you want your future telephone to do?

Innovations

French companies have made considerable developments in other fields of telecommunications and a wide range of products has been created to complement digital transmission and the télématique program.

- CIT-Alcatel has developed the Celtic telephone concentrator system for use with submarine cables or satellites. Last January, AT&T ordered the system, which increases transmission capacity on long-distance links by utilizing the idle time of conversations, for a submarine link between Florida and the Virgin Islands.
- SAGEM, which developed the world's first transistorized teleprinter in 1962, has refined a new generation of printer terminals using microprocessor-based software which controls the modules and peripherals.
- Sigma Industries has created and manufactured a springless alphanumeric keyboard using magnets to support the keys. Inventor and company president Edouard Serras-Paulet says each key can be depressed 10 million times before showing signs of mechanical fatigue.
- Matra, in collaboration with the CNET, has developed a video telephone which is being used in an experimental network serving over 100 subscribers in four cities located 560 kilometers apart.
- TRT has manufactured a transmultiplexer which facilitates the introduction of digital equipment into an analog telephone network allowing the coexistence of both transmission techniques.
- Compagnie Générale d'Automatisme has begun operating a coinless public telephone which is primed when a magnetic credit card is inserted into the unit. Cards are purchased for a fee and the cost of a call is deducted with each use.

Exporting Know-How

Naturally the technological processes, innovative products and new services discussed in this report are only an abbreviated version of the total activity in the French telecommunications industry. But they are an indication of the productivity and prosperity in the country's telecommunications sector.

Most observers of recent French progress feel the true test of the quality of French equipment – from the large tdm switching systems to the developing télématique products – will depend on how it is accepted in other countries. There is little question that French manufacturers are taking an increasingly active role in forming attachments with international markets.

"No large European country nowadays can make profits by staying within its own borders," says the DGT's Gérard Théry. "A national priority for the past five years has been to modernize the French network. As a result of our achievements, it is now

Photograph courtesy of SCORE.

French companies attend numerous international trade shows to promote télématique products developed for domestic and international markets.

imperative that we export our products and expertise."

Jean Syrota, head of the DAII, believes French exports will increase substantially during the next five years.

"French firms sold $600 million worth of telecommunications equipment outside France in 1979 and had orders for another $925 million," he says. "This amounted to 19 per cent of the total industry turnover. I expect that in 1983, exports will account for 30 per cent of turnover and that this will increase to about 50 per cent of the turnover in 1985."

Because of the country's domestic expansion program the French government has been, in many cases, the largest customer of French-manufactured goods. To assist in the export effort, the government has formed promotional offices to advertise French progress and products. France Telecom Inc. has been established in New York (1270 Avenue of the Americas, New York, New York, 10020, Telephone: 212-977-8630) and Singapore to act as a coordinating center for foreign companies seeking information about the progress made in the French network and the range of equipment available. Intelmatique has been established to promote télématique-related products.

"The expertise developed in France is just spreading beyond the border," says Marie-Monique Steckel, president of France Telecom Inc. in New York. "Other nations are just beginning to realize the international applications of French products and services."

French companies believe their recent progress has given them a head start in many areas of telecommunicaions and agree the US and other export markets are a major priority.

"We are looking for intelligent partnerships with American companies for a wide range of our developments," says Thomson-CSF Telephone's director of marketing Pascal Lusseyran, who notes that 40 per cent of the parent company's total sales of $3,700 million last year were outside France. Thomson-CSF is represented in 90 countries through subsidaries, delegations or representations.

CIT-Alcatel's international department director, Francois-Xavier Montjean concurs "If our exports to the US become very large, local production is a necessity and that often requires some form of association with an American company."

In fact, most French companies are eager to enter the US market in one way or another.

Edouard Serras-Paulet of Sigma Industries has commissioned an American company to study the establishment of production facilities in the US. Matra is in the process of establishing distribution agreements for its Matrafax in Japan and the US. Télic's Leclerc says his company is looking for an American partner to increase sales of the company's pabx line. TRT's export manager Bernard Goutay is discussing licensing arrangements in other countries for the company's analog-to-digital transmultiplexer.

Although the French have a presence in international telecommunications markets it remains to be seen how successful they will be in marketing their digital technology and consumer products associated with the télématique program. Have their recent advances given them a significant technological edge?

Says Barry Domber, who was vice president of planning at Tele/Resources Inc. in New York before joining Jeumont-Schneider earlier this year, "The French have simply been more innovative in many sectors of telecommunications – digital transmission and the télématique products for example – than other countries and that should pay off."

Adds former ITT senior vice president Frank Barnes, "The future of the French presence in the United States and other countries depends on the availability of service and support. The best opportunity they have is in areas where they are developing special products which aren't yet in other marketplaces – like their electronic directory, consumer facsimile and videotex products."

Concludes the CNET's Maurice Bernard, "The products we are developing are geared for use worldwide and have international applications. We would like to see more international scientists participate in our research and development programs and obviously we would like to see developments resulting from this research and development like digital technology and télématique – related products, find a market outside France."

THOMSON-CSF : ONE OF THE WORLD LEADERS IN TELEMATICS

Telecommunications and Data Processing are among the fields which have grown most rapidly in recent years. The increasing convergence achieved in the two fields, made possible through general evolution in electronics, has led to the emergence of a new technology known as "telematics".

This new means of communication which, through the host of possibilities it can offer to data collection, storage, processing, handling and transmission, gives an entirely new dimension to current usage and also opens up a new era in private and professional applications.

The requisite diversity of technologies and facilities calls for a broad spectrum of capabilities in systems design and in the development of component parts and associated software. THOMSON-CSF can supply both the necessary equipment and software and, furthermore possesses an extensive experience in the design and implementation of telecommunication networks and distributed DP systems.

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BOOKS

Analytic approaches to coal and other energy sources as alternatives to petroleum and gas

by Philip Morrison

COAL—BRIDGE TO THE FUTURE: REPORT OF THE WORLD COAL STUDY, Carroll L. Wilson, project director. Volume 1. Ballinger Publishing Company ($12.95). ADVANCES IN ENERGY SYSTEMS AND TECHNOLOGY: VOLUME II, 1979, edited by Peter Auer. Academic Press, Inc. ($29). The big tankers pass in unending procession both ways from the mouth of the Persian Gulf, either around the Cape and up to Western Europe or across the lonely Indian Ocean and north to Japan. That flow is now strong, but it seems sure to decline. Oil has supplied four-fifths of the increase in energy use in Western Europe and Japan during the past two decades of rapid economic growth and profligate use of cheap energy. The next 20 years too will require fuel, even with modest growth, even with new care for frugal employment of always more expensive energy. Perhaps the still unmatched oil reserves of the Persian Gulf will somehow flow cheaply and copiously, but more likely it will never happen again. Uniformly dwindling expectations for nuclear reactors can also be documented. This study makes a clear case for a practical if transient return to an older solution. Coal can bear the largest share of the growth in world fuel needs for the next generation. It was coal that fueled the industrial world before 1960; its time will come again.

Oil today provides the measure of large-scale transformation of energy. Worldwide oil production (1978) was more than 60 million barrels per day, half of the total energy consumed. About 30 million barrels of this amount surfaces in OPEC lands (20 million flowing out of the Persian Gulf alone). Natural gas added the equivalent of about 20 million, distributed mainly by pipeline, and coal furnished the equivalent of about 30 million barrels of oil per day. Most of the coal is consumed in the producing countries; among them the U.S.S.R., China and the U.S. produce 60 percent of the coal today.

Coal is sold on the buyer's terms; it is dangerous to produce, not easy to transport, difficult and dirty to burn. Yet we hold it in plenty: the reserves of coal dwarf the oil pools of the world. The present market offers oil not far from $30 per barrel, but coal can be mined and hauled across an ocean for between $30 and $60 per ton. About half of the cost is that of mining and half is that of the several links in the transport chain. In energy terms a ton of coal is worth five barrels of oil. That $100-per-ton margin is available to make coal safe, clean and usable. British practice offers safe underground-mining standards; economic transport by special train and ship is workable today; removal of the dust and the sulfur content both before and after combustion are technologies at hand, although development continues. It appears that the cost of the entire set of improvements needed, from coal face to ash disposal, lies well within the oil-coal price difference at present, and that the complex investments necessary to claim coal's energy are fully within reach of the big economies.

It is clear that coal must be burned well. Indeed, the chief costs, beyond land reclamation and mine health and safety control, are incurred at the point of burning. The use of coal will therefore remain dominated by burning in big and well-managed grates to raise boiler steam in central electric-power stations. Coal for metallurgical reduction—coal as a reagent as well as a fuel—is indispensable but is secondary in quantity. Industries such as cement that need high process heat can convert to coal, at least in large plants. Home heating will not be an important use. Coal-burning ships are on the way back, and coaling stations will once again serve them around the world. The main consumers, however, must be the electric utilities, ending most present or future employment of oil to raise steam. Some coal will go to supply the synthetic liquid fuels, gas and oils, but it will not be the biggest fraction.

The power stations of busy Japan, a cautionary example, now supply electricity that is only 4 percent derived from coal; it looks reasonable that coal's fraction there will grow threefold by the year 2000. The tankers must still parade in from the Persian Gulf, from Indonesia and perhaps from Alaska, but with them will ply big coal carriers out of ports such as Newcastle in southeastern Australia and San Pedro in California. It is New South Wales, West Virginia and the American West that will be the new Persian Gulf, the sources of most new flows of energy in international trade. Canada, South Africa, Poland and the U.S.S.R. will offer the bulk of the rest. Most of the coal will continue to be consumed in the country of its origin, but the seas will deliver coal to the ready ports of the Low Countries, Japan and the newer industrial lands of Asia. A ten- or even fifteenfold rise in international coal trade is foreseen, within an overall doubling or more of total coal consumption. Even such an expansion will not rival the physical flow of oil across the oceans: the most generous extrapolation shows a coal trade that amounts to maybe eight million barrels of oil per day, less than a third of the future flow in scarcer oil. Some appreciation of the scale of the world's consumption of oil can be gained by the observation that a million barrels per day measures the energy transformed by close to 40 big modern central power stations.

One barrier stands in the way of coal: the unknown but suspected risk of worldwide climate modification by the influx of manmade carbon dioxide into the atmosphere. *Coal—Bridge to the Future,* a quick, clear and lively report that summarizes the work of small expert teams from 16 coal-consuming and -producing countries, finesses that issue sensibly if sketchily. These experts recognize the danger, and they argue only that by the year 2000 no large effect can be expected. A long-run solution must go beyond their exercise in continuity. Hence the title: coal is only a bridge to another stage, no sure causeway to an indefinite future, in spite of the huge reserves. Only nuclear energy, whether that released on the earth or that released within the sun, can promise more until we have sure forecasts of climatic change.

This book is the first volume of two; the second one, not available as this review goes to press, will be thick, technical, narrower. It will carry the studies country by country. Volume 1 brings overall results, with broad support by summary data, and a two-page energy accounting, present and projected, for each of the 12 OECD countries that participated. The additional participation of Poland, India and Indonesia, and to a degree of experts from China, has much widened the value of the study. We miss indexes, lists of tables and similar apparatus.

A reader is left musing at the invisibility of the coal miner, the man or woman close to the coal face who supports it all. A few sentences recognize the "skilled, specially trained work force" required for underground mining, "one that regards itself quite properly as a separate profession." We are given no inkling, however, of the numbers and circumstances of the worldwide training and supply of what must be a million new miners. Will enough Aussies go down into the pits? We are told that over the decades most coal will still have to be won in that savage underground, although for the time being it is the near-surface deposits that will be heavily exploited. This neglect of the economics of essential labor is the one serious gap in a very readable and specific account of the future of coal. Eventually one would also like to know more about the problems of disinvestment if the rising tide of carbon dioxide proves to be a serious hazard.

So much for continuity, which is mainly resource economics. Now for innovation, which takes the form of serious engineering advocacy. *Advances in Energy Systems and Technology,* edited by Peter Auer of Cornell University, is the second of an annual series offering critical reviews of energy issues at a fairly technical level, each the length of several journal articles. Four pieces make up the 1979 issue; the latter two are primarily economic in their approach. One of them examines on-site solar energy in buildings, with emphasis on system scale and the proper treatment of the complex matter of discounts over an uncertain future. The cost of solar energy is of course dominated by initial expenditures, and the subject is assuredly a subtle one.

The other piece is an even more sophisticated study of supply-and-demand models for energy-system assessment in the large. Both of these reviews will tax the general reader. It is certainly interesting to learn that all three models of the U.S. energy system used in 1975 to study the economics of synthetic fuel programs estimated "negative net benefits." The official task force that had asked for the computer modeling "did not adopt the results." There was conflict between the models and the publicly announced million-barrel-per-day goal of President Ford. "Either the model takes all contingencies of interest into account, or the decision makers mistrust the ability of the model to represent the real world" of political and economic interest.

The other two pieces are some 50 pages each of fascinating conceptual engineering. Both examine solar power, not the homely kind of the roof collector or the hoped-for photovoltaic cells but large-scale inputs picked up by novel advanced technology, one on the high seas, the other even higher, out in geosynchronous orbit.

Sea thermal power is the goal of J. Hilbert Anderson, a senior engineer with long experience in the refrigeration industry, and a younger collaborator,

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David F. Mayer. They describe and figure a prototype power plant, a free-floating marine structure like an offshore oil-drilling rig, in steel or aluminum at about 25,000 tons displacement ("not unusual today"). Floating in tropical seas, a sloping screened perimeter would admit the shallowest layer of sun-warmed water, pumped at 30 tons per second to heat the big evaporators. There a volatile working fluid (a halocarbon or simply propane) is set boiling to drive the high-efficiency vapor turbines that turn the generators. The vapor is recondensed by cold ocean water pumped from the depths. Solar energy is thus collected over enormous areas and around the clock. The scheme goes back to 1881, when Jacques d'Arsonval proposed such a closed-cycle plant with ammonia as the working fluid. One of d'Arsonval's students, Georges Claude, built an actual system off Cuba 50 years ago, but it had an open cycle, with the seawater itself as the working fluid. The prototype was damaged by storm and was given up. A still larger project was begun by the French government in the 1950's but was abandoned for a variety of reasons.

This scheme in the broad sense has been under study by the Department of Energy for about a decade. It has grown into the largest solar-electric project in the DOE program, and there is now a component-test system off Hawaii. Several studies have offered competing designs and estimates; the Anderson article centers rather on his own ingenious features. One is the vertical cold-water intake pipe, which is a monster, 10 meters in diameter and 1,000 meters long. Anderson's patented design looks to building this tube as a stockade of lightly linked lengths of standard pipe. It is assembled on site, the pipes loaded with oil or gas for neutral buoyancy. The heat exchangers, the heart of the plant, are equally apt. They are modular assemblies of moderate-gauge aluminum sheet separated by spacers and sealed with rubber, without welds or precise joining. Such light and leak-tolerant construction is made possible by pressure balancing.

The heat exchangers are submerged to a depth such that the head of external seawater pressure about matches the modest pressure of the working fluid. Leaving a head of a few meters of water as leeway, the pressure balance is chosen to be slightly inward, quite adequate to prevent the loss of working fluid, at the small expense of separating some immiscible seawater during operation. The modules would be arranged to allow individual sealing off from the main flow. A particular shutdown module can then be defouled by circulating within it a slurry of water, sand and detergent to restore bright metal surfaces even during routine operation. It is worth recalling that there is a total of 120 acres of metallic heat-transfer surface. Finally, there is a patented deaeration system, which removes dissolved gases under vacuum. The oxygen-short water inhibits corrosion and the growth of fouling organisms; the outgassing of dissolved carbon dioxide provides a source for organic synthesis and makes possible the controlled disposal of carbon dioxide at depth if a large-scale flow of carbon dioxide from the gas-rich cold waters welling up should become an environmental hazard.

The open cycle and an even more ingenious foam-mist idea are described briefly. It is clear that other studies of the closed-cycle scheme do not confirm Anderson's very profitable estimates: his power-to-displacement ratio is four kilowatts (electrical) per ton, eightfold better than the competition! This happy result he ascribes to the decisive lightness of his heat-exchanger design; the four excellent engineering groups that have made the other estimates (their schemes "cannot possibly form the basis for economical power plants," he says) no doubt require attention. This is nonetheless a persuasive piece. It is all the more true, although he says nothing about it, if his scheme is combined with an idea of one of his competitors: Lockheed. Its publications have argued for siting its plants (mostly concrete) in the tropical waters very near the Equator, within a slowly shifting band where severe cyclonic storms are never encountered, since there the spiraling winds do not know which way to whirl! Then the hardware can survive as an investment until it corrodes away, even though normally the open ocean is no place to put an expensive plant. The example worked out here is scaled for 100 megawatts electrical—rather small—at a cost of some $2,000 per ton of gross displacement.

Plant output can be chosen from a long menu of valuable bulk commodities: liquid oxygen, liquid hydrogen, liquid carbon dioxide, ammonia, methanol, fresh water, chlorine, caustic soda. They all use seawater and air inputs alone, and they deliver to tankers. Electric-power delivery requires a cable and a location tethered to some city or industrial market, perhaps not the best place for long-run safety at sea. The return on investment at Anderson's cost estimates runs about 20 percent per year, after the prototype. One may well envision after a few decades 2,000 or 3,000 such plants, built by all the shipbuilding nations, circling the watery Equator, a source of most quantity chemicals and much of the world's energy ("... by far the most logical possibility for providing the world's great energy demands").

Such a sea system is grand enough. A curious voyager would sight one of these rigs every few hours anywhere he sailed in the equatorial waters of the earth. The scheme outlined in the remaining essay of this volume, by Peter E. Glaser, is still more striking. It is nothing less than a new manmade ecliptic. Any clear night along the celestial equator a watcher would see a gleaming line of a few score new planets, each as bright as bright Venus, an unprecedented constellation. (Astronomers will clearly grumble as dark skies disappear forever.) These luminaries would not rise or set but would stand still in the sky. Each is an artificial solar-energy collection area, perhaps of silicon photovoltaic cells, as much as five by 10 kilometers in dimension. There in the all but perpetual sunlight and good vacuum of space (they are eclipsed by the earth typically for an hour or so during the months of equinox) each converts the incoming sun's radiation into microwave power for beaming by a dish a kilometer in diameter.

Every dish is aimed at its own receiving area below, a spot on the earth some 10 kilometers across where an orchard of six-inch dipoles stands. The rectified power enters the nation's power grid, say a total of 500 gigawatts, more than the present total U.S. installed power. Each station is 50,000 or 100,000 tons of material, mainly the active cells on a modular structure of graphite fiber or aluminum beams, all semiautomatically assembled in orbit. This wide-spreading surface too is fouled, not by space algae and barnacles but by radiation damage at the atomic level, caused by photons and charged particles from the sun. Annealing away the damage every few years by a pulsed energy-beam treatment seems practicable. The stations would be assembled by shuttle flights, one every few days for the first few years, rising in increasing tempo. Each station requires 1,000 manned shuttle visits or so, aided by a proposed high-orbit tug. Transport is certainly half of the cost. A full account with many more considerations is in the text.

Sea thermal power proceeds by relatively easy increments and could start at once. The orbital scheme puts much bigger chips on the world table somewhat later. One station in orbit costs as much as a few hundred rigs at sea, and it may offer a less than proportionate amount of electric power, although right to the power grid. Orbital cost estimates per kilowatt are higher by a factor of five, unlikely to be firm in the state of either of these arts of the future. There are many points still at issue; engineering truth rests in the details of experience. Neither author has spent much time searching out difficulties, which is perhaps as it should be for general papers by proud innovators. A wise assessment will take time. It does not seem that war is compatible with either of these sys-

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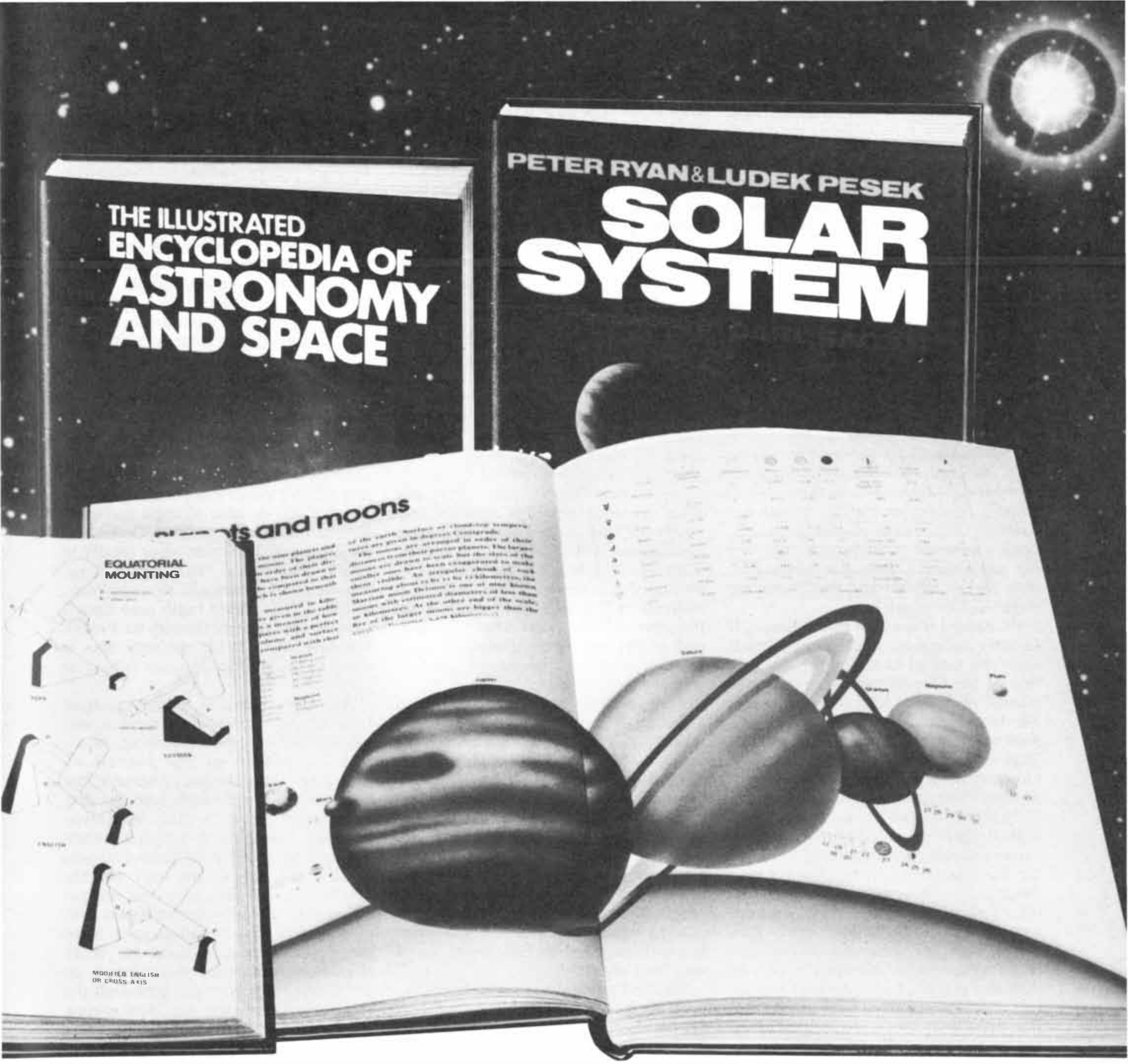

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tems, both floating and isolated hostages to reason. Maybe that is a sign of better times to come.

GREENWICH TIME AND THE DISCOVERY OF THE LONGITUDE, by Derek Howse. Oxford University Press ($24.95). John Flamsteed, the first Astronomer Royal, won his post and a new observatory in the old riverside park at Greenwich as the outcome of a fine intrigue. The actors included one "Mons. St. Pierre the French Longitude Man" and Louise, the king's favorite, the darkly good-looking French noblewoman created Duchess of Portsmouth. The plot turned on the fact that the Royal Observatory in Paris was eight years ahead in the race for longitude. Derek Howse has well told that story before now, during the celebration of the three centuries of Greenwich. In this book he extends the tale far back to the ancient roots of the problem and on to the successive meaning of Greenwich time first for astronomers, then for navigators, then for all Britain and finally for the world as Universal Time.

Flamsteed was a first-rate scientist, if no easy colleague, and he set himself early the task of checking the assumption of the Copernicans that the earth rotated on its axis with constant speed. The two clocks, made by Thomas Tompion of London, whose 13-foot pendulums were fitted into the Great Room at Greenwich, were the decisive instruments. Flamsteed would soon write: "My theory of the Equation of Days I looked upon but as a dream at first because one part on which it was founded, viz the isocroneity of the Earth's revolutions, was only supposed, not demonstrated by me; but the clocks have proved that rational conjecture a very truth." Tompion's clocks could be relied on to within seven seconds per day. In the long sequel it was the best pendulum clocks Greenwich ever owned, the free-pendulum Shortt clocks, that in the 1920's and 1930's finally set limitations on Flamsteed's rational conjecture.

Edmund Halley, Flamsteed's rival, had already concluded from eclipse studies that the moon's motion was accelerating. By the late 19th century comparisons of sidereal time with the motions of the moon and the planets had shown that some of the discrepancies arose from the slow lengthening of the day by tidal friction, about 1.5 milliseconds per century. Less cumulative but more important today are irregular fluctuations of both signs, perhaps due to deep-lying variations in the mechanical coupling between the earth's solid mantle and its fluid core. These have slowed the earth spin by about 18 seconds since 1955 or so, as they sped it up in Victorian times. The current day length increases by several milliseconds per year. The Shortt clocks could even signal annual seasonal changes in the earth's rate: the spin is slow in May, faster in October, a matter of a millisecond per day. The Invar suspension and the clever mechanical scheme that allowed the master pendulum to swing free for half a minute between impulses from its own slave pendulum gave the Shortt clock a reliability of within some tens of milliseconds per day.

Quartz piezoelectric oscillators took over from the Shortts completely by 1943, with an accuracy that reached .1 millisecond per day. The time is no longer handed down by any single national observatory but is based on the computations of the Bureau International de l'Heure in Paris, which keeps the world's statistical mean clock, its input some 80 atomic clocks in two dozen countries. They are consistent within microseconds over a year. The time scale is now dual: the equable time marked by the cesium-beam frequency standards is called International Atomic Time (TAI), and by it the official Coordinated Universal Time (UTC) is controlled. The spin of the earth is not forgotten; UTC is kept within one second of the lagging rotational sky time by a scheme of semiannual optional leap-second insertion.

Time remains based on Greenwich, although it is no longer defined there. Indeed, the brass line that parts the old courtyard, shown in a photograph through "the center of the transit instrument at the Observatory at Greenwich," is no longer the world's true prime meridian. That agreed origin of all longitudes and of the civil day is no longer material at all: it is an abstract statistical fit to the results of a worldwide net of observations. It will, however, remain floating within a few meters of the earthly partition there in Greenwich for a very long time.

The first public time signal is said to have been the dropping of the big ball on the Eastern Turret at Greenwich, done every day since 1833 "at the moment of one o'clock P.M. mean solar time." (At noon the astronomers were busy *finding* the time.) Navigators could rate their chronometers at all the London docks and on the busy river, and much of London could peek. The railways and their timetables soon carried Greenwich time all over the island, and by 1855, 98 percent of the public clocks in Britain told not local mean time but Greenwich Mean Time (GMT). Oxford, true to this lost cause too, fought bravely: a photograph shows the Great Clock of Tom Tower there in about 1860, fitted with two minute hands, with local time seen to be slow by five minutes. It was the multiplicity of the American railway companies with their bewilderingly idiosyncratic standards for time that led to the successful proposal by Charles F. Dowd of Saratoga Springs for "A System of National Time for Railroads," his pamphlet of 1870.

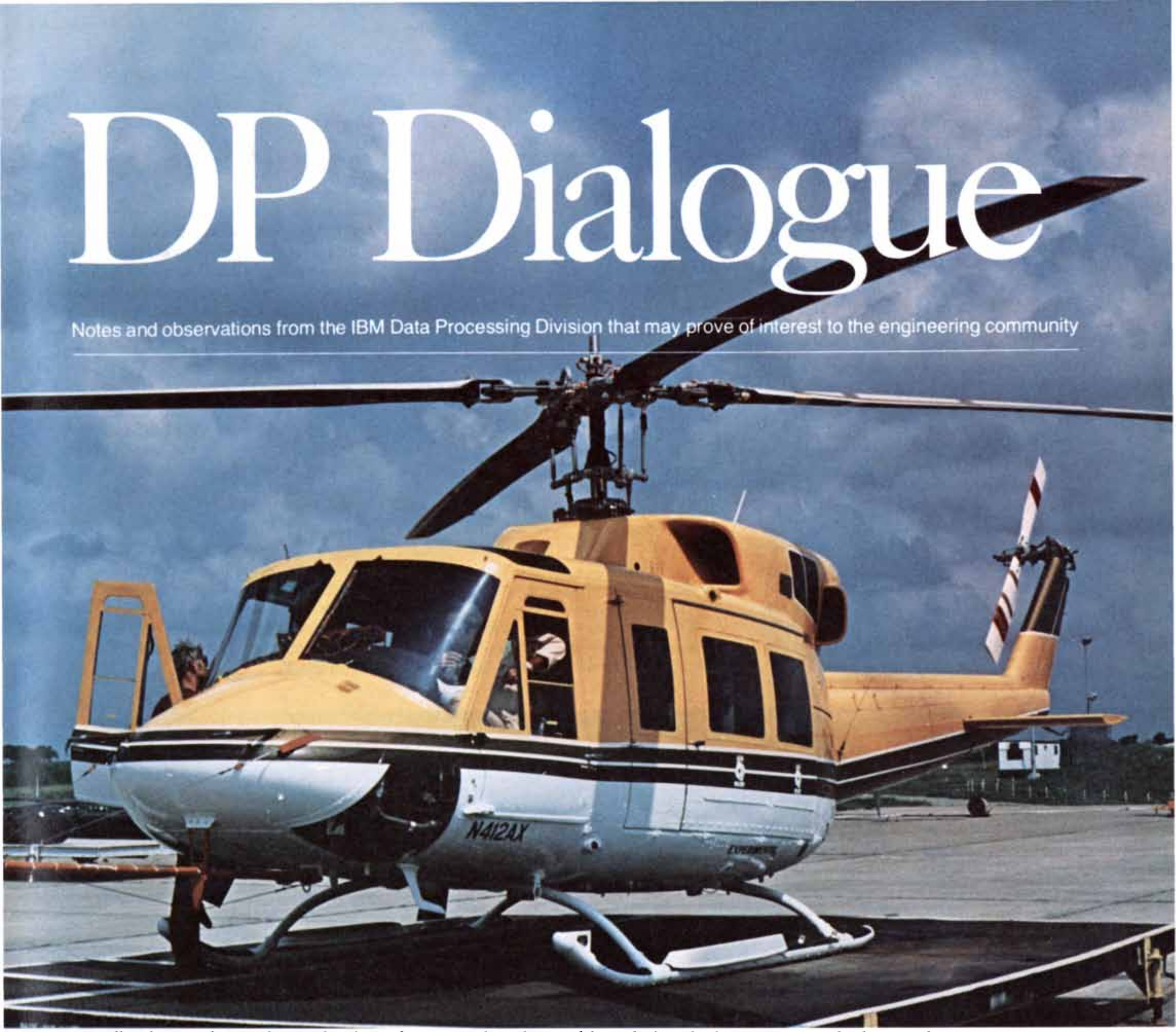
Dowd's proposal held the present scheme. It was taken up country by country worldwide after an International Meridian Conference at Washington in 1884, a meeting that did not actually recommend any time-zone scheme. That conference, admirable and hilarious in turn with its mix of good sense and curious posturing, did fix on the Greenwich meridian as the zero of longitude. The reasons included the need to have a working observatory "of the first order" as the origin (the peak of Teneriffe and the Great Pyramid were neutral but lacked certain utility) and the dominance of British shipping, already reckoning by that meridian, two-thirds of all ships by number and by tonnage. Almost unanimous votes favored a single meridian at Greenwich, a universal day and decimal division of angle and time. France nonetheless resisted Greenwich for a long while. It went over legally to GMT, described as "Paris Mean Time, retarded by 9 minutes 21 seconds," only in 1911. Then world radio time signals were unified internationally at French initiative from 1912; accurate time is ruled today by that famous bureau in Paris.

An interwoven but distinct story is here: how the geographic origin of longitude came to rest at Greenwich. Much seems to depend on *The Nautical Almanac and Astronomical Ephemeris*, first published by Nevil Maskelyne, the fifth Astronomer Royal, in 1767. Maskelyne included therein the first truly accurate and convenient tables of lunar distances between selected bright stars and the disk of the moon. His tables cut computation time down from more than four hours per sighting to half an hour. Even the French reprinted them for more than a decade. They were based on the Greenwich meridian. Although the chronometer method for determining longitude won the field, good navigators appreciated the lunar backup. The usual practice of computing longitude differences only, using as a zero in each new voyage the port of origin or of destination, worked well enough with the chronometer scheme, but published moon tables required some convention. That choice clearly imposed no important burden on the other algorithm. Thus all British shipping, and much more, went over to counting longitudes from Greenwich, as we do today.

Howse has told this story expertly and well. His book is both a narrative and a reference. About the only gap he leaves is just why there should be no doubt that it was Pierre Le Roy in France who in the 1770's was the inventor of the modern marine chronometer, not the glorious pioneer John Harrison nor the gifted British clockmakers after him, whose chronometers multiplied for gen-

DP Dialogue

Notes and observations from the IBM Data Processing Division that may prove of interest to the engineering community



Bell Helicopter knows the weight of new designs, such as this Model 412, before the first prototype is built. An online IBM computer keeps tabs on the weight of 20,000 separate parts of the vehicle.

Bell Helicopters Lift Off Without an Extra Ounce

"We save money and our customers get a better, safer product, through the use of a data system to keep track of the weight of a vehicle as the design progresses," says Richard Mathieson of Bell Helicopter Textron. Mathieson is group leader, weight management systems. "Before we put the first prototype model on the scale, we know its weight within one-half percent.

"A helicopter must meet a performance specification – a required air speed, payload and fuel range – and success depends on controlling its weight."

At Bell, a computer stores the weight of each part of a complete helicopter – structural members, pumps, tubing, even screws and rivets. In excess of 100,000 separate parts may be interrogated through the Weight and Value Engineering System (WAVES), which runs on an IBM System/370 Model 168 computer at the company's Fort Worth, Texas, headquarters.

"With the online system," Mathieson notes, "engineers can enter the weight of any new or revised parts and assemblies directly at terminals. Paperwork is eliminated, saving 2,000 to 3,000 engineering manhours a year, and information is more accurate and complete. Weight is now current daily: a designer can push a button and obtain the vehicle or component weight within seconds.

"At the beginning of a new design, we enter estimated weights for major sections of the helicopter. Then, as the design progresses, these estimated weights are replaced by more detailed calculated weights, and finally by measured ones.

"An accumulation of small differences can easily cause a design to be overweight," he continues. "Now we catch any such trend much earlier. And WAVES is really invaluable when a proposal is needed on a tight schedule. We can do many more tradeoff studies – cost vs. weight – in the same amount of time. If required, we can get two or three turnarounds per day, as against days for one turnaround under the old system. When last minute changes are required, WAVES can redo the calculations in a few minutes."

COMBIMAN Sits in for Air Force Pilots

Can a U.S. Air Force pilot readily reach all of the hundreds of controls typically found in a high-performance aircraft? Can he see all of the indicators? How well can he see outside the plane?

Today, at Wright-Patterson Air Force Base in Ohio, the designer of a new plane can answer such questions quickly and easily, by manipulating the COMputerized BIomechanical MAN-Model (COMBIMAN): a model of a human figure in an aircraft cockpit or work station. It permits the designer to sketch a work space around the figure directly on the screen of a computer terminal, using a light pen and the keyboard.

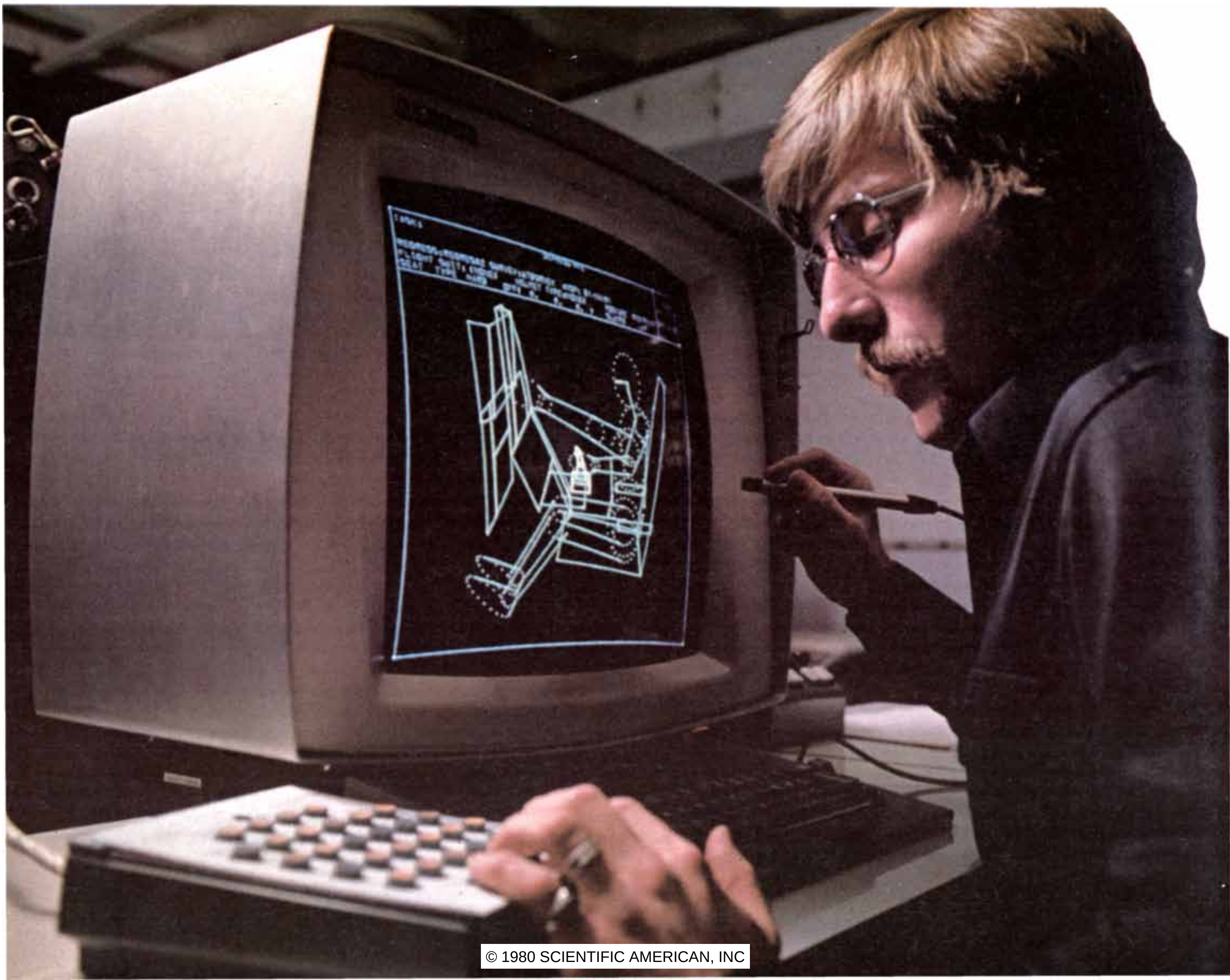
By touching the light pen to a "menu" of options, the user can select the variables that affect movement, reach, and sight lines, such as the size of the pilot, type of harness and clothes. With the cockpit layout and the human figure visible in the display, he can command a programmed "reach" to any selected point. The figure then executes a five-step reach, showing clearly whether – and how easily – a pilot can perform the same operation. The user can vary the proportions of the figure, using realistic combinations of human measurements stored in the computer. He can adjust the work-station design by moving, rotating, adding or eliminating elements.

The program was developed by the University of Dayton Research Institute under the sponsorship of the Aerospace Medical Research Laboratory of the Air Force Systems Command. Says Dr. Joe W. McDaniel, who directs the COMBIMAN project: "In the display, the workspace is very easy to modify, to experiment with, so the designer can try many more possibilities. When the physical mockup is first built, it will be much closer to optimum."

The figure can be made to lean or turn its head in order to calculate realistic sight lines for pilots with various body measurements. As with the hand, the reach of the figure's foot can be checked to insure that a pilot can readily reach the rudder control or other pedal. As the user builds a complete workspace, the computer – an IBM System/370 – accumulates the details. At any time, the system can be commanded to generate a plot of the design on paper.

"COMBIMAN lets the workspace designers get involved much earlier in a project," McDaniel adds. "This avoids later costly retrofit, or the need to compromise on performance."

The COMBIMAN human figure and workspace can be projected on the screen of an IBM 2250 Graphic Display Terminal in an off-axis perspective view. The designer can test and modify a workspace by interacting directly with the computer through the terminal.



International Harvester farm tractors are designed at the company's Hinsdale, Illinois Engineering Center. CADAM, the computer-based design system, has improved the quality of engineering drawings as well as the productivity of designers and draftsmen.

CADAM® Draws the Tractor that Draws the Plow

Using the computer as a drafting aid, International Harvester now develops engineering drawings much more rapidly: the gain in productivity is sometimes as high as 20 to one, and averages between two and three to one.

At the company's Engineering Center in Hinsdale, Illinois, the Computer-Graphics Augmented Design and Manufacturing (CADAM) system is used to design farm tractors and implements. Comments E. J. Wynard: "We see the biggest gains where there is some repetition or symmetry, or where we can reuse drafting work already in the computer memory. For example, in an assembly drawing we can incorporate previously stored drawings of parts. CADAM lets us change the scale of an element, rotate or move it, or replicate it any number of times. We keep a large number of frequently used or standard items in an online library, where they can be incorporated with the touch of a light pen."

Wynard is manager of engineering information systems for the Agricultural Equipment Group. He points out that one drawing can be superimposed on another, or movable parts can be viewed in several positions, to check clearances or interference, or look for drawing errors. The engineer or draftsman works at an IBM 3251 Graphic Display Station, online to a System/370 Model 138 computer.

"There has been fantastic acceptance by both experienced and novice users," Wynard notes, "because CADAM uses familiar drafting techniques. When we want to change or correct a drawing, we can rework it and get the revised drawing to the shop in a few minutes. CADAM lets us analyze more design possibilities in a limited time."

Adds Wayne Orkwiszewski, designer of agricultural implements: "There are fewer 'downstream' errors, because the drawings are accurate, detailed and readable. There is less scrap, and we build fewer design models.

"On large implements, there is a lot of repetitive detail and mirroring – left and right parts – the kind of thing CADAM handles very well. It's also good for developing a series of variations on a basic design. A family of hydraulic cylinders, for example, appeared in various sizes and was very complex, with many sectional views. One model required 79 drawings. We put the basic design in the data base, then adapted it without any further drafting by changing dimensions and rescaling certain drawings."

Adds William Knapp, manager of implement engineering: "The reaction of the professional people has been enthusiastic. They come in to work on their own time, and they accept inconvenient hours to get time on the system."

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erations in what "might almost be called mass production."

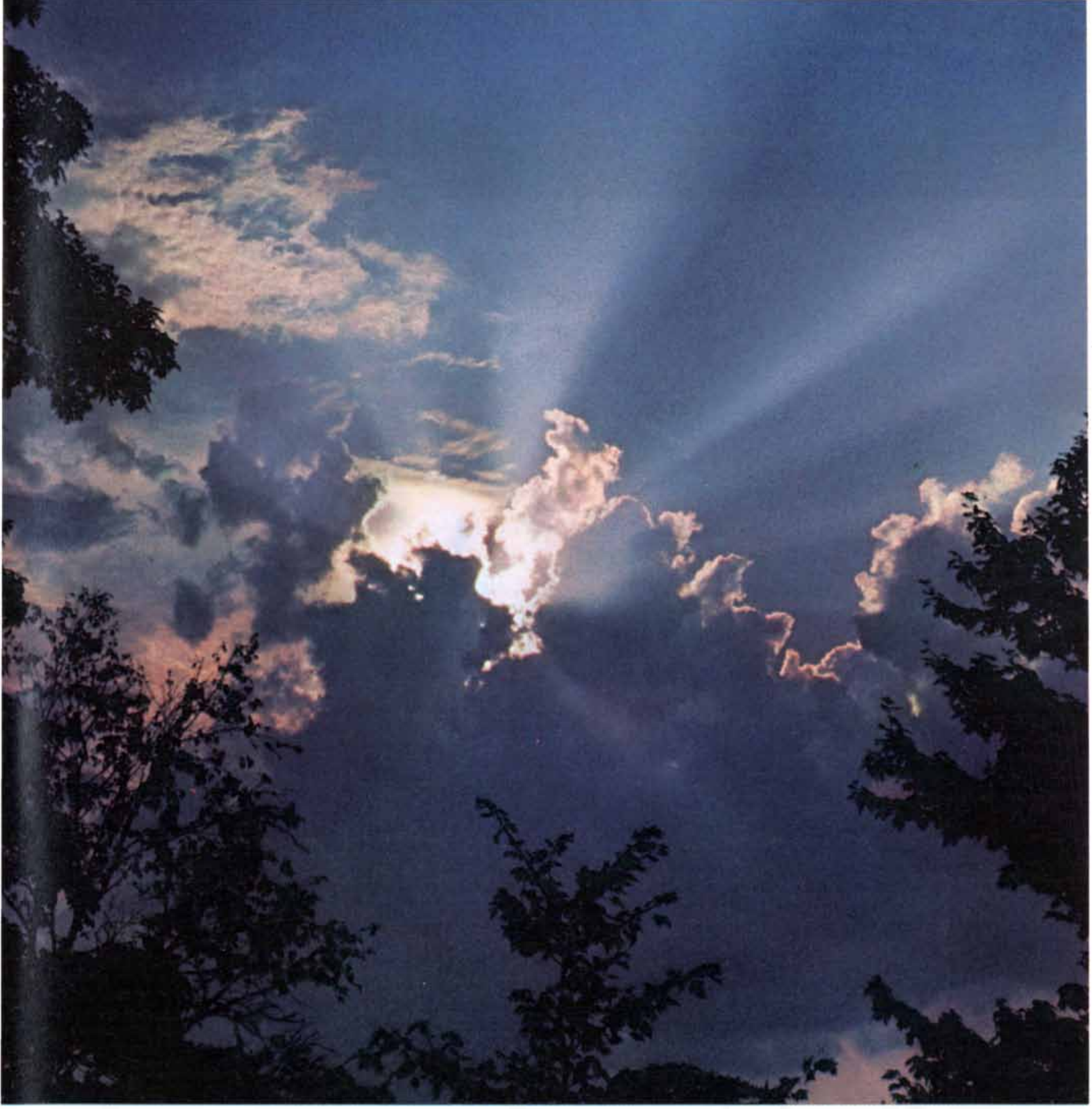
THE GREAT BRONZE AGE OF CHINA: AN EXHIBITION FROM THE PEOPLE'S REPUBLIC OF CHINA, edited by Wen Fong. The Metropolitan Museum of Art and Alfred A. Knopf, Inc. ($40). Five years ago Americans were treated to a touring exhibit of recent archaeological finds in China. They sampled the full depths of Chinese history, artifacts of rich variety, from an evocative dumpling, dry for 1,000 years beside the Silk Road, to the little masterpiece of a Kansu horse in bronze. This big, luxurious volume both documents and celebrates another display, with a much sharper focus on finds from the Three Dynasties that wrought so well in bronze between about 2000 and 200 B.C. These objects (not all of them are of bronze; some are of jade and terracotta) have been chosen by Chinese scholars to travel during 1980 and 1981 to five fortunate American cities: New York, Chicago, Fort Worth, Los Angeles and Boston.

Most of the 121 color plates made in China expressly for this exhibition glow with the varied patinas of the long-buried bronzes of Xia, Shang and Zhou. These forms with their intricate yet balanced surfaces appeal to all who seek unity in the works of the hand and the mind. They were almost always cast—decorations, flanges and all—in one pour of the metal; "both shape and decoration emerge together from the mold." Technique and form are one. Four detailed essays, 10 detailed summaries and comparisons of the works (mostly by U.S. scholars) and careful catalogue descriptions piece by piece treat of the bronzes and their context, particularly the changes new finds and new ideas have wrought in what we know of this part of the human drama. Ma Chengyuan, curator at Shanghai, tells us of the copper knife found a few years ago, dated to about 3000 B.C., the oldest metal artifact yet sure in China. By 1900 B.C. ritual vessels are known; they are here, made 500 years before the classical period of the finds at Anyang.

An ancient copper mine on an enormous scale was found in 1974 in Hubei province, not far from the classical sites. It consists of vertical shafts several dozen meters into a mountaintop, with many horizontal tunnels along the veins of the ore. Bronze tools and even wood gondolas and framework have been found. "The entire mountainside is wasted," and the slag from the on-site refining operations amounts to 360,000 metric tons. The age of the oldest workings there is uncertain, but it cannot be later than 600 B.C. With such mines at the expected metal yield the bronzes of ancient China must have been counted by the millions over the millenniums. What the mines produced, of course, was not mere metals but political power. Bronze, both the ritual symbol of the kinship-based aristocracy and the dominant material of war, was the very substance of rule.

The rulers draw ruthlessly on the skill and energy of the people they dominated. At the site of Anyang, the source of the earliest Chinese writing as well as of the highest order of bronze working, there was found in 1979, after a generation or two of archaeological efforts among the long-robbed grave sites, the first specifically identifiable intact burial tomb. It held a royal consort, the female general Fu Hao, with 200 bronze vessels, almost twice as many as were recovered in all from the dozen other looted tombs of royal size in the same area. Fu Hao's coffin was surrounded by 16 sacrificial victims, in the cruel tradition of the funeral cult of the Shang kings. "Who went with Duke Mu to the grave?" asks the Book of Songs. "Now this Yen-hsi / Was the pick of all our men; / But as he drew near the tomb-hole / His limbs shook with dread. / That blue one, Heaven, / Takes all our good men." So run the moving lines of Arthur Waley's translation, cited in a splendid essay here by K. C. Chang of Harvard, his brief synthesis of Bronze Age China.

This time too reality offers an exhibit more varied than plan and title imply. The archaeologists have never penetrated the great tumulus at Mount Li, where lies buried the unifier of China, the first emperor of Qin, even though the historian has told us of its wonders. For 30 years of Shihuangdi's power 700,000 conscripts labored at the task, still unfinished at his death in 210 B.C. "With quicksilver the various waterways of the empire... were created and made to flow and circulate mechanically," we are told in the old chronicle of unseen wonders. But in 1974, after hints from a few chance finds over the years, a guardian army was found buried only a kilometer from the emperor's burial mound. These are not dead men; even Shihuangdi could not command such sacrifice so late. They are an army of 7,000 in terracotta, the figures of men and horses large as life, in full uniform and kit, with weapons, arrayed for imperial review. The faces are individual, almost portraits. A regiment stands buried, nine infantry columns of four each of 150 ranks, backed up by chariots and charioteers. At a little distance are marshaled their cavalry units, and a third pit holds the elite command. The pottery army is breathtaking; six men and two horses from their ranks are in the show, the first of them ever to travel outside China. Here they are in color plate; not bronze, no longer in the abstract mode of those older times, but messengers over 22 centuries from life itself.



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Economic Development

The nations of the impoverished three-fourths of mankind press for the creation of a new economic order to redress the asymmetry in relations between the developed countries and developing ones

by K. K. S. Dadzie

The General Assembly of the United Nations is about to meet in a Special Session that is charged to launch the global negotiation of an agenda for the better management of the world economy. At issue in the negotiation is the asymmetry now prevailing in the relations between the 30 or so industrial "developed" countries and the 130 or so nonindustrial "developing" countries. The asymmetry is evident in the relative access of the two groups of countries to supplies, to markets, to science and technology and to credit. As long ago as 1974 the developing countries pressed in the General Assembly for the creation of a "new international economic order." The Special Session is charged also to adopt a "new international development strategy," looking to the acceleration of the economic development of the developing countries. It is apparent that the two exercises are interlinked. A restructured and properly functioning world economy is the necessary environment for the sustained growth of the developing countries; the development of those countries is needed to move the world economy forward from the "stagflation" in which it is becalmed.

The momentous questions underlying this agenda touch the interests of everyone, but particularly of the poor who constitute more than half of mankind. To increasing numbers of the poor around the world economic development means not only the betterment of their material condition but also greater human dignity, security, justice and equity. It is a transformation of their lives, a liberation. Development therefore implies profound change in the economic arrangements within as well as among societies. Such change can be facilitated by rapid and sustained growth of income. Thus although statistical measurements of growth exclude nonpecuniary values, they provide initial, useful indicators of the advancement of social welfare and individual rights.

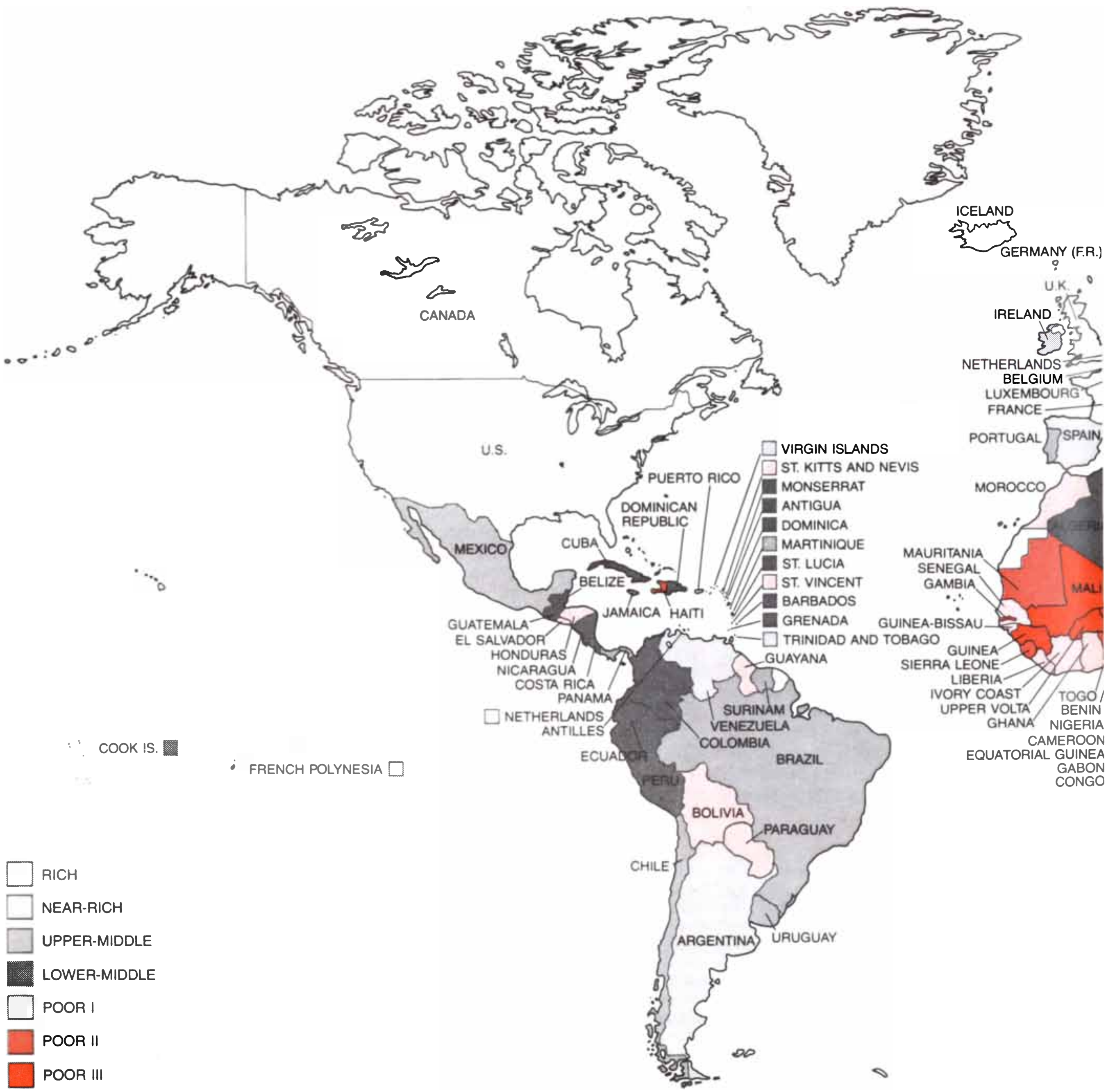
Convened principally on the initiative of the poor nations, this Special Session of the General Assembly comes at a time of disjunction and uncertainty in the world economy and polity. An era of unparalleled economic growth sustained by cheap energy has closed; the era to come is as yet undefined. The developed market-economy countries are unable to bring the claims of adversary social groups in their societies into a reconciliation that will make it possible to have growth without inflation. The centrally planned economies find it increasingly difficult to sustain increase in the productivity of labor. The developing countries are racked by tensions from the failure of growth or from marginalization of the poor in those few countries that have seen an overall rapid growth. In the economic relations among the developed market economies there is crisis stemming from the dispersion among them of economic power and the breakdown of the financial and trading arrangements by which they had harmonized their competing interests. Between the developed countries and the developing countries relations are in a flux that bespeaks the shift in their relative economic and political power. The drift from crisis to crisis from year to year and month to month threatens to trigger far-reaching political and social dislocations.

MAGNITUDE OF THE TASK confronting economic-development officials in the less developed countries of the world is suggested by the satellite image on the opposite page, which shows part of the Ganges River delta in the vicinity of Dacca in Bangladesh (*greenish gray area at top left*). The delta is one of the world's poorest, most densely populated large agricultural regions. Much of the land is devoted to the production of rice and jute on very small irrigated fields, which are typically owned by petty landlords and worked by tenant farmers and their families. This particular scene was recorded by the *Landsat 2* earth-resources satellite from a height of more than 900 kilometers on March 6, 1979. At that time most of the rice fields were either being prepared for planting or had just been planted. The latter fields appear as tiny red dots in the composite image, which was made by combining data from three of the four wavelength bands acquired simultaneously by the satellite's multispectral scanning system. (Growing vegetation generally appears red in such composites.) The scene has been used by analysts at the World Bank to study erosion and deposition of sediments along the Ganges and to monitor changes in the course of the river. It is one of several Landsat images in this issue that have been digitally reprocessed by the Earth Satellite Corporation, using special algorithms for geometric and radiometric corrections, edge enhancement, gray-scale adjustments and scan-line suppression. The dimensions of the image are roughly 160 kilometers by 120.

The world presented a significantly different picture not so long ago. In 1963, when *Scientific American* devoted an issue to economic development [see "Technology and Economic Development," SCIENTIFIC AMERICAN, September, 1963], there were still grounds for the hopeful expectation that the rich nations—in the spirit that had brought the founding of the UN and its associated technical agencies—would render substantial economic and technical assistance to help ease and expedite the development of the poor countries. There was, to begin with, the euphoria of success emanating from the economic growth of western Europe and Japan. Countries whose economies had been shattered by war had managed not only to recover in less than two decades but also to maintain the highest rates of economic growth in history. Japan, notwithstanding its poverty of resources, had achieved an average annual growth rate of 12 percent over the years 1957–62. The European economies, accustomed to a growth rate of 2 percent in the prewar years, had achieved a growth rate of 5 percent—which they managed to sustain into the early 1970's.

Furthermore, this remarkable growth performance had received an important impetus from economic assistance rendered by the U.S. beginning in 1947. Although the flow of aid under the Marshall Plan was sustained by "cold war" motivations, it came to be seen also as directed against "hunger, poverty, desperation and chaos." Throughout this period the U.S. pursued a liberal free-trade policy that amplified the positive effects of its economic assistance to western Europe and Japan.

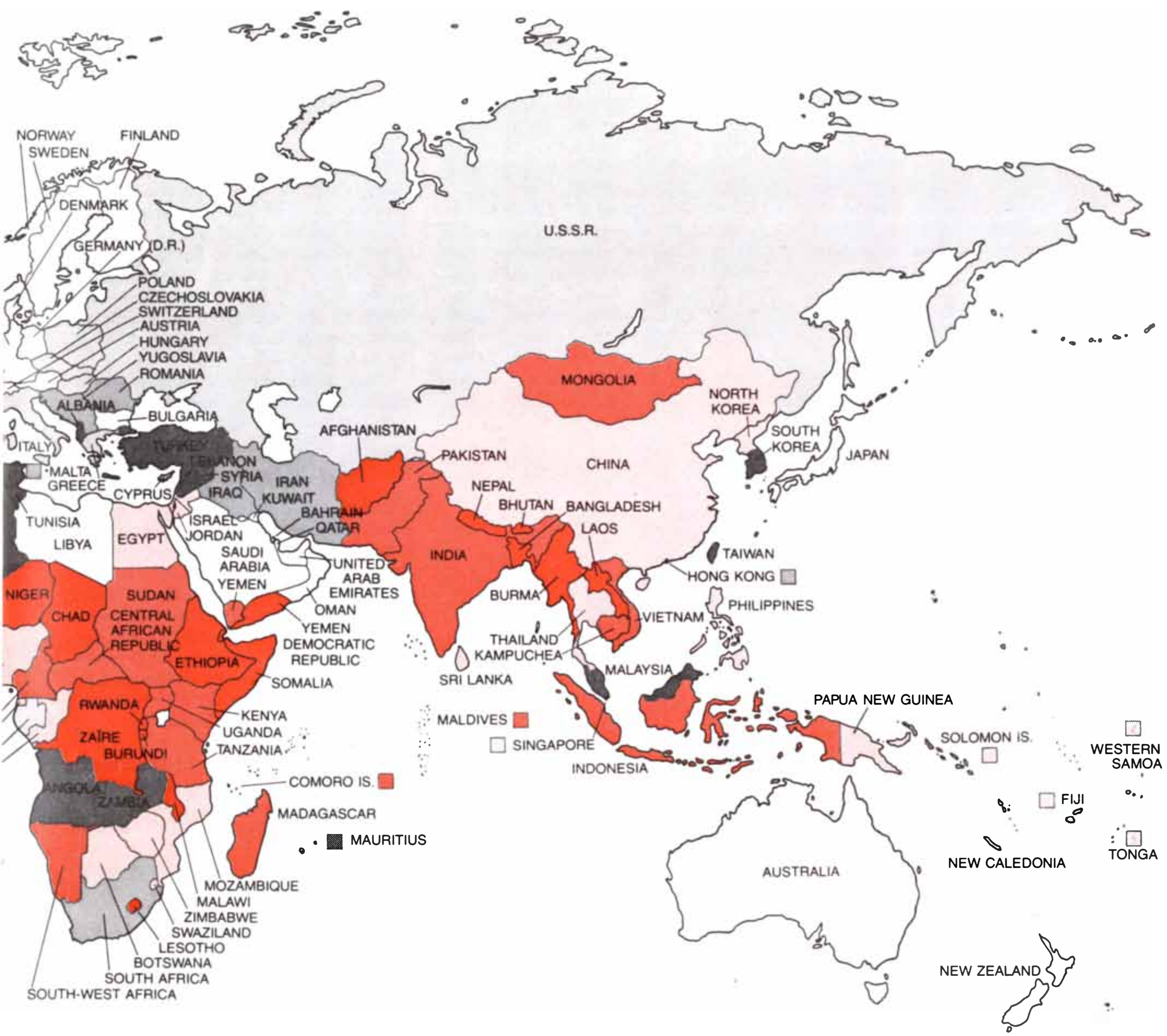
The hope and promise that economic assistance might ease the way for the poor countries was articulated as early as 1948 by President Truman in "Point Four" of his inaugural address that year.



SEVEN ECONOMIC CATEGORIES are indicated for eight world regions on this map: Europe (including Turkey), North America, the Caribbean, Latin America, Africa, the Middle East, Asia and Oceania. Countries and other political divisions are categorized as rich (*see key*) if the per capita gross domestic product (the output produced within the country) is more than $5,000, as near-rich if the G.D.P. is between $3,500 and $5,000, as upper-middle if the G.D.P. is between $2,500 and $3,500 and as lower-middle if the G.D.P. is between

President Kennedy renewed the promise with his proposal that the 1960's be designated a "development decade." The UN General Assembly adopted this proposal in 1961, expressing "the desire of the world community to accelerate the development process in the less fortunate areas of the world." Such good intentions had substance at the time: the developed market economies, by their official estimates, were advancing $8 billion a year, or about 1 percent of their combined gross national product, to the poor countries.

In reflection and reinforcement of this mood among the makers of policy the theory of development flourished as a subspecialty of academic economics in the U.S. and other market-economy developed countries. The literature of that time pictured the underdeveloped countries as rich countries at an earlier stage of development. Authors envisioned development itself as a linear process divided in stages, from "takeoff" to "high mass consumption," with the necessity for "catching up" and "breaking vicious circles" on the way. All countries, including the developed ones, were seen as starting from the same point and facing the same obstacles as they proceeded on the same



$1,425 and $2,500. If the G.D.P. is between $875 and $1,425, the rating is "poor (I)," if it is between $500 and $875, the rating is "poor (II)" and if it is between $275 and $500, the rating is "poor (III)." The categories take into account the tendency for comparisons based on exchange rates to underestimate actual purchasing power as per capita G.D.P. declines. They were established by Garret FitzGerald on the basis of world data collected by Irving B. Kravis, Alan W. Heston and Robert Summers, economists at the University of Pennsylvania.

course. Some would simply move faster than others; the others would no doubt follow, albeit at a distance. The poor countries now starting into the process "could learn from the mistakes of the rich countries" and could benefit from the continued growth of the rich through such phenomena as "spillover effects" and "trickling down" as well as from the policy of economic assistance.

In the perspective of 1980 the two decades of development may well be characterized as "decades of disappointment." The great mass of the people in the developing countries continue to live in dire poverty. They have barely enough to eat and rarely have enough potable water. Health services are thinly spread. When work is available, pay is low and conditions are close to intolerable. Insecurity is permanent; there are no public systems of social security to cushion the unemployment, sickness or death of the family wage earner. Malnutrition, illiteracy, disease, high birth rate, underemployment and low income close off in turn each avenue of escape. In the two decades the gap between the poor and the rich has widened. The flow of financial assistance has diminished from 1 percent of the G.N.P. to a now officially estimated .35 percent.

Yet it cannot be said that the developing countries have seen no growth in this period. For this group of countries as a whole growth proceeded at an impressive average rate of 5 percent from 1950 to 1976. This rate was higher than that of the developed market economies (4.2 percent), although substantially less than that of the centrally planned economies of eastern Europe (7.7 percent). The absolute increase of the income of the developing countries was much smaller, however. The $1,820-billion increase in the income of the rich countries, from $1,250 billion in 1952 to $3,070 billion in 1972, was 3.5 times the $520-billion total income of the developing countries in 1972.

Like any average, the average rate of growth of the developing countries conceals a wide variation in performance. The countries of one group have moved so fast, from 5 percent up to 9 percent for a decade and a half, that they are coming to be known as the "newly industrializing countries," or N.I.C.'s. They include most of the Latin-American countries. The vigorous expansion of those countries has multiplied their combined G.N.P. five times over that of 1950; Argentina, Brazil and Mexico, with their industrial base already established, have grown the fastest. Certain countries in eastern and southeastern Asia—South Korea, Taiwan, the Philippines, Malaysia, Singapore and Thailand—have attained still higher rates of growth. In manufacturing industries, in diversification of exports and in capacity for framing economic policy they have acquired strengths such that they were able to sustain their growth through the 1974–76 recession in the world economy.

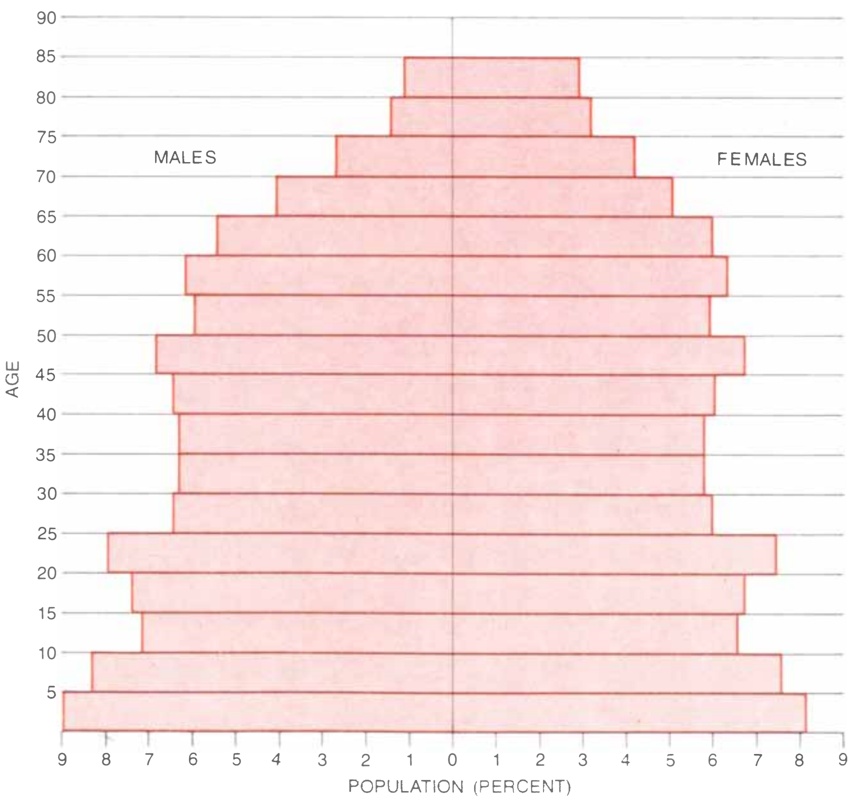
The petroleum-exporting countries have also, of course, made their way into a class by themselves through their control of the supply and price of oil. Three of them—Kuwait, Qatar and the United Arab Emirates—had a per capita G.N.P. in excess of $10,000 in 1976, which bespeaks their small populations as well as their large oil exports. The others ranged from $6,000 (Libya) down to $300 (Nigeria) and $240 (Indonesia). Oil promises to give a new and further lift to the expansion of the Mexican economy.

The N.I.C. and OPEC countries have about a fifth of the population of the developing countries other than China and account for 40 percent of the product of those countries. Some 45 "middle income" countries, with middling growth rates of 5 or 6 percent, have a fourth of the population and produce another 40 percent of the output of all the developing countries.

There remain the "low income" countries. They exhibit average per capita incomes of less than $250; they grew at a rate just under 4 percent in the 1960's and at less than 2.5 percent in the first half of the 1970's. Their people, more than half of the population of the developing countries, subsist on a fifth of the total income of those countries. Indonesia and the three countries of the Indian subcontinent—Bangladesh, India and Pakistan—have two-thirds of this population. Most of the remaining third live in the contiguous "poverty belt" countries of Asia and Africa, designated by the UN as "least developed," a category that also includes Bangladesh.

Slim margins hedge the bare subsistence of these 1.2 billion people from disaster. Their increasing numbers endanger the fragile tropical environment in which they live. They have cut down their forests. Lacking any water-management infrastructure and so lacking adequate irrigation, they are afflicted alternately by flood and drought and suffer persistent loss of the long-term fertility of their soil to erosion and creeping deserts. Malnutrition makes them the more vulnerable to endemic diseases. The sun that might someday provide a source of electric power currently saps their vigor, while their insolvent economies import expensive fuels.

The condition of the poorest countries deteriorated in the 1970's. Not only did their low and inadequate growth slow down still further; even the increase in the meager assistance from the international community was offset by de-



POPULATION STRUCTURE of a developed nation, presented graphically in the form of a pyramid that arrays the percentage of males (*left*) and females (*right*) in each of a series of age cohorts, is seen to differ greatly from the population structure of a developing nation. This pyramid depicts the population of England and Wales in 1968 in five-year cohorts up to age 80 and above. Both the low birth rate and low mortality make for a straight-sided structure.

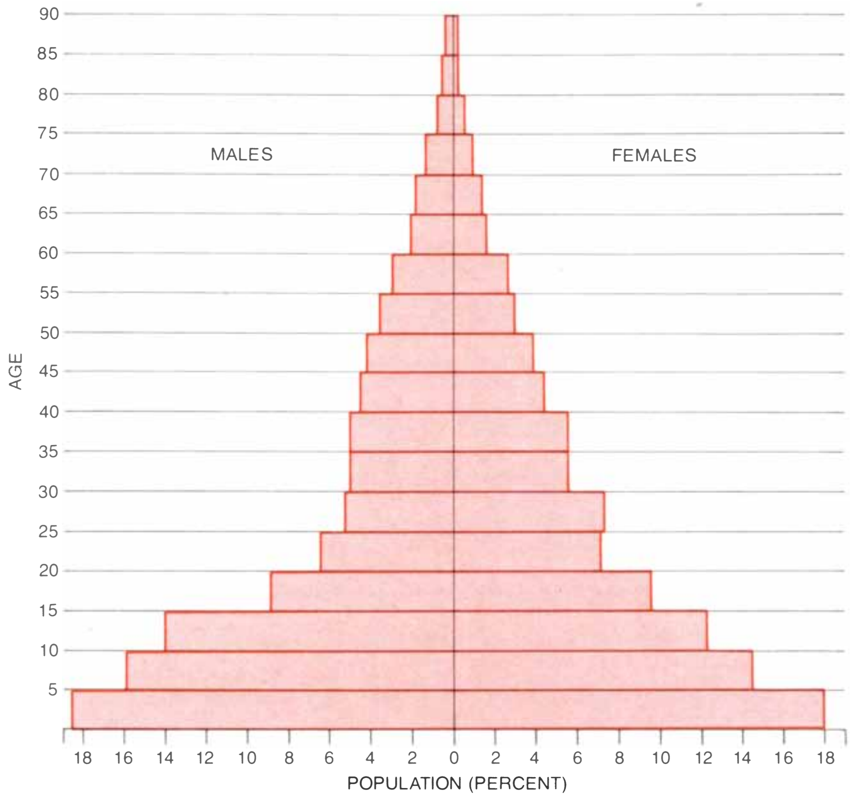
cline in the purchasing power of their exports. These countries have had to begin to face the grim possibility that their ecosystems may not be capable of feeding their people unless measures to reverse the deterioration are taken now.

Nor have the higher rates of growth in the N.I.C., OPEC and middle-income countries brought appreciable change in the conditions of existence of the great mass of their people. The trickling down of modernization and progress has not reached the poor strata of these societies or has yielded them no more than marginal benefits. The number of people in critical poverty continues intolerably high; unemployment and underemployment have not decreased significantly, and social indicators of health and literacy have shown little improvement and in some countries regression. This characterization of the situation of their poor applies particularly to Latin America. According to the report of the 1979 conference on employment held by the International Labor Office, "in 12 out of 23 countries, where reliable statistics exist, over one-half of the population had incomes insufficient to buy a basket of goods and services considered essential to a minimum level of welfare.... For Latin America as a whole the proportion of the population in such a plight may be as much as 40 percent."

The unrelieved poverty in most developing countries is due in some degree to the pattern of growth of those countries. In 14 African countries agricultural production has lagged behind the growth of population. Countries that have striven for industrial growth have found that the kind of industry they have favored has not significantly increased employment. In all countries the poor have weak links to the organized market economy; they own little by way of productive assets, have little education and are chronically in poor health.

An in-depth examination of the process of development and of the linkages between the developing countries and the world economy reveals features that explain the call for a new international economic order. They also provide a measure of the power—and the staying power—of the old order.

At the heart of the existing system is the problem of unequal exchange. The international division of labor encourages and even compels the developing countries to produce for and constantly adapt to the needs of the industrial countries. The institutions of the international system, particularly the key ones in trade and credit, were created during and in the immediate aftermath of World War II. At that time, of course, most of the developing countries of Asia and Africa and the newer countries of the Caribbean were still colonies of one or another imperial power. The international credit-and-trade system functions, therefore, in such a way as to



POPULATION PYRAMID constructed for a developing nation contrasts strongly with that for a developed nation (*see illustration on opposite page*). This pyramid depicts the population of Madagascar in 1966. The youngest cohort constitutes some 18 percent of the total population, in contrast to 9 percent in England and Wales. Men and women aged 40 to 45 make up less than 5 percent of the Madagascar population, and the percentage per five-year cohort declines thereafter. In England and Wales four successive 40-plus cohorts are nearly identical.

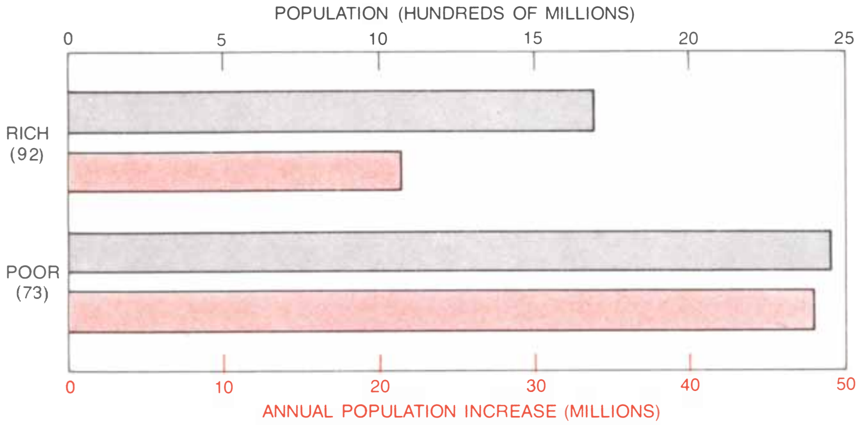
perpetuate the dependent economic relations of the colonial era.

In consequence the economies of the developing countries are disarticulated: they lack organic linkage, rooted in an indigenous science and technology, between the growth and structure of their domestic production and the growth and pattern of their domestic demand. The principal economic activity other than subsistence agriculture is dominated by exports of primary commodities for which the control of production as well as of market decisions lies at their destinations abroad.

Such commodities do not constitute a home base for development; they cannot be reckoned as domestic production surpluses. Imports tie the developing countries to one or more industrial "patron" countries in a complementary bond of dependency; they satisfy a high proportion of total consumption in the monetary part of the developing economy and supply almost all the means of production. Development strategies aimed at greater internationalization of the developing economies have therefore generally left them bereft of indigenous sources of dynamism. Even in the high-growth countries this kind of development has excluded the great mass of the people. What is more, it has blocked most developing countries from exploitation of their natural endowments. Thus it has been only in the past three decades that India has built the beginnings, at least, of a steel industry based on its own coal and iron, and that "agricultural" countries such as Tanzania have begun to seek self-sufficiency in food production and to take an inventory of their mineral resources.

(The exclusion of China from the foregoing review of conditions in the developing countries is now explained. From 1949, when its revolutionary government assumed power, until the past decade the People's Republic of China proceeded to conduct its development in isolation from the international economic order. A fast-growing poor country, it has now opened negotiations on its own terms with the developed market economies for inputs of technology calculated to speed its growth.)

There can be no genuine development without personal freedom and security. The formal process of political decolonialization was therefore a condition precedent to economic development of the "third world." In Africa even this phase of development was still in process in 1963; it has come nearer to a close with the independence of Zimbabwe in



RICH AND POOR DIVISIONS of the world differ both in total population and in annual population increase. The 92 countries and other political divisions with per capita G.D.P. between the equivalent of $15,000 and $1,425 had an estimated total population of 1.69 billion in 1978. Their estimated annual population increase was 21.5 million. The remaining 73, with per capita G.D.P. between $1,425 and $275, had a population one-third larger: 2.46 billion. Their annual population increase, however, was 48 million, more than twice that of the rich 92. As in the map on pages 60 and 61, comparison is based on tables prepared by FitzGerald.

1980. Although they are now politically independent, these countries have just begun their journey toward economic and cultural liberation. Continuing domination by the industrial countries deters and diverts them from determination of their own development path. They still have too little control over their own resources and too little access to those they need from outside their borders; they do not yet participate on an equal basis in the taking of decisions affecting them and cannot yet make those decisions autonomously.

The theory of development in academic economics and the practice of economic assistance by the industrial countries took no adequate account of these political and cultural considerations. Development was a matter of "things," to be attained by capital accumulation, infrastructure building, management training and so on. The two decades of development and disappointment have shown that these things and processes may underpin development but that they do not constitute the whole or even the most critical part of it. Development is the unfolding of people's individual and social imagination in defining goals and inventing ways to approach them. Development is the continuing process of the liberation of peoples and societies. There is development when they are able to assert their autonomy and, in self-reliance, to carry out activities of interest to them. To develop is to be or to become. Not only to have.

The approach to development from the developed market economies could have been more successful, notwithstanding its built-in misconceptions, had it received more substantial implementation. With the thawing of the cold war, as symbolized by the détente between the U.S. and the U.S.S.R., the U.S. substantially reduced its outlays to economic assistance. Other countries followed suit—with the notable exception of the Scandinavian countries and the Netherlands, which have increased their outlays above the target .7 percent of G.N.P. The new conservative mood of the rich countries arose from two contradictory perceptions of their relations to the developing countries. On the one hand the N.I.C.'s now appeared as "cheap labor" competitors. On the other the sluggish performance of the countries where foreign capital inflow had not reached an appropriate threshold was taken as proof of the futility of economic assistance.

By the end of the 1970's the flow of economic assistance had dwindled to half of the promise of .7 percent of G.N.P. made at the beginning of that decade. This had a profound, although differential, impact on the prospects of the developing countries. Those in the N.I.C. category were able to take advantage of the enormous private-bank liquidity of the 1970's, partly generated by the recycling of "petrodollars," and of investments by the giant transnational corporations. The transfer of technology thereby accomplished also brought along the transfer of the consumption patterns of the industrial societies to the new arrivals in the upper-income strata of the recipient countries. On the prospects of the so-called aid countries this turn of affairs had a double impact: they failed both of aid and of financing by the banks and of investment by the transnational corporations.

The 1970's had meanwhile witnessed the culmination of deep-running changes within the community of the market-economy industrial countries. The rapid growth of western Europe and Japan had eroded U.S. hegemony, leading to increasing divergence among these countries on monetary and trade policies. But the increase in trade and capital flows within the community and the rise of the transnational corporations had at the same time brought a de facto reduction of national sovereignty over economic policymaking. This was happening at a time when most European governments held only slight majorities in their legislatures and were compelled to respond sensitively to domestic pressures in formulating foreign policy. Those pressures, moreover, were on a constant rise in the contest of adversary social groups for shares in the economic product, pressures that compelled increasing intervention by the government in the economic and social life of those countries.

Even before the inexorable closing in of the petroleum horizon had terminated the era of cheap energy the tensions and conflicts in the community of the market-economy industrial nations brought the collapse of the international monetary system and protectionist compromise of the liberal trade policies. The oil crisis followed, signifying that those nations had lost control of the resource on which their growth and affluence most critically depended.

In the quadrupling of oil prices by OPEC the developing countries saw welcome evidence that the developed market economies were losing their economic dominance. In the "nonaligned" movement those countries had been developing political cohesion, and in the caucus of the "Group of 77" a common position on economic questions. At their instigation the UN General Assembly was called into its Sixth Special Session early in 1974. That session adopted a declaration and a program of action on the establishment of a new economic order and a charter of economic rights and duties of states.

In effect these documents call for the replacement of the economic order characterized by inequity, domination, dependence, narrow self-interest and segmentation by a new order based on equity, equality of sovereign nations, interdependence, common interest and cooperation. They seek to establish "new rules of the game" and to redress the old imbalances. In particular they assert the sovereignty of nations over their own natural resources and over the activities of foreign nationals and corporations operating within their borders. That such rules and objectives had to be voiced is a measure of the degree to which the old order departed from principles of equity and justice on which all people agree and which ordinarily go without saying.

These declarations by the UN General Assembly were to be translated into negotiable issues involving particular institutions and markets. The key markets are those in which the developing countries are suppliers (of commodities and of a lengthening list of manufactures) and in which they are customers (for technology and finance). The key institutions are those that generate and distribute international liquidity, particularly the International Monetary Fund.

It is no surprise to find, after half a decade, that the new international economic order remains largely on paper. Its implementation is tantamount to the replacement of an imposed asymmetry by a negotiated symmetry, an event that has no precedent in history. The developed market-economy countries could hardly be expected to volunteer such readjustment: changes in power structures have always come from below. Once the industrial countries had weathered the first oil price increases and the tidal wave had been dissipated by the recycling of petrodollars back into their domestic markets, they found no compelling need to negotiate. The developing countries, having seized a timely moment to press their demands, appear to have relaxed in failure to perceive their historic role. Nor have they, through the negotiation of trade-offs with one another, achieved a sufficient coordination of their national interests to organize themselves as a force with sufficient negotiating power to compel recognition by the developed countries.

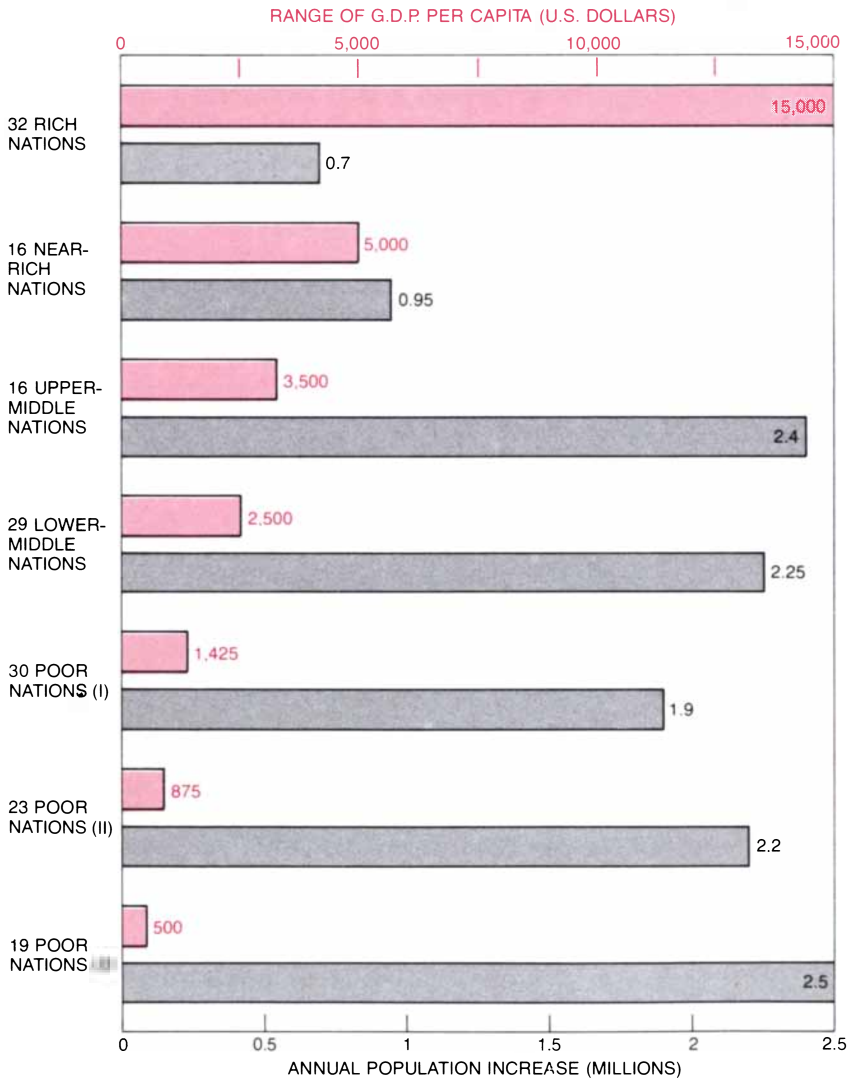
To the developed and the developing countries alike the past five years of drift and stagflation have begun to show, however, that the structural problems of the world economy are not distinct from those confronting the development of the developing countries. Significant and tangible issues are ripe for negotiation in the impending Special Session of the General Assembly. Restoration of growth, particularly in the industrial countries, depends on an adequate energy supply. The overall deterioration of the world economic situation and the prospect of a long and difficult conversion of energy technology to a new resource base give strong impetus to long-term oil conservation policies in the producer countries. Those countries must be given incentives to sustain or increase their production. In other commodity markets as well the ending of hegemonic control over the natural resources of the new nations makes access to these resources by the developed countries a serious issue for international economic negotiation. In the case of the flow of trade in manufactures the developing countries as a whole now constitute an increasingly significant market for a number of the industrial countries. In the international capital markets the great private financial institutions are now so exposed by the credits they have extended to the developing countries that problems in those countries can have a magnified impact on the economies of the developed countries.

The global round of negotiations will proceed also in the dawning realization by the world community that the old order has begun to work significant deleterious effects on the productive base of the world economy. Erosion of the balance between man and nature by ill-considered uses of technology makes it impossible to sustain development on the prevailing terms.

In the industrial countries that celebrate themselves as "bread baskets" imprudent recourse to technological inputs may result in long-term diminution and exhaustion of soil fertility. The tropical lands in the course of similar exploitation appear even more vulnerable. There may be no "limits to growth" in the short run, but there are clear limits to waste.

The agenda of the 1980 Special Session of the General Assembly thus underlines the need for a new system of managing the world economy geared to both equity and efficiency. Such a system must be global and must embrace all aspects of the economy. It must redress the imbalances that deter the development of the poor nations and must bring their productive capacity and their markets into the world economy on terms of parity.

In such a system the industrial countries as well as the developing ones have a high stake. All concerned must listen to the voices of the poor, who have paid the highest price for the passing order and can no longer be kept in convenient silence. The issues call for an international politics of human survival, based on broad public understanding and statesmanship suffused with vision and courage.



DISPROPORTION between per capita G.D.P. and population increase is evident in a comparison of the data for the world economic categories. For the rich and near-rich, with a per capita G.D.P. ranging from $15,000 to $3,500, the percent of annual population increase is less than 1. For the other five categories, with G.D.P. ranging from $3,500 to $275, minimum percent of increase is 1.9 and the average is 2.25. This comparison is also based on FitzGerald's tables.

People

The goal of economic development is to improve the well-being of people. Health for all is not just a by-product of development. It is a primary lever for initiating the development process itself

by Halfdan Mahler

The ultimate goal of economic development is to improve the well-being of people. The building of factories, the terracing of land and the training of engineers are but means toward that end; enhancing the reputation or wealth of political leaders and increasing the prestige or power of nation states are irrelevant. Improving the health of people is fundamental to improving their well-being. This being so, it is important to know what "health" means. Health has long been defined by the 155 member states of the World Health Organization (WHO) as "a state of complete physical, mental and social well-being, and not merely the absence of disease or infirmity." The ultimate goal of development can therefore be said to be health, in this broad sense, for all the people of the world. It is as simple as that—and as complex.

It is complex because when it comes to defining health policies, assigning priorities, allotting funds and planning and operating programs to give effect to the policies, it is not easy for political leaders or technical experts in either the underdeveloped or the developed countries to keep in mind the centrality of human development. There are two conventional ways to view the relation between health and development. One sees health as a prerequisite for development. The other sees health as a concomitant of development. Both views are supported by evidence and both can motivate humane development programs. They are not even mutually exclusive; rather they are mutually supportive.

Health is indeed a prerequisite for economic and social advance. Mahatma Gandhi once put it: "God does not speak to an empty stomach or a sick body." Neither does the development message. Human energy is the fuel that drives development, the source not only of physical work and other economic activity but also of hope for the future, social awareness and the ability to absorb and apply new knowledge, all of which are essential to development. Genuine measures to improve health are likely to contribute to general socioeconomic advance.

The question is not how much countries can afford to spend on the health of their people; it is how much they can afford not to spend on it. Relying on economic calculations to determine the minimum fraction of a nation's resources that should be devoted to health carries the danger of providing a theoretical minimum energy level for economic production. The critical amount of human energy in question, however, is the amount required to initiate social and economic development. Even more important, when so-called health measures are motivated primarily by economic objectives, they are often not accepted by the public. The history of attempts to limit population provides a good example. People have been unwilling to limit their families simply because a government or a well-meaning international agency thinks they should do so in order to slow population growth and so relieve pressure on a country's resources or the world's. Health measures, including family planning, are effective only when they are oriented toward the perceived needs of individuals, families and communities.

Just as health promotes development, however, so development tends to promote health. There is a strong correlation between per capita gross national product on the one hand and such indexes of health as life expectancy and infant mortality on the other. The correlation is observed not only when the developed world is compared with the underdeveloped but also when poor countries are compared with the very poorest and when the urban and rural areas of a particular underdeveloped country are compared.

And yet not all activities aimed at economic growth promote health. Presumed economic advances can dislocate viable communities, worsen the lot of small farmers, create urban slums and widen income disparities. (The well-meaning "green revolution" provided dramatic examples of some of these effects.) Development projects unattended by preventive-health measures can increase the incidence of certain diseases. And, as is well known, in many developed countries with advanced health establishments and technology the acute infections have disappeared as major causes of death and illness only to be replaced by chronic mental and physical conditions promoted by stress, pollution, industrial hazards and family disruption.

Health is a fundamental human right, as the constitution of WHO recognized more than 30 years ago. It must therefore be pursued for itself, and not only as a prerequisite for development. The true goal of development—the well-being of people—can be achieved only by way of an approach to development that is oriented to the needs of people.

Nearly a billion people are trapped today in a vicious circle of poverty, malnutrition, disease and despair that saps their energy, reduces their work capacity and limits their ability to plan for the future. For the most part they live in the rural areas and urban slums of the underdeveloped world. The depth of their deprivation is measured by a few statistics. Whereas the average life expectancy at birth is some 72 years in the

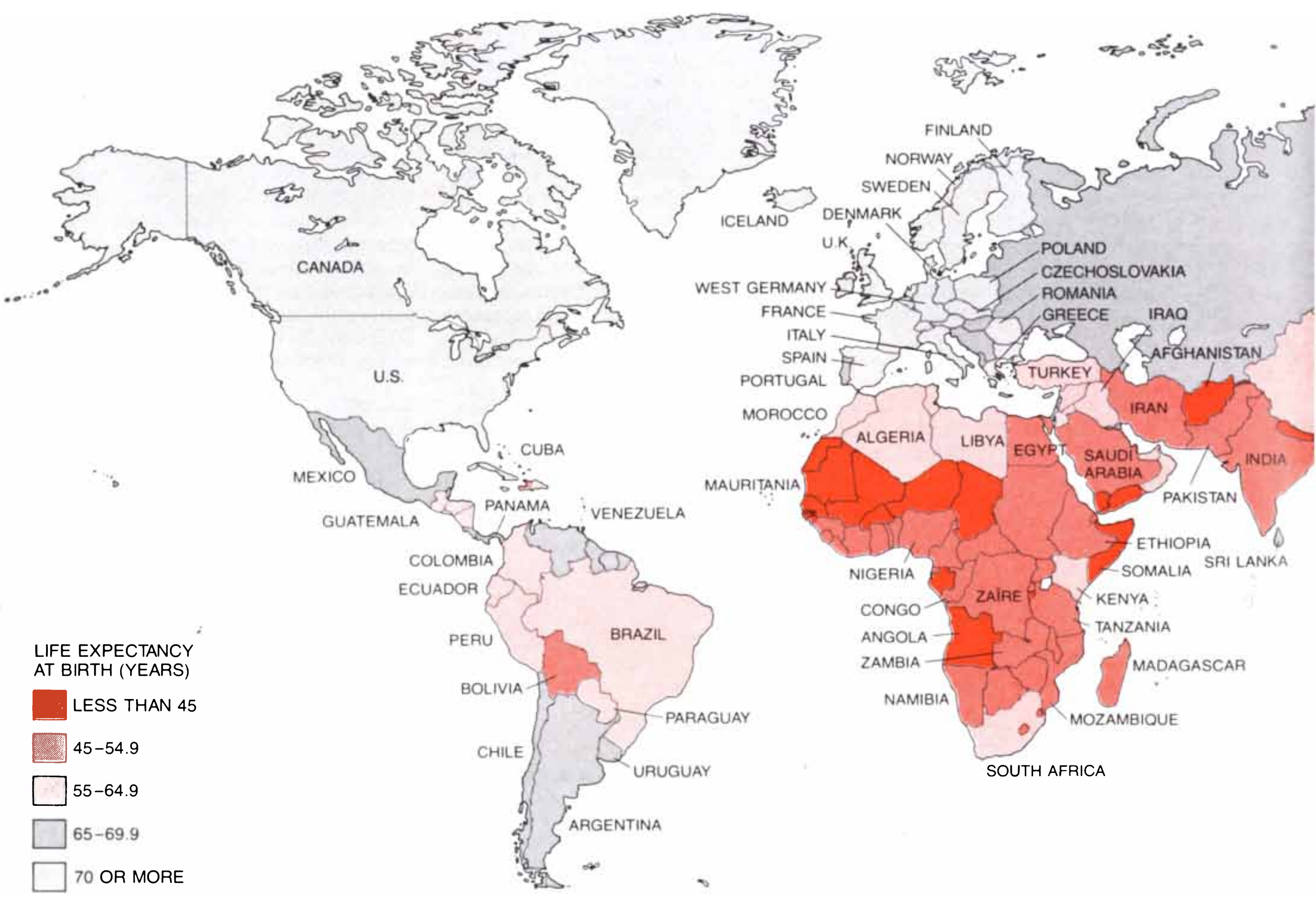
TWENTY MILLION PEOPLE live in the Tokyo-Yokohama metropolitan area, which is defined in the partial Landsat image on the opposite page by the light bluish tone characteristic of urban areas in such false-color reproductions. The Tokyo-Yokohama and New York metropolitan regions are now the two largest conurbations in the world. By the year 2000, according to a United Nations projection, they will rank third and fourth, behind Mexico City and São Paulo. In spite of the density of population in this agglomeration and in Japan as a whole the health level is high (life expectancy at birth is 75, compared with 73 in the U.S. and an average age of 57 in the less developed countries), owing largely to rapid economic development. Fringe of Tokyo Bay is incised by docking facilities, indicative of role as one of world's busiest ports.

developed countries, it is about 57 in the underdeveloped world as a whole; in Africa it is only about 49, in southern Asia 51. The wide differences stem largely not from varying longevity but from the differential impact of infant and child mortality. Whereas fewer than 20 of 1,000 infants born in most developed countries die during their first year, the infant-mortality rate in most developing countries ranges from nearly 100 to more than 200; in the poorest regions of those countries half of all children die in the first year of life. Whereas the death rate for children between one and five is less than 1 per 1,000 in most developed countries, it averages about six in Latin America, 10 in Asia, 30 in northern Africa and more than 30 in Africa south of the Sahara. In a typical underdeveloped country more than a third of all deaths are among infants and children under five. Even for those who reach that age life expectancy in the underdeveloped countries is from six to eight years less than it is in developed countries. The extent of sickness and disability is much harder to document than mortality, but some studies have suggested that a tenth of the life of the average person in a developing country is seriously disrupted by illness.

The pattern of disease in the underdeveloped world is very different from the pattern in industrialized countries. In a typical developing country, it has been estimated, more than 40 percent of the deaths are from infectious, parasitic and respiratory diseases (compared with about 10 percent in a typical industrialized country, where the major causes of death are heart and vascular diseases and cancer); studies have shown that as the percentage of deaths due to infectious and parasitic disease drops life expectancy increases. The most widespread diseases in developing countries are diarrheal ones transmitted by human fecal contamination of soil, food and water. Only about a third of the people in the world's poorest countries have dependable access to a safe water supply [see "Water," by Robert P. Ambroggi, page 100]. The parasitic diseases in particular are usually chronic and debilitating rather than acute, and they are endemic in most poverty-stricken areas.

Diseases transmitted by insects and other vectors are also widespread and have serious impact in particular regions. Malaria remains the most prevalent disease in spite of the fact that it can be prevented by routine administration of inexpensive drugs or by spraying to kill the *Anopheles* mosquito and its larvae; some 850 million people live in areas where malaria has been only partially controlled, another 350 million in areas that still lack active control efforts. Schistosomiasis, caused by a snail-borne parasite, is endemic in some 70 countries, where an estimated 200 million people are infected. Onchocerciasis, or "river blindness," is caused by a worm whose larvae are transmitted by blackflies of the genus *Simulium*, whose larvae in turn live in fast-flowing water; in some hyperendemic regions more than 20 percent of the adults may be blinded by the disease. Ironically, development projects have increased the incidence of schistosomiasis and onchocerciasis: drainage and irrigation canals provide a habitat for the snails, the spillways of dams for the blackfly larvae.

At least some 450 million people—perhaps as many as a billion—have less food than is necessary for basic survival; in the underdeveloped world about a fourth of the people have a food intake



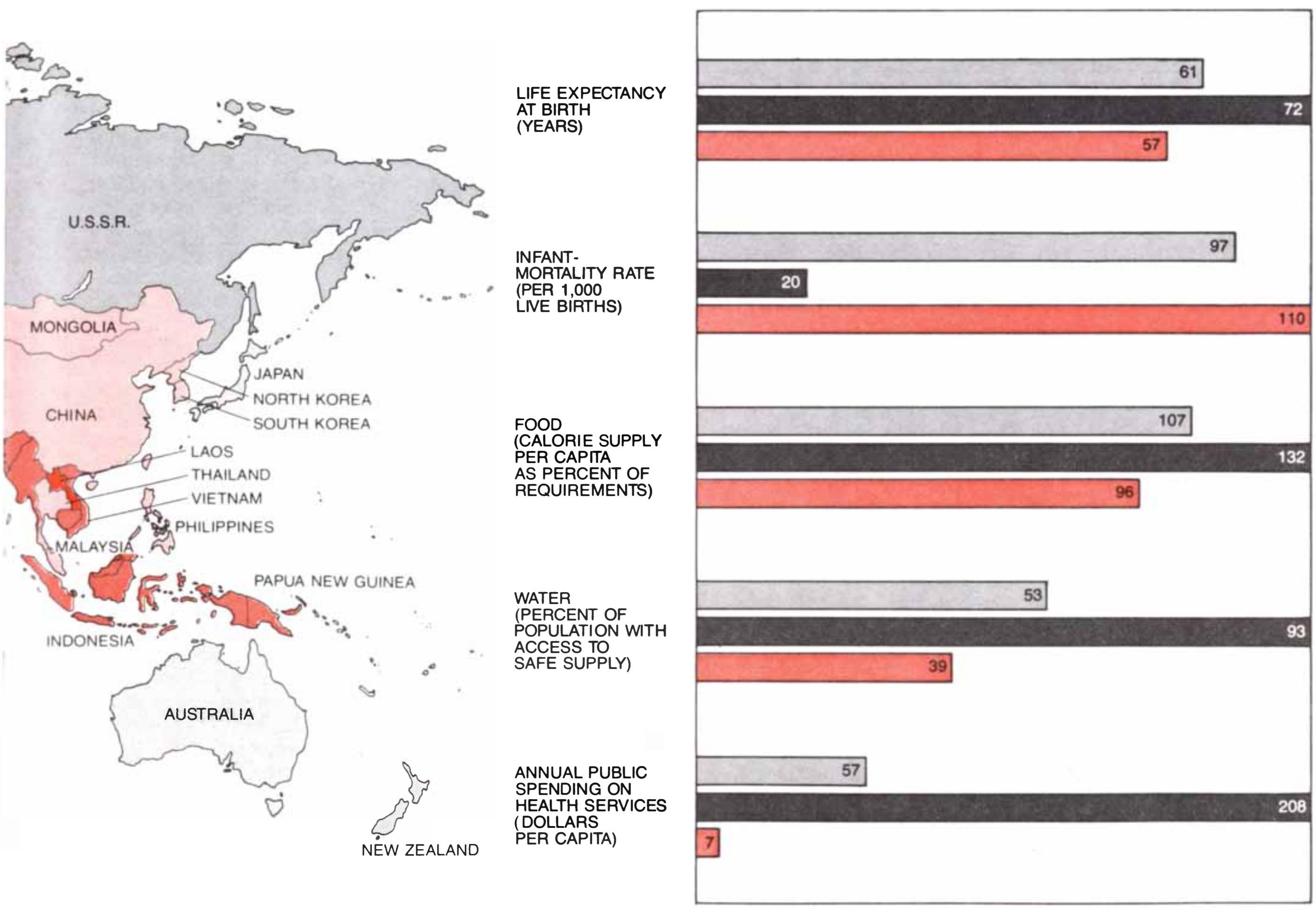
LIFE EXPECTANCY AT BIRTH, the best single measure of the health level of a population, varies from less than 45 years in some of the poorest countries to more than 70 years in the rich countries, as is indicated on the map. The bars (*right*) show average values (weighted

below the critical minimum level [see "Food," by Nevin S. Scrimshaw and Lance Taylor, page 78]. Malnutrition debilitates entire populations in many parts of the world. It predisposes to disease and death by contributing to prematurity and low birth weight and by impairing immune processes; disease in turn exacerbates the effects of malnutrition by inhibiting the absorption of nutrients. Moreover, in some countries malnutrition is severe enough to be listed as a primary cause of death among children under five. And in times of famine starvation kills hundreds of thousands of people of every age.

The major direct cause of hunger is of course poverty; infections and parasites, poor distribution and sanitation and a rate of population growth that increases demand more than supply are contributing factors. The interplay of these factors perpetuates malnutrition, disease and in turn poverty.

If the poverty of nations and individuals is the root cause of miserable living conditions, why not concentrate on relieving poverty, to some extent redressing the imbalance between the rich and the poor regions of the world? Certainly a good argument can be made that the institution of a new international economic order [see "Economic Development," by K. K. S. Dadzie, page 58] would in time raise the level of health in the underdeveloped countries. The association between indicators of material wealth and of health status has been demonstrated time and time again; it is implicit in some of the statistics I have cited. To an extent history reinforces the development-first argument. The improvement in health standards that began in western Europe and the U.S. in the 19th century owed more to rising living standards than to medical care as such. Death rates began to drop in northern Europe early in the 19th century, long before medicine could cure or prevent many diseases. The incidence of cholera and typhoid fell in Britain long before there were effective methods of treatment. In the U.S. the tuberculosis death rate dropped from 200 per 100,000 of population in 1900 to 70 in the 1930's, before lung-collapse therapy or even rest in sanatoriums was widely prescribed; the rate had declined to 30 per 100,000 before a definitive chemotherapy became available during the 1950's.

I do not think, however, that the underdeveloped world can wait for economic development to have its slow effect, with health as a by-product. The first reason is that the promotion of better health is a moral imperative in itself. I would argue, moreover, that it is the ideal lever and carrot for development. Good health is a fundamental goal of people everywhere in the world, and it always has been. Even people living below the subsistence level voluntarily devote substantial effort and resources to obtaining health support in the form of meaningful remedies or of placebos, traditional or modern. Moreover, the idea that people deserve decent health is generally accepted by policymakers; health aspirations are less controversial politically than most other social and economic aspirations. Finally, in spite of the correlations between development and health status, a number of countries have shown that providing essential health care for the total population and improving the nutritional status of all the people can have a marked effect on life expectancy and



by population) of five indicators of health status for the world (*gray*), the more developed countries (*black*) and the less developed ones (*color*). (The UN categorizes Europe, North America, the U.S.S.R., Japan, Australia and New Zealand as the "more developed" countries.)

other health indicators even in the absence of general or industrial economic development.

If health is accepted as a major goal in its own right and as a major lever for economic and social development, what is to be done? The task is formidable. Most of the people of the world now have no access to any organized form of health care. The gap between levels of investment in health care in the affluent countries and in the developing countries is widening. Government spending for health in many underdeveloped countries is less than 1 percent of the gross national product and it seldom exceeds 2 percent of the G.N.P. in any of them, compared with from 6 to 12 percent of the G.N.P. in most developed countries. This translates into an average of a few dollars per person per year in the underdeveloped countries as opposed to several hundred dollars in most developed ones. To make matters worse, much of the spending is for services that reach only a small fraction of the population.

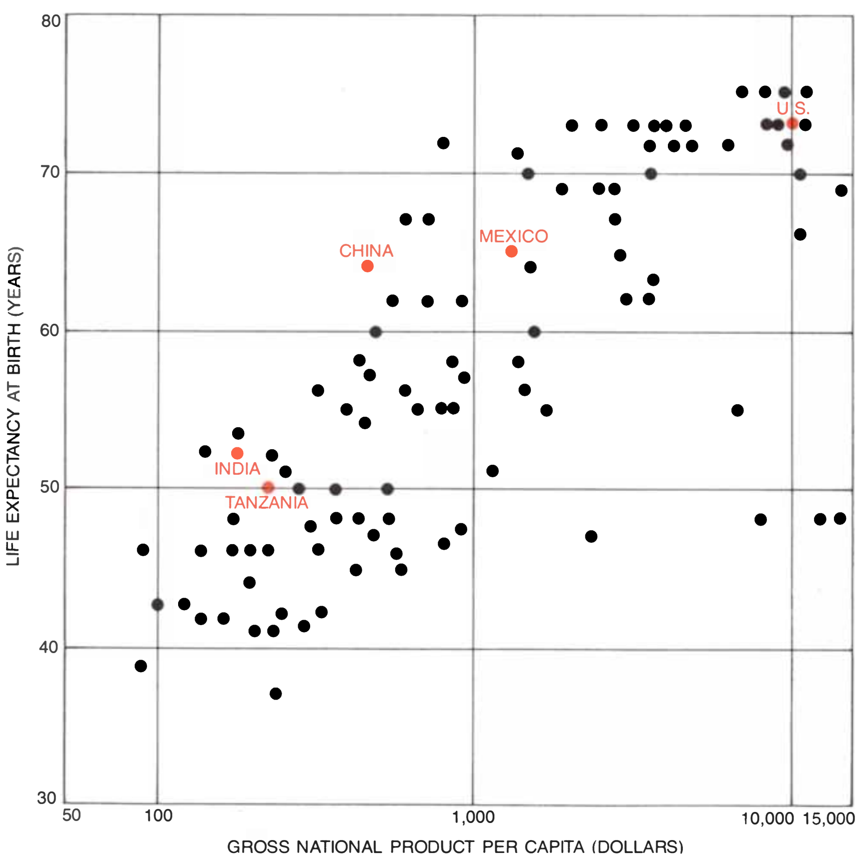
The equitable distribution of health resources is basic to raising the general standard of health in any country; for a poor country with limited funds in particular it is essential to allocate those funds preferentially to the most deprived people. This implies proper choices not only among geographic and demographic sectors but also among forms and techniques of health care. The failure to reach the majority of the people can be attributed first to inaccessibility. Rural populations are spread thin in most underdeveloped countries, and transportation is lacking. Hospitals are completely beyond reach for most people, and even scattered dispensaries are usually patronized only by people in their immediate vicinity. Well-organized community health-delivery systems are required, with people and community health workers interacting and with links to and from more central health facilities.

Yet in many poor countries a major share of the health budget has been devoted to building hospital complexes that are often difficult to run because annual operating funds or management skills are lacking. More money has gone to establish medical schools, which train physicians who are reluctant to turn their attention from advanced medical research and high technology to the basic needs of the population. None of this is surprising: the underdeveloped countries, their elites and their medical establishments are simply following the example of the developed world. A few years ago WHO's executive board reported that "widespread dissatisfaction among populations about their health services . . . occurs in the developed as well as in the third world," in particular because of "an inability of the health service to deliver a level of national coverage adequate to meet the stated demands and the changing needs of different societies, . . . rapidly rising costs without a visible and meaningful improvement in service and a feeling of helplessness on the part of the consumer, who feels (rightly or wrongly) that the health services and the personnel within them are progressing along an uncontrollable path of their own, which may be satisfying to the health professions but which is not what is most wanted by the consumer."

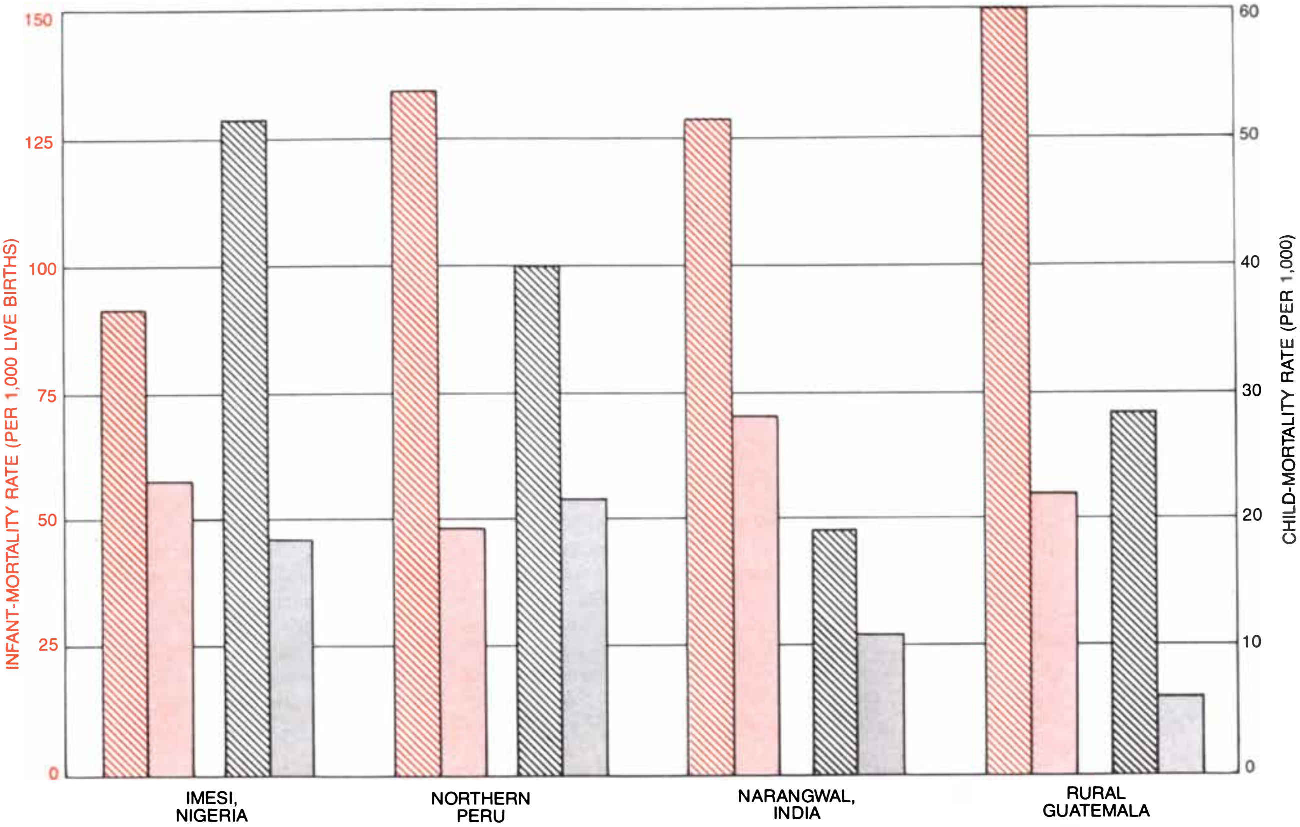
Far too many of the world's medical schools prepare doctors not to care for the health of people but to cure diseases, and to do so by the application of increasingly expensive medical technology. They prepare doctors to deal with less common clinical conditions rather than with the common health problems of the community, to look at disease episodes rather than at the whole individual and his or her interaction with society. Medical systems, and in many countries the insurance systems that help to support them, are oriented toward inpatient hospital care rather than outpatient care, home care and self-care. Much of the admired technology is essentially "placebo" technology. I include in that category not only the prescription of many drugs currently in vogue but also the indiscriminate resort to coronary bypass surgery, intensive-care units, "life support" systems, whole-body scanners and so on. In the name of "quality" medical care perhaps 80 percent of the world's health resources are being applied to fewer than 10 percent of the world's health problems.

In 1977 the annual World Health Assembly resolved that the main social target of governments (and of WHO) in the coming decades should be "the attainment by all citizens of the world by the year 2000 of a level of health that will permit them to lead a socially and economically productive life"—a goal that is encapsulated as "health for all by the year 2000." In 1978 an international conference sponsored jointly by WHO and the UN Children's Fund at Alma-Ata in the U.S.S.R. identified primary health care as the key to achieving health for all by the year 2000.

As the Declaration of Alma-Ata put it, primary health care is "essential health care based on practical, scientifically sound and socially acceptable methods and technology, made universally accessible to individuals and families in the community through their full participation and at a cost that the community and country can afford to main-



CLOSE CORRELATION between a country's level of health and its level of economic development is revealed when life expectancy at birth is plotted (on a linear scale) against gross national product per capita (on a logarithmic scale) for a sampling of countries; the points fall approximately along a line. U.S. and four countries treated at length in this issue are in color.



INFANT AND CHILD MORTALITY can be reduced by direct efforts to provide health care and nutrition, according to a survey by the Overseas Development Council of 10 "direct intervention" projects. The bars show the effects on infant mortality (*color*) and child mortality (*gray*) of four experimental projects, each covering a rural population of limited size. In the first three experiments rates in control villages (*hatching*) are compared with rates in places where medical care and nutrition supplements (Nigeria), nutrition alone (Peru) or medical care alone (India) was supplied; in Guatemala rates before (*hatching*) and after medical-care delivery and nutrition are compared. Child mortality refers to deaths between one and five except in Indian experiment, where it refers to deaths between one and three.

tain at every stage of their development in the spirit of self-reliance and self-determination." It addresses the main health problems in the community, providing promotive, preventive, curative and rehabilitative services. It includes at least education about health problems and their control, promotion of food supply and proper nutrition, safe water and basic sanitation, maternal and child care including family planning, immunization against major infectious diseases, control of endemic diseases, appropriate treatment of common diseases and injuries and the provision of essential drugs.

The delivery of primary care, thus defined, is now officially the agenda for WHO and its member states. Four principles underlie the concept of primary care: a multisectoral approach, community involvement, equitable distribution and appropriate technology.

The multisectoral approach is dictated by the varied elements of primary care and the different activities and facilities required to implement them. Medical care and education by doctors, nurses and a broad range of auxiliary workers are only part of the story, public-health functions another part. Food production and distribution, a safe water supply, adequate transportation to health facilities, decent housing and sanitation can be supplied only through the joint efforts of many different sectors. Health considerations need to be integrated into all aspects of development. To take one example, when an irrigation system is built in an arid region where certain epidemiological factors prevail, people need to be educated by health personnel about the danger of schistosomiasis; if they are to be kept from doing their wash or bathing in the irrigation ditches, alternative facilities must be provided.

The involvement of individuals in promoting their own health and community involvement in allocating health resources are also essential. People want to feel well and keep well; they have notions about what health is and how to attain it. The value of self-care has long been underestimated by the medical professions. Given the right information, people can be influenced to avoid unhealthful behavior, whether it is smoking or chewing betel nut or abandoning breast-feeding for powdered-milk preparations mixed with contaminated water. Health-education programs are therefore an important part of primary care. Involvement also means having a role in selecting health goals and priorities. Even in affluent, sophisticated societies people are puzzled by medical mysticism and resentful of medical elitism. Rural inhabitants of developing countries are all the more suspicious of strangers who come with take-it-or-leave-it health packages, or promulgate rules and enforce practices that conflict with traditional beliefs, or establish arbitrary goals that do not coincide with local priorities. A program for "health care" in the abstract means little. In a given community one chicken per family may make more sense, then a water supply within 10 minutes' walking distance instead of an hour's, then vaccination against measles and perhaps only then family-planning instruction and a dependable supply of contraceptives.

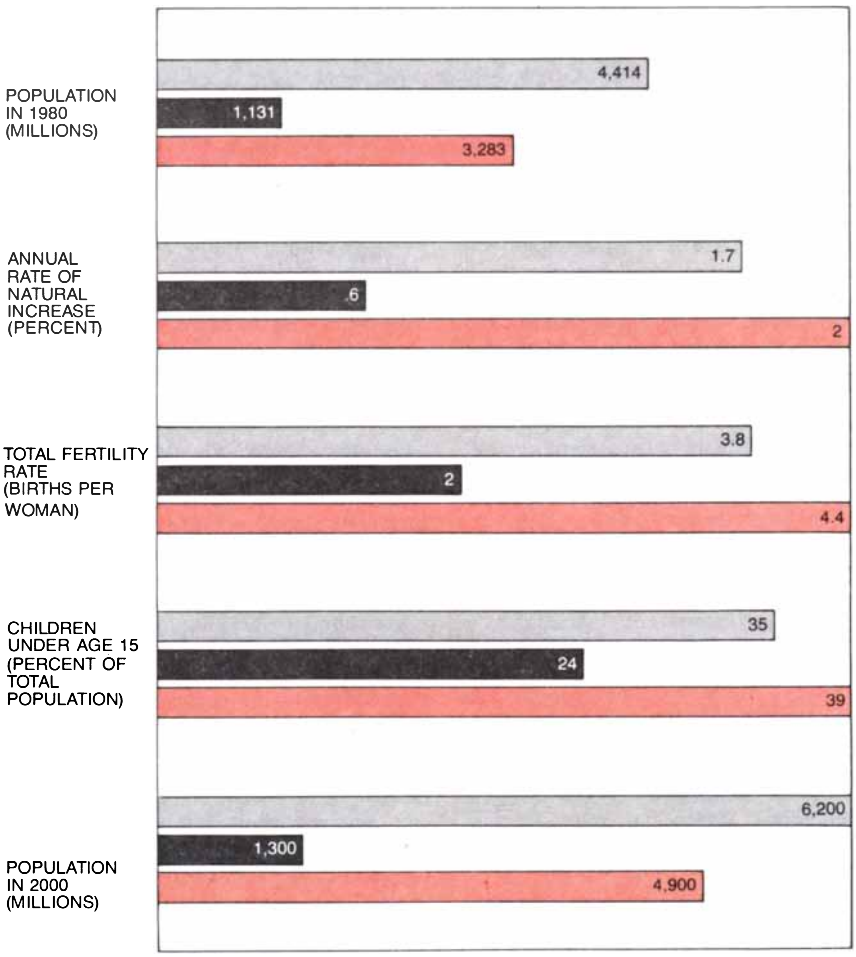
I have already discussed at some length the necessity of equitable distribution. In developing countries (as in any country) that means getting the health care dispersed into the farthest reaches of rural areas and into the foulest depths of urban slums—to precisely those people who have the least political and economic force with which to assert their claim. It means resisting pressures for excessive spending on services that reach only a few and instead allocating funds preferentially to those in most need. It means developing a broadly based pyramidal health system, in which as many services as possible are provided as near people's homes as possible but in which each level of care is closely supported by a higher level to which patients can be referred (and to which they can somehow get). Equity also demands better international distribution of resources for health. It is not likely that rich nations will skimp on their CT scanners or even cut back on their unnecessary surgery to provide money for training community health workers in the third world, but world interdependence requires that they help to provide some of the funding and equipment the less developed countries will need if they are to deliver primary care to all their people.

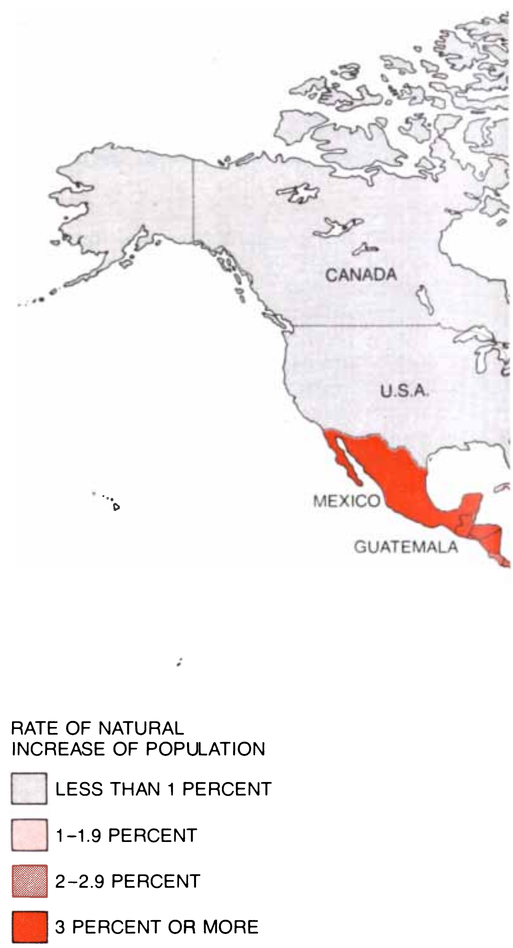
The principle of appropriate technology, properly understood, is crucial to the success of any health system. It is often misinterpreted. "Appropriate technology" for the underdeveloped world does not mean "small is beautiful"; it is not a prescription for cheap, primitive technology for poor, primitive people. It calls instead for scientifically sound materials and methods that are socially acceptable in a particular context, directed against relevant health problems and effectively delivered, by affordable systems, where they are most needed. The generation of appropriate technology is not easy; often it calls for the highest scientific sophistication and perceptiveness.

Take my own experience in tuberculosis. When I went to India for WHO in the 1950's, the standard treatment was rest in a sanatorium; chemotherapy was just being developed. India had some three million tuberculosis cases and no possibility of treating them in sanatoriums or hospitals. It was necessary to experiment: to develop an appropriate technology. The tuberculosis center in Madras developed the concept of intermittent home-based treatment with such drugs as isoniazid. It turned out that a course of treatment providing a 95 percent cure rate would cost so much that it was better to adopt a regimen providing about an 85 percent cure rate for 100 times as many patients. The function of WHO was to give the Indian authorities courage to adopt a regimen that would have been unacceptable in richer countries. Madras standardized diagnostic procedures, proved the effectiveness of chemotherapy administered in the home and devised a course of treatment that was eventually certified by a WHO expert committee.

Appropriate technology is often simple technology but it is not simpleminded. One of the key inventions leading to the recent eradication of smallpox was a small bifurcated needle that administered just the right small dose of vaccine much more effectively than fancy jet injectors. Another example is the treatment of diarrheal diseases by rehydration with solutions of simple chemicals. Trials in Mexico began in district rehydration centers, but they were expensive, required specialized personnel and were dependent on transportation systems. Further research developed a packet for preparing solutions that could be administered in the home by anyone. It was equally effective, much cheaper and locally acceptable.

"Appropriate" implies cost-effective.





POPULATION and some factors affecting it are indicated (*left*) for the world (*gray*), the more developed countries (*black*) and the less developed ones (*color*). The rate of natural increase is the difference between a population's average birth rate and death rate. The total fertility rate is the number of children a woman would bear if she conformed, throughout her child-bearing years, to current average age-

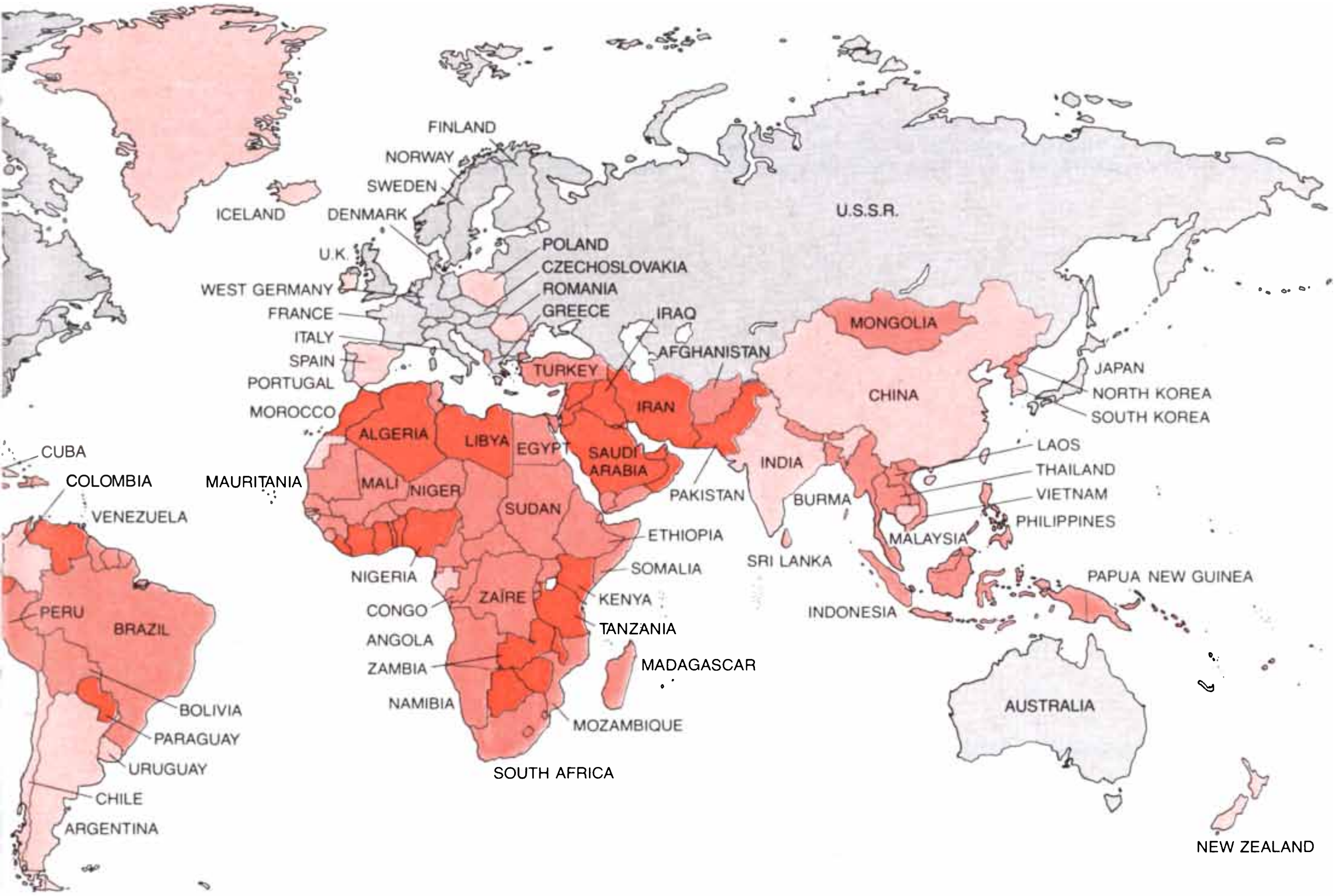
The prime minister of one of the underdeveloped countries recently asked WHO to provide a computer-assisted whole-body scanner. I pointed out that this would absorb WHO's entire budget for his country for two years; for the same amount of money his country could immunize all children against measles for 10 years, thereby saving the lives of perhaps 500,000 children. The president of another country, concerned about malaria, wanted help for a campaign against the mosquito vector. A vector-control campaign can be effective, but it takes time; the thing to do right now to prevent the death of 100,000 children a year in his country is to get inexpensive malaria-control pills to everyone suffering from the disease or exposed to it.

Can primary-care strategies make any difference or will they have the same fate as many earlier well-meant but ineffective efforts? Most of the evidence in their favor has been intuitive or circumstantial. One would like to conduct some broad, carefully controlled tests. Agricultural extension services might be provided, for example, to two groups of about a million people each, with a small proportion of the funds allocated in one case to primary health care. Would the effects of health care be reflected in yields per hectare? I believe they would be, but an experiment of this kind would be difficult, expensive and time-consuming, and there is no time to wait.

A recent analysis of more limited studies, however, shows encouraging results. Davidson R. Gwatkin, Janet R. Wilcox and Joe D. Wray of the Overseas Development Council examined the results of 10 experimental projects, covering from 2,000 to 65,000 people each, designed to improve health and nutrition essentially in ways supported by the Alma-Ata declaration; the projects had been carried out in various settings on four continents over the past 25 years.

Their annual cost was low: from 80 cents to $7.50 per person covered, or from about .5 percent to 2 percent of the per capita G.N.P. of the countries involved—close to the level of health expenditures reported for most developing countries. The basic finding is that the projects worked, specifically in lowering infant and child mortality [*see illustration on page 71*]; in some cases children's physical-growth rates were also increased or a high fertility level was reduced. The ODC report shows how people can be helped to extricate themselves from the vicious circle of poverty, disease, malnutrition, high death rates and family growth in excess of family economic capacity.

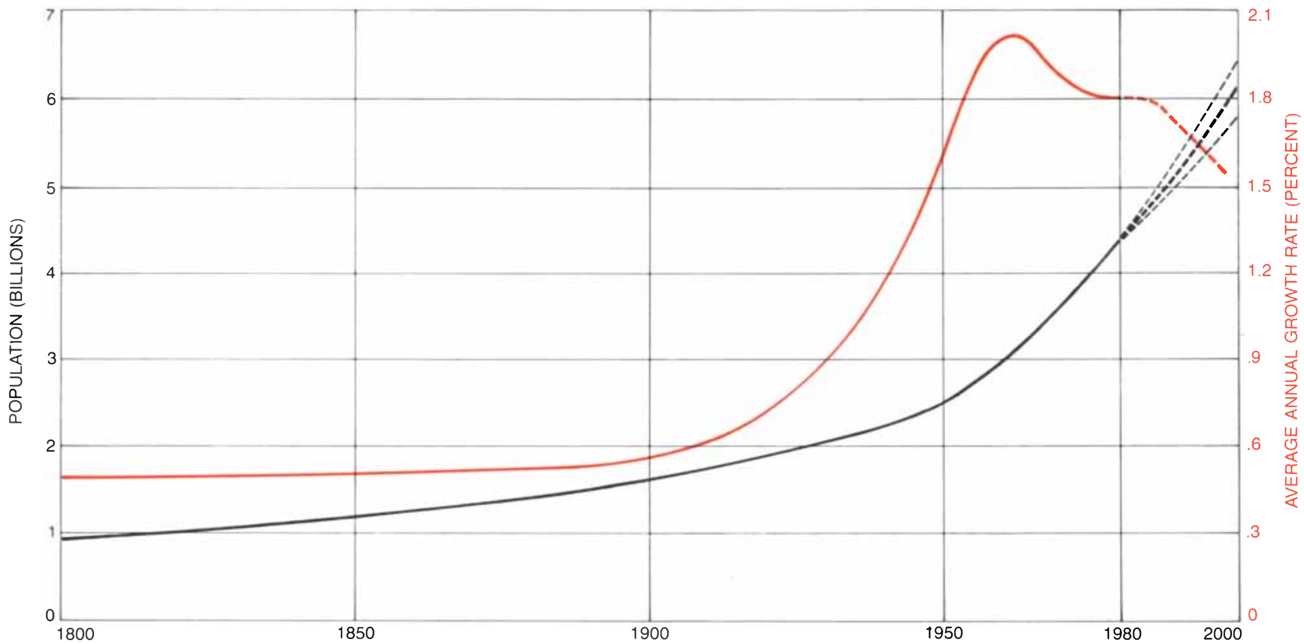
That brings me, at what I take to be the right stage of this discussion, to the subject of fertility rates, which is both more meaningful and more tractable when it is examined at the level of the individual family than when it is viewed as a global "population problem." Family planning and excessive fertility would be of concern to health planners even if there were no relation between fertility and development. As a result of high birth rates children under 15 now account for about 40 percent of the total population of the less developed countries, compared with less than 25 percent in the more developed countries. Children are particularly suscepti-



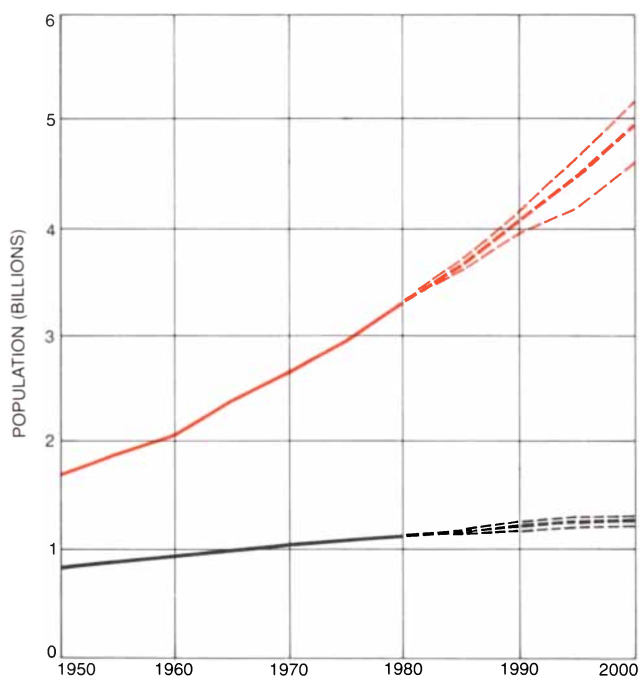
specific fertility rates. The relative size of the population under 15 reflects recent fertility patterns and affects future growth. The combined effects of fertility, mortality and age structure lead to the population projected for the year 2000. The map shows rates of natural increase by country. Data for bars and map, largely from UN sources, were brought up to date by the Population Reference Bureau.

ble to many diseases prevalent in poor societies, and so the death rate increases. Large families are harder to feed on a subsistence income. Crowding in unsanitary housing spreads communicable diseases. Above all, high fertility increases maternal illness and mortality. Inadequate spacing of births puts a heavy burden on women, and there is a steady increase in death at childbirth after the third birth. High fertility also increases resort to illegal abortion, which carries grave health risks. Such reasons would be enough to account for the inclusion of family planning as a necessary component of primary health care quite apart from any development considerations.

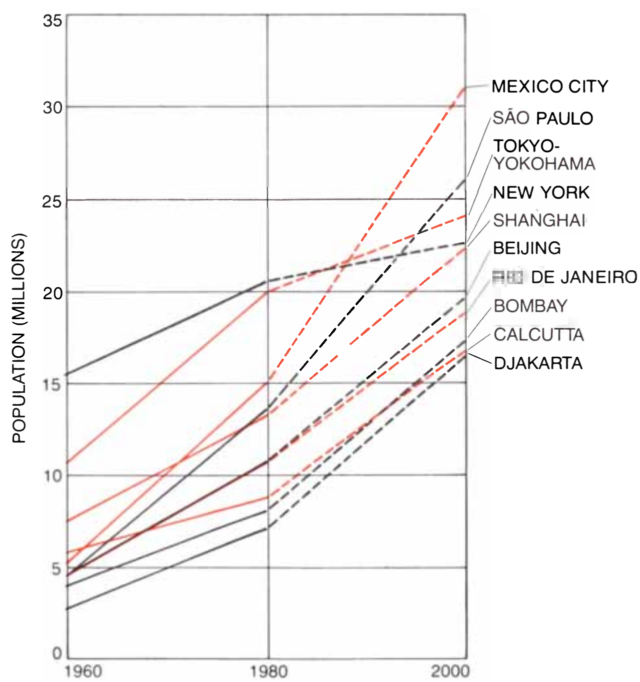
Development is, however, affected by population growth. As the World Population Plan of Action adopted at Bucharest in 1974 put it, "population variables influence development variables and are also influenced by them." Country af-



TREND OF WORLD POPULATION (*black curve*) **from 1800 to the present is shown, with three projections to 2000: the UN's high, medium and low variants (*broken black lines*), which differ primarily in their assumptions as to future fertility. The average annual growth rate (*colored curve*) peaked between 1960 and 1965 and is likely to keep declining, according to medium variant (*broken colored line*).**



LESS DEVELOPED COUNTRIES (*color*) **will continue to grow faster than the more developed ones (*black*); in 2000 they will account for 79.5 percent of the world population, according to the medium UN projection. The broken lines show the high and the low variants.**

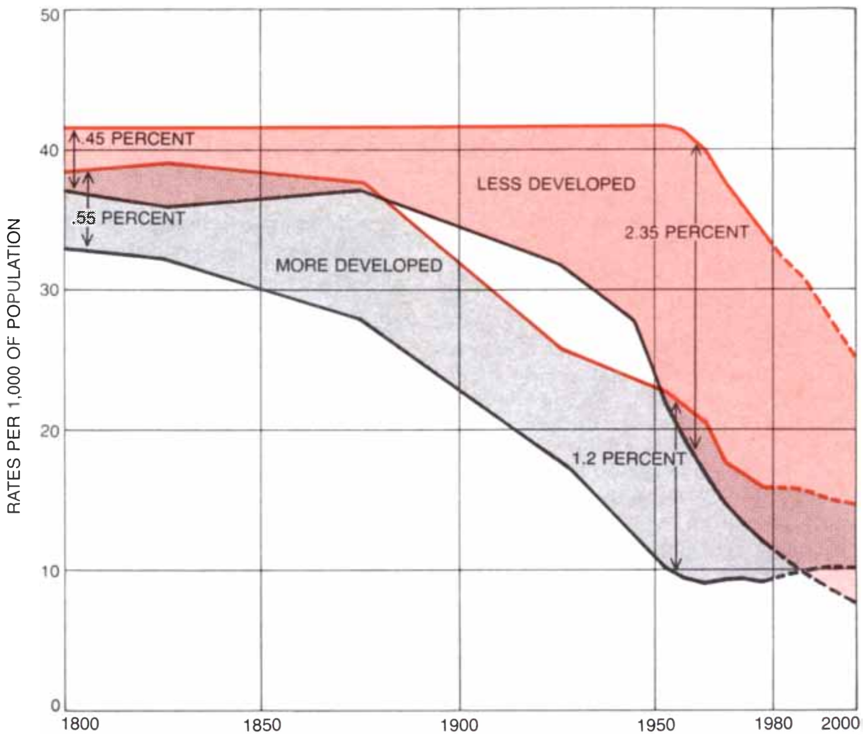


MOVE TO CITIES will swell urban agglomerations in the less developed countries. Of the 10 largest metropolitan areas in 2000, eight will be in underdeveloped countries, where the urban fraction of the population will increase from the present 29 percent to 41 percent.

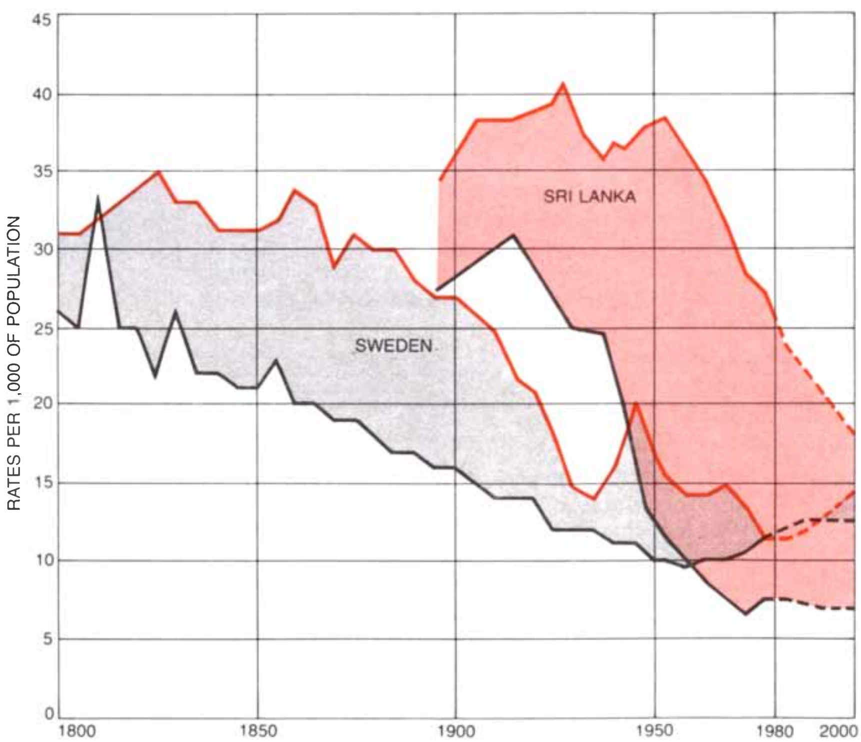
ter country has seen painfully achieved increases in total output, food production, health and educational facilities and employment opportunities reduced or nullified by excessive population growth. Most underdeveloped countries therefore seek to limit their population growth: a UN survey in 1976 showed that 54 countries accounting for 82 percent of the developing world's population considered their fertility levels too high. Recently there have been signs of some success in lowering those levels. After increasing exponentially for some years, the world's population-growth rate seems to have peaked at about 2 percent per year between 1960 and 1965. The growth rate is now about 1.7 percent, and a UN projection suggests that current trends will bring it to less than 1.6 percent by the year 2000. The continuing World Fertility Survey indicates that in many underdeveloped countries women's expressed desire to have fewer children is now being reflected in lowered fertility. China, with more than a fifth of the world's population, is engaged in a massive fertility-control campaign that has sharply lowered its birth rate in less than 10 years.

Yet the rate of population growth in the less developed countries is still about 2 percent per year; at current rates of increase almost two billion people will be added to the world population by the end of the century, nearly as many as were added between 1950 and 1980. More than 90 percent of the increase will be in the underdeveloped countries, whose population alone in the year 2000 will be nearly twice that of the entire world of 1950; about 80 percent of the world's population will then be living in the underdeveloped countries. Quite aside from mere numbers, rapid growth in developing countries drives poor people from rural areas to cities. In 1980, 16 of the world's 26 cities with more than five million inhabitants were in developing countries; by the end of the century 45 of the world's 60 cities of that size will be in developing countries. People flock from the countryside to urban slums in search of jobs and better services. The best way to curb this trend is to bring economic opportunity and services—including health care—to the rural areas.

The underdeveloped countries cannot shed their excess population to colonies or North America as the industrialized countries of Europe could when they were passing through a comparable demographic phase. And in many cases tradition and lack of services have hampered the ability of women to limit their families even when they wanted to. In response to the very real negative impact of excessive fertility on individuals and individual countries and to the more dramatized fear of a world "population explosion," efforts to spread the message of family planning through the de-



BIRTH AND DEATH RATES (*colored and black curves respectively*) **were both high in 1800 and the rate of natural increase was small (*arrows*) in the developed as well as the underdeveloped countries. The death rate fell gradually in the developed countries; for a time the rate of increase grew, but then the birth rate declined sharply and the rate of increase diminished. In the underdeveloped countries the drop in the death rate, when it came, was steeper and the birth rate lagged more, generating a large natural increase. Less developed countries have yet to reach last stage of demographic transition: low birth rates as well as low death rates.**



DEMOGRAPHIC TRANSITION in Sweden (*gray*) is compared with the much more abrupt transition (*color*) through which Sri Lanka is now progressing. Sweden has reached the stage of "zero population growth" and is expected to stay at about that level through 2000. Sri Lanka's birth rate has yet to decline to a level near that of its sharply decreasing death rate, which is now even lower than Sweden's because Sri Lanka's population is younger than Sweden's.

veloping countries have proliferated in the past 25 years. In some cases well-meaning technocrats made misguided attempts to sell a technological solution to unwilling villagers; sometimes the technology was experimental and not demonstrably safe, and sometimes this extremely sensitive subject was addressed without consideration of local customs and beliefs.

The Bucharest conference recognized formally that "all couples and individuals have the basic right to decide freely and responsibly the number and spacing of their children and to have the information, education and means to do so." The Alma-Ata declaration included family planning as part of the maternal- and child-care component of primary health care. The message of family planning and the means to accomplish it are best delivered not by a central government but by local health workers who have gained the confidence of local people. They should suggest a range of techniques rather than a single government-prescribed method, and the techniques should be safe, effective and socially acceptable. The lesson of recent years is that virtually wherever health-care facilities have been made available, women have demanded information and the necessary materials for spacing their children and limiting their families. Better health motivates family planning. Moreover, the delivery of family-planning services along with health care can provide an entry to the acceptance of other health services, and of development measures in general, in particular by mobilizing women to take increasing control of their own lives.

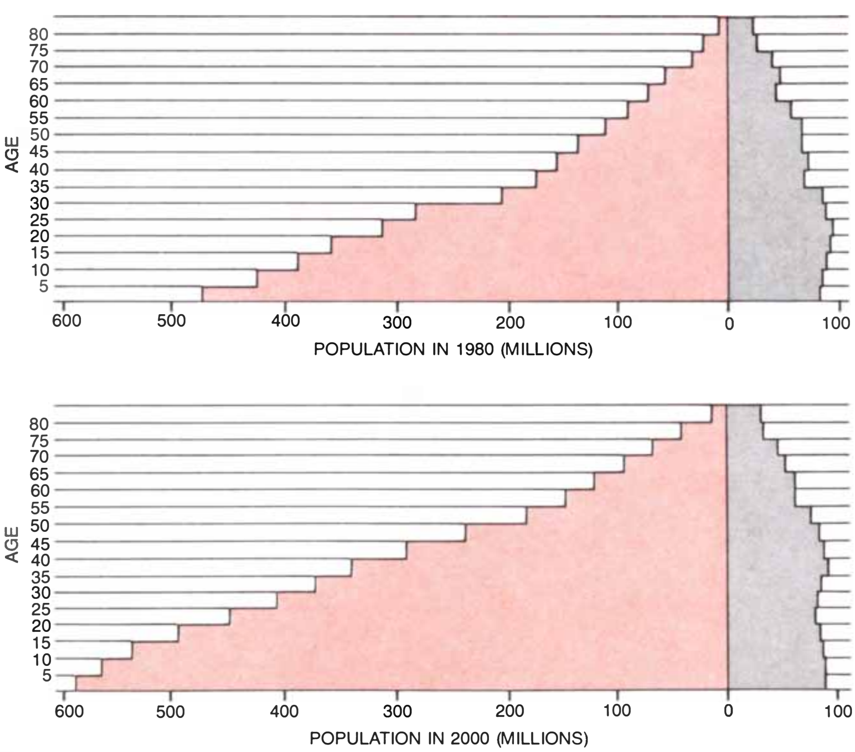
I insisted at the outset that health must be a goal in its own right. It is also a primary lever for development; health is for people, by people—and people are both the subject and the object of development. Health is also primary in a hardheaded political sense because the attainment of health is a relatively unexceptionable goal. The rich countries that can provide the relatively small amount of funds (as well as the skills and scientific knowledge) the poor countries will continue to need in order to promote health must recognize, among other things, that many third-world health projects return large benefits to affluent countries. The eradication of smallpox, to take one example, is saving the affluent countries billions of dollars in vaccination, surveillance and quarantine costs. Smallpox eradication was not the most important health need in the poor countries, in some of which hundreds of thousands of children die of malaria every year. It was undertaken because it was important to worldwide health, and it illustrates the interdependence of all the world's people when it comes to health problems and their solution.

So far I have concentrated on people in developing countries. This does not mean that all is well in developed countries. If most of the ill health in developing countries results from poverty and deprivation, much of it in the developed countries results from abundance and consumerism. The health problems of people in these countries are all too often the consequence of oversmoking, overeating, overdrinking, overdriving, overuse and abuse of drugs, overpollution of the environment and alienation in gigantic urban agglomerations. Moreover, the health systems of the developed countries are too costly. If the costs are not curbed, even the richest countries will not be able to maintain their advanced medical technology and at the same time to provide essential health care for all segments of the population.

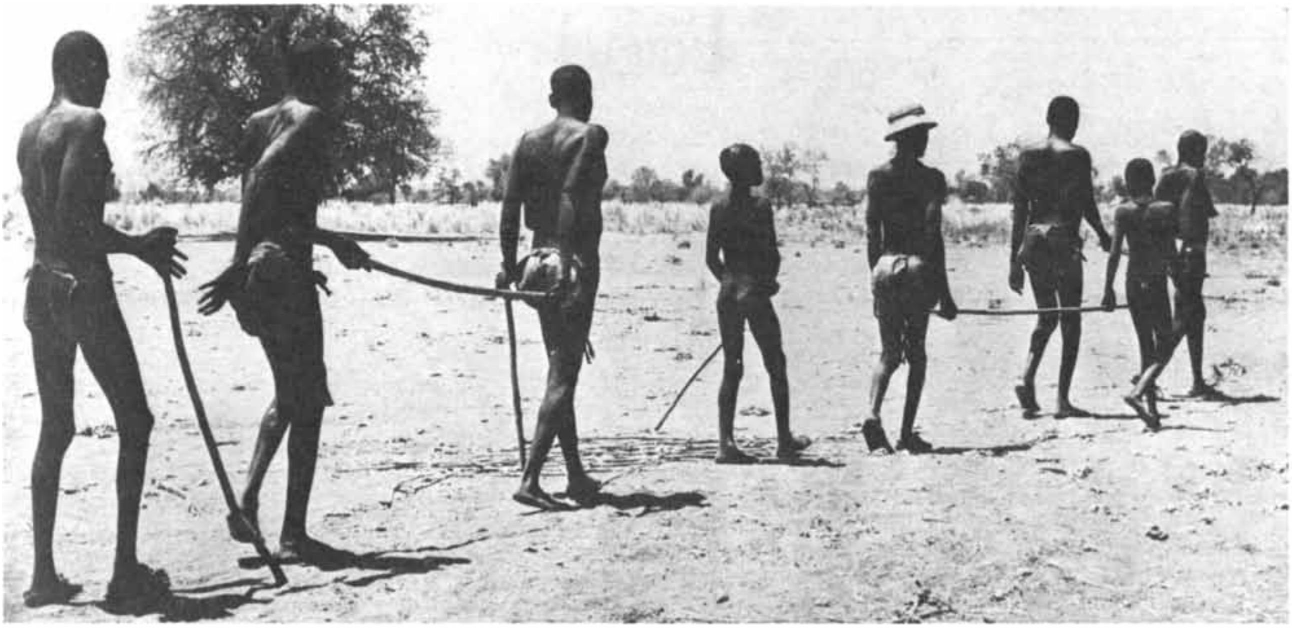
At a recent symposium on health for all in the developed countries the U.S. presented preliminary ideas on its strategy for attaining that goal for its people by the year 2000. The report stated that "behavioral risk factors are today some of the leading causes of unnecessary death and disability in the U.S.... Risks in the physical environment include contamination of air, water and food; workplace hazards; radiation exposure; excessive noise; dangerous consumer products, and unsafe highway design. Risks in the socioeconomic environment which affect health include income level, housing and employment status, family ties and social supports.... People need health education and information to choose healthy lifestyles and to make effective use of available services. Social pressures and many kinds of advertising can support or discourage such choices."

The report continued: "Lack of access to effective services which promote, maintain or restore health is associated with more frequent and more severe illness.... 49 million Americans live in areas officially designated as medically underserved, 22 million in urban areas and 27 million in rural areas; 14.9 percent do not have a regular source of medical care; 20 to 25 million Americans have no health insurance...and 19 million Americans have inadequate health-insurance coverage. An additional 46 million Americans have inadequate insurance against large medical bills. Almost half of all individuals with incomes below the Federal poverty level are not covered by Medicaid."

The U.S. health-for-all strategy includes measures to prevent disease and promote health, including immunizations for all children and programs to deter smoking and prevent alcoholism. The strategy also aims at ensuring access to services for all Americans by eliminating current barriers. Health re-



SIZE AND AGE STRUCTURE of the population of the underdeveloped regions (*color*) and of the developed regions (*gray*) of the world are depicted as of 1980 (*top*) and as projected for 2000 (*bottom*). The shapes of the two sides of the pyramids are characteristic respectively of an expansive population with a high birth rate and high death rate (*left*) and of a nearly stationary population (*right*). Comparison of the 1980 and 2000 shapes shows how the underdeveloped countries' large population now under 15 will move into labor-force years, exacerbating unemployment, and how baby-boom cohorts of developed countries will have aged.



ONCHOCERCIASIS, or "river blindness," is one of the endemic diseases that ravage many regions of the underdeveloped world and could be controlled by aggressive health programs. It is caused by infestation with a worm, *Onchocerca volvulus,* whose larvae travel through the skin and penetrate the eye. The disease is transmitted by the bite of blackflies that breed in running water; in some West African river-valley communities a fifth of the adults may be blind, as are these men being led through a field in Chad. Control of onchocerciasis through medical care and elimination of its insect vector would open to cultivation many large fertile areas that are now abandoned.

search is to be oriented not only toward the discovery of fundamental knowledge but also toward applying that knowledge to clinical practice and developing better ways of organizing and financing health services. Finally, health surveillance is proposed in order to identify gaps in the health system, with a view to responding to them so that those at risk and in need receive priority, in conformity with the equity principle of health for all.

I know of no country that can be complacent about its health situation and health system, just as I know of no country that can be complacent about its human-development level. Human development implies progressive improvements in the quality of life. Without health life has little quality; even if health is not everything, without health the rest is nothing. I am saying nothing new. Some 2,500 years ago Heraclitus recognized that health is fundamental to human well-being and development when he wrote: "When health is absent, wisdom cannot reveal itself, culture cannot become manifest, strength cannot fight, wealth becomes useless and intelligence cannot be applied."

DELIVERY OF HEALTH CARE to widely dispersed rural populations is a major problem in underdeveloped countries. Here a mobile X-ray unit is at work in a remote area of Lesotho in southern Africa in a World Health Organization tuberculosis-control program.

Food

The task of feeding everyone adequately calls for an investment in the agriculture of developing countries of more than $100 billion. Without a fairer distribution of income many will still go hungry

by Nevin S. Scrimshaw and Lance Taylor

Adequate nutrition for all human beings must be one of the major goals of development between now and the year 2000. Its achievement will be difficult and uncertain even if sufficient global production of food is attained. Although technical advances in food production, food conservation and food processing will be needed to ensure food availability, meeting food needs will depend even more on greater social equity and fairer income distribution within the developing countries themselves. External assistance can be of some help, but the outcome in each country will be determined by the effectiveness of measures undertaken by its government. With heightened awareness of food issues around the world and of both the potential and the limitations of the introduction of new high-yield crop-plant varieties (the "green revolution") 1980 is a good time to attempt an assessment of the prospects for providing all human beings with their nutritional needs by the end of the century.

One way to begin the assessment is to look at the recent past. In the 15-year period between 1961 and 1976 food production in 94 countries classified as developing market economies by the United Nations Food and Agricultural Organization (FAO) expanded at the rate of 2.6 percent per year, barely keeping abreast of overall population growth and failing to attain levels capable of meeting increases in demand due to rising incomes. In 1975, according to the conservative FAO estimate, more than 23 percent of the people in 86 countries with a total population of 1.9 billion were undernourished. On the brighter side, food production expanded faster than population in 24 developing countries. Against an annual population growth rate of 3 percent these countries raised their production of staple foods by 3.9 percent per year. In India, which accounts for nearly a third of the total population in the 94-country FAO sample, yearly average gains in food production (2.6 percent) slightly exceeded population growth (2.4 percent) over the 15-year period. The experience of China, which is not included in the FAO sample, is uncertain, but the evidence is that it is close to being self-sufficient in food production, exporting some crops in most years while importing other crops to meet local needs.

Collecting food statistics and judging nutritional adequacy for scores of diverse populations is understandably difficult. Planners begin by collecting information about patterns of food production and consumption, country by country. The FAO compiles such information for the 90-odd countries classified as developing and for the 30-odd countries regarded as developed. One presentation of such information is the food balance sheet, an accounting of the different types of food available for human consumption. Most of the developing countries have a diet consisting mainly of a single staple plus a small number of other foods. For example, in Afghanistan and Pakistan the staple is wheat, and in Mexico and Central America it is maize. In the region of the world with the largest populations, China and southeastern Asia, the staple is of course rice.

A food balance sheet is computed by adding food imports to domestic food production and subtracting exports, estimated losses, seed and animal feed. The remainder is the food available for consumption. Although such an accounting helps to give a broad picture of the food system, its estimates are clearly subject to large errors. Moreover, a food balance sheet provides no information on how the available food is distributed among socioeconomic groups, among families or within families.

A more desirable starting point would be data on actual food consumption. Even when such data are available, however, they are usually reported only for an entire household because of the difficulty and cost of ascertaining what each member consumes. Family-consumption studies nonetheless demonstrate the extent to which food consumed by a household varies with income. The source of supply can be either the market or foodstuffs produced at home, but in either case the consumption of protein and the total calories increase with family income. Diet patterns also change with income. Up to a certain income level, roughly from $250 to $300 per person per year (in 1980 U.S. dollars), the calorie intake from the local staple-food energy source tends to increase. At higher income levels calories from fats, sugars, fruits, vegetables and animal products play an increasing role. Careful studies in selected regions, for example Brazil, show that both the amount and the nutritional quality of protein rise directly with income.

The implication of such observations is that the monotonous, cereal-based diet of the poor in developing countries is a matter of economic necessity rather than choice. A poverty-level family in a stable social environment may be undernourished simply because it cannot afford a better diet. Disruption of the

INTENSIVE CULTIVATION typical of farm areas in the highly productive northern Great Plains states of the U.S. is represented by the enhanced false-color Landsat image on the opposite page, which covers an area of approximately 7,500 square miles in the corn belt of northern Iowa and southern Minnesota. The rectangular strip-field pattern of agriculture characteristic of the region is aligned precisely along north-south, east-west axes. The path of the satellite, and hence the orientation of the image, is slightly askew (by about 13 degrees of arc). The border between Iowa and Minnesota runs diagonally (due east-west) across the upper half of the page. The principal crop grown in the region is corn, with a small admixture of soybeans and other crops. The image was acquired in October after most of the fields had already been harvested. The darkest fields have also been tilled, exposing the rich black soil for which the area is noted. The lightest fields have been harvested but not yet tilled; cornstalks and other trash account for their high reflectivity. The yellowish fields have standing ripe crops (mainly corn) that have not yet been harvested. The reddish fields have alfalfa and other forage crops. The irregular red shapes result from vegetation along streams and in other uncultivated spaces.

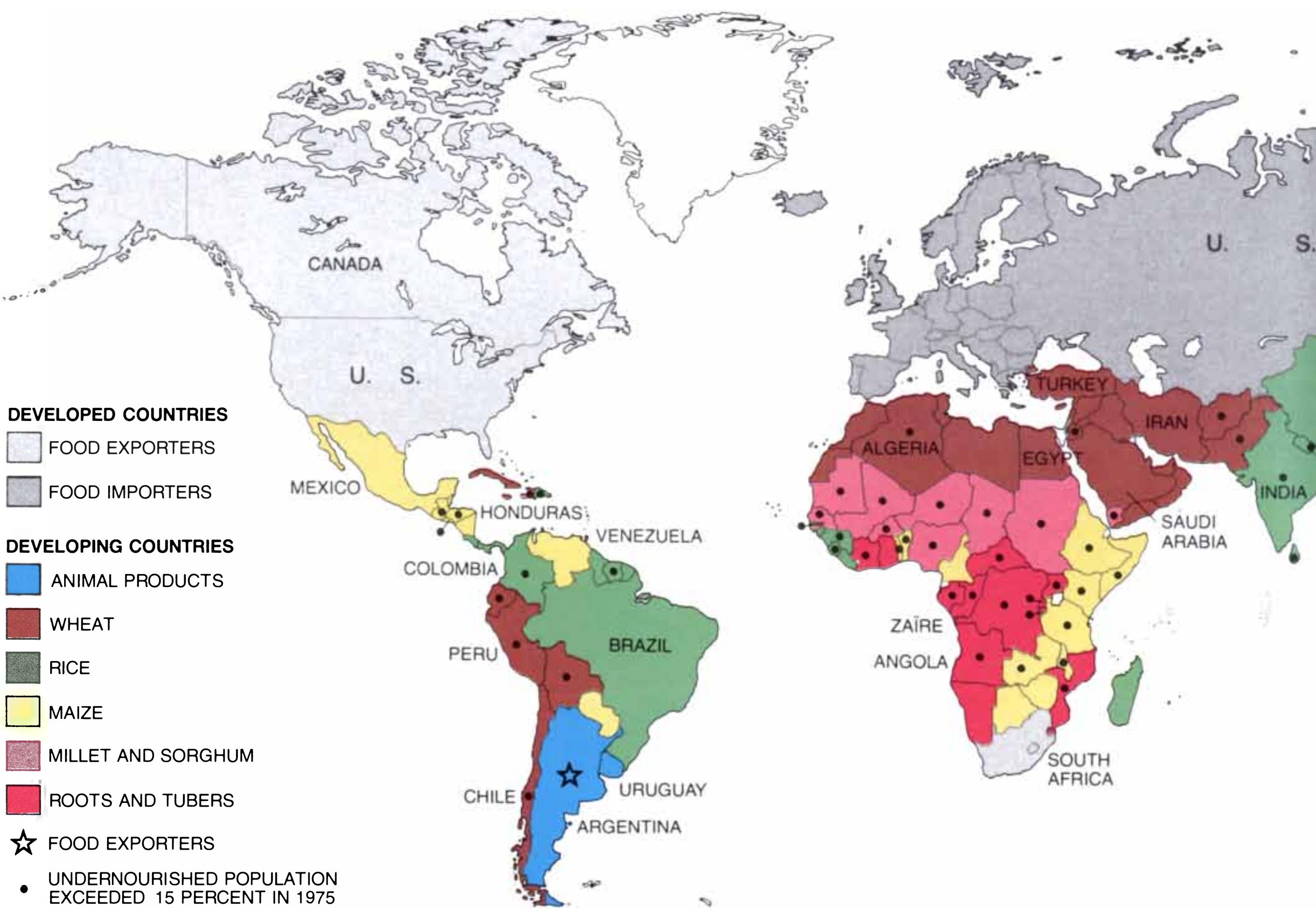
environment by war, migration or social pathology can only intensify the malnutrition of a poor family. Such disruptions aside, malnutrition is a clear sign that a family cannot get enough food through the usual channels of production, purchase, barter or welfare distribution.

Working with the relation between food consumption and income, several recent studies have tried to estimate the number of undernourished people in the world. One procedure is to present the observed distribution of household income in a country in a Lorenz curve [*see illustration at left at top of page 84*]. The horizontal axis shows percents of the population ordered by their level of household income: the bottom 20 percent, the bottom 40 percent and so on. The vertical axis gives the percent of income that each population share receives. A typical Lorenz curve may show, for example, that the poorest 20 percent of the households receive 5 percent of the income, the bottom 40 percent receive 15 percent and so on. The Lorenz curve connects the points relating population and income shares.

Information about a country's income distribution, as summarized in a Lorenz curve, can be combined with food-supply data from a food balance sheet and the observed relation between household income and food consumption to estimate the distribution of food consumption by household. The fraction of households with predicted levels of calorie consumption per household member that fall below a certain cutoff point can be considered undernourished. The FAO estimates that even with the cutoff set at the low value of 1,600 calories per day (only 20 percent above the basal metabolic rate) more than 436 million people, or 23 percent of the population, are undernourished in a sample of 86 poor countries.

A working group at the new United Nations University in Tokyo has recently emphasized that the FAO criterion provides for only minimal physical activity. The stringency of the FAO calorie standard can be judged from the observation of Fernando Viteri of the Institute of Nutrition of Central America and Panama that when male agricultural laborers are offered food freely, they can consume 3,555 calories per day without gaining weight. A World Bank estimate based on assumptions less stringent than the FAO's indicates that 1.1 billion people, or more than a fourth of the world's population, are undernourished.

The countries with populations most subject to undernourishment are those where the staple foods are either millet and sorghum or roots and tubers. In the FAO survey of food supplies in 1975 more than 15 percent of the population was undernourished in nine of the 10 countries in which millet and sorghum are the chief energy source and in 10 of



WORLD FOOD RESOURCES AND DIET PATTERNS are depicted for the developed countries and for the developing countries followed by the United Nations Food and Agricultural Organization (FAO). Populations in the developed countries (roughly defined as those with annual per capita incomes greater than $300 in 1979 U.S. dollars) have for the most part an adequate and varied diet. Only four countries in the world are major exporters of cereals: the U.S., Canada, Australia and Argentina. Virtually all the rest, with minor exceptions such as Thailand, are net importers. The color key shows the predominant source of food calories in 90 developing countries according to the most recent FAO classification. China and Mongolia, not included in the FAO list, are classified among the rice countries. A number of smaller countries, also omitted by the FAO, are assigned a diet similar to that of their neighbors. Black dots identify 52 developing countries where more than 15 percent of the population was undernourished by FAO standards in 1975. (The FAO defines a diet containing fewer than 1,600 calories per day as inadequate; a typical "first world" diet averages about 3,100 calories per day.) The "third

the 11 countries in which roots and tubers are the chief source [*see illustration below*]. Millet and sorghum, although hardy crops, are looked down on by the more affluent consumers, who consider them to be poor people's foods. They were included to some extent in the plant-breeding studies that made possible the green revolution, but in most parts of the world they have not shown major increases in yield, largely because increased supplies of fertilizer and irrigation water have not been provided to make the most of improved seed. Without irrigation even millet and sorghum do poorly in a severe drought. The famine of the 1970's and the continuing precarious food situation in the belt of countries south of the Sahara result to a large extent from the combination of marginal rainfall and the region's dependence on millet as its staple crop.

Even in countries with a fairly adequate overall food supply undernourishment persists because of gross inequality in income distribution and the lack of welfare programs for the poor. This is most striking in relatively prosperous Latin-American countries such as Chile, where wheat is the staple and more than 15 percent of the population remains undernourished in spite of successful agronomic efforts. Similarly, maldistribution of available food is evident in countries such as El Salvador, Guatemala and Honduras, where the diet is based on maize.

world" countries where wheat (*brown*) and rice (*green*) are the principal crops have been the most successful in meeting food demand. In 11 of the 17 countries where maize (*yellow*) is the chief crop more than 15 percent of the population was undernourished in 1975. In populations that subsist on millet and sorghum (*pink*) or roots and tubers (*red*) some degree of malnutrition is virtually universal.

Although a country's staple food is its primary source of carbohydrate, it must also serve as the principal source of protein for much of the poor population. The degree to which this source of low-quality protein is supplemented by more valuable, or at least complementary, sources of protein depends on income. Total protein consumption rises with income in parallel with calorie consumption. The nutritional inequality among income groups is thus intensified by differences in the composition of the protein consumed. The diet of poor people is lower not only in total protein but also in the proportion of total protein from animal sources and legumes. As a result the differences in the fraction of protein that can actually be utilized are even more marked than the differences in total calories. Whereas only 30 to 40 percent of the inadequate protein calories can be utilized in the diet of the poor, 50 to 60 percent of the more abundant protein calories can be utilized in the diet of the most affluent fraction of the population [*see illustration at right at top of page 84*].

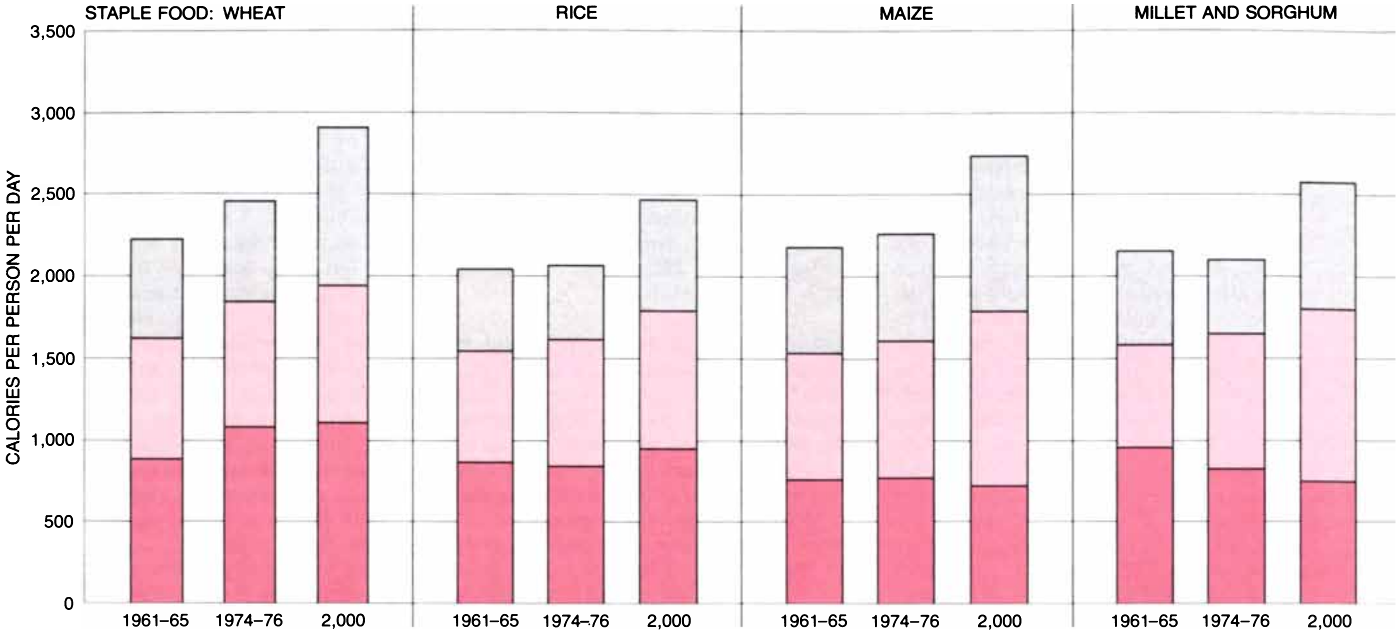
Within the family itself dietary deficiencies can arise for a variety of reasons. Preschool children are particularly at risk between the time when breast milk is no longer adequate as the sole source of food and the time when the children fully share the family diet. In developing countries this critical period is most commonly between the ages of four to six months and 18 to 24 months. In this period between 15 and 25 percent of the children suffer malnutrition and retardation of growth to the degree that their weight is between 25 and 40 percent less than that of well-nourished children. The percentages vary so much from country to country that overall estimates are difficult, but judging by retardation in weight for age the World Health Organization conservatively estimates that more than 500 million children in each age cohort suffer second-degree malnutrition or worse. If one were to choose weight-for-age criteria closer to normal values than those adopted by the WHO, one could reach numbers considerably higher than 500 million. Evidence is accumulating from many studies that there is a correlation between impaired physical growth and development and increased susceptibility to infection. The impairment is also found to alter performance on some tests of learning and behavior, with the prospect of diminished adult capacity.

The malnutrition of infants and preschool children will not necessarily be eased by increases in overall food supply or even by a higher average level of family food consumption. Educational and public-health measures can sometimes improve the lot of the preschool child, but there are limits here as well, depending strongly on the cultural environment of the family. For example, in some cultures the unconscious withholding of care from certain children can be interpreted as a socially sanctioned form of population control.

The burden of such observations is that any substantial reduction in undernutrition will depend on policies aimed not only at increasing the supply of food but also at its equitable distribution in meeting human needs. The task will require raising both the relative income and the social status of those now most impoverished. Increased income is likely to be most effective in a market-oriented economy, where food production will respond to an increase in demand. Nevertheless, a discussion of ways to remedy undernutrition can be given more focus by first considering the role of farmers as the ultimate suppliers of the world's food.

Running a manufacturing plant involves many complex decisions, but running a farm is hardly less complex and includes uncertainties of nature that the manufacturer is spared. In order to gain a better understanding of the decisions a small farmer faces in a poor developing country the week-by-week activities of a single farmer and his family in Yojoa, a small Honduran village, were carefully recorded for a year. On six hectares (15 acres) of land the farmer raises maize, rice and beans, along with chickens. With cash from the sale of his produce and the services of his oxen and oxcart the farmer buys seed, fertilizer, occasional labor, household necessities and clothes for his family. The inputs and outputs to this miniature "agribusiness" make an intricate web [*see illustration on pages 86 and 87*]. What cannot be shown on such a chart is the careful timing required to keep everything running smoothly and on schedule.

A small farmer with five hectares in the Punjab area of Pakistan faces a quite different but no simpler set of problems. Timing is again crucial: he can get two crops per year by adroit crop selection and land allocation. After his principal food crop, wheat, is harvested in May, he can plant rice and maize in June and July and harvest both before wheat must be planted again in November. Elsewhere on his small farm he is simultaneously growing beans, cotton (in sequence with a late oilseed crop such as rape or mustard), sugarcane and fodder



TRENDS IN DIET PATTERNS between the early 1960's and the mid-1970's, with a projection for the year 2000, have been charted for 88 developing countries by the FAO. Countries where the staple food is wheat have shown the strongest gains and promise to do best overall by the year 2000. The rice countries, which include those with the largest populations, made no gain in calories per capita in the dozen years separating the first two bars but are expected to show a significant improvement by 2000. (As in other FAO studies, China is not included.) Although maize production per capita appears to have stabilized, the populations in maize-growing countries have been adding calories from other foods, a trend that should continue. Supplemental foods will also be essential if diet is to improve in countries

for draft animals [*see illustration on page 88*]. How much land area to devote to each is a difficult decision, depending partly on relative prices and also on practical constraints such as the possible crop rotations, the need to have enough fodder for the animals and to have enough mechanical energy or manpower on hand to harvest one crop when it is time to plant another.

For the farmer and his family a good harvest is close to being a life-and-death matter. He has strong incentives for avoiding risk. As students of peasant agriculture have long emphasized, the traditional resistance to change in the countryside is based on this fact. Time-tested agricultural techniques have pulled peasant communities through good times and bad, and farmers have no guarantee that any new technology will do as well.

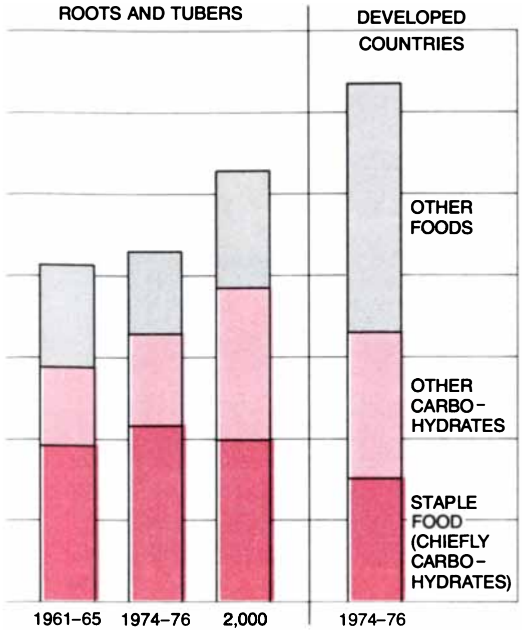
Moreover, risk-sharing institutions in agriculture often help to maintain an inegalitarian economic status quo. Cases in point are the usual forms of sharecropping and the high interest rates the poor are charged by the village moneylender. Such social inventions minimize risk at the expense of perpetuating the unequal distribution of both income and food. In effect the precarious social position of rural poor people forces them to accept low average food consumption year after year in return for social guarantees that in a bad year they will not be allowed to starve by the moneylender, the landlord, the government authority or other beneficiaries of the system's economic surplus. When agriculture is a component of a market-directed economy, the traditional risks of a food shortage in a region are complicated by fluctuating prices for nonfarm commodities. Landless laborers and other poor people tend to be victimized as their pay for labor lags behind rising prices in times of inflation, whereas the holders of surpluses in the system often find ways to cushion themselves against inflationary shocks. A well-known means of such cushioning is preferential access to official credit.

The experience of most poor farmers scarcely prepares them for turning to their own advantage the growing variety of technical innovations and the institutional improvements offered by the government and other agencies. A measure of the importance of such innovations and improvements to the poor farmer is provided by Pakistan, where the reliable provision of water for irrigation and of inexpensive power sources for threshing and other operations has in recent years led to large gains in agricultural output. Also central to the green revolution, along with higher-yielding seed, have been cheaper and more reliable sources of chemical fertilizers and pesticides and modern knowledge of multiple-cropping practice.

The consequences of such developments must be evaluated in both social and economic terms. Will the large absolute profits derived from exploiting new technology induce large landowners to mechanize and throw their traditional tenant farmers off the land? The immediate beneficiaries of the new technology must make fateful decisions. The way they use their new surpluses may further depress nutritional levels in a region at the same time that total food production is going up.

Against this background of microeconomic considerations let us now assess the potential for increased agricultural output on a large scale. Land, water and fertilizer are the major agricultural inputs, along with energy, which is a significant component in all three and essential for mechanization. Although the dramatic increase in energy costs in the past seven years has certainly been burdensome for agriculture in the developing countries, it has not had the crippling impact that might have been expected. The explanation, briefly, is that as long as crop prices remained strong the cost of additional fertilizer was amply repaid.

Could there be, on a worldwide basis, a shortage of land suitable for agriculture before the year 2000? It seems unlikely. There is room to exploit both the "intensive margin" of increasing yields and the "extensive margin" of irrigation and bringing larger areas under the plow. Since the mid-1960's a number of estimates have been made of the total amount of arable land available around the world. Roger Revelle of Harvard University, who has summarized the estimates, calculated in 1974 that the total world area available for cropping (counting more than once those areas where multiple crops are grown) is about 4.1 billion hectares. Less than half



where the staples are millet and sorghum or roots and tubers. The last bar shows the typical diet pattern in developed countries. In such countries roughly half of the daily calories are supplied by separated fats and oils, animal products, sugar, fruits and vegetables.

of this area is now cropped in any given year, so that there is substantial room for agricultural expansion, provided capital is available for land reclamation and irrigation.

Indeed, the situation may be better than it seemed only a few years ago. A new collection of soil maps prepared by the United Nations Educational, Scientific and Cultural Organization was recently given a fresh analysis by a group at the Wageningen Agricultural University in the Netherlands. The Wageningen group has found that only about three-fourths of the cultivable land in southeastern Asia is now in use; in earlier estimates the fraction had been as high as 93 percent. The areas of potentially cultivable land in Africa and South America are far larger, more than 600 million hectares in all. Argentina alone has roughly the same amount of cultivable land as India and has a population only 4 percent as large as India's. Brazil, which now farms 47 million hectares, has another 50 million hectares of savanna that is considered suitable for soybeans and wheat (if the aluminum-rich soils are properly treated), and this is without touching the ecologically fragile Amazon rain forest.

Working with FAO data, Alan Strout of the Massachusetts Institute of Technology recently estimated that bringing a hectare of new land under cultivation will produce .9 metric ton of cereal grain, a year's supply of food for about five people at the FAO minimum nutritional standard of 1,600 calories per day. If the land is well irrigated, the total production increases about fourfold to 3.5 metric tons. Revelle has estimated that land available for crops through future irrigation is 1.1 billion hectares, or enough to feed more than 10 billion people at twice the FAO levels.

The greatest potential increase in food production lies, however, in the more intensive cultivation of the somewhat less than two billion hectares currently devoted to crops. As against the 3.5 metric tons of cereals that can be expected from a well-irrigated hectare, Strout estimates that the same hectare can yield between nine and 13 tons of crops if it is supplied with a ton of nutrient content in fertilizer (nitrogen, phosphate and potash). Remarkably, there do not seem to be any diminishing returns to the application of fertilizer across a range from 20 kilograms (.02 metric ton) per hectare in India to more than 500 kilograms per hectare in Belgium and the Netherlands. To be sure, chemical fertilizer requires costly oil or natural gas for its production, but the amounts required are less than 1 percent of the current level of world petroleum use. The potential crop increase from the application of chemical fertilizer is of course in addition to what might be achieved with organic fertilizer or the recycling of organic wastes.

The benefits to be expected from the increased application of fertilizer, compared with the benefits from irrigation or bringing in additional land, can be seen in a study by Strout of the contribution made by these inputs and others to total crop production in a 90-country FAO sample between the early 1960's and the mid-1970's [*see top illustration on page 85*]. The contribution of new cropped land has declined since the early 1960's as the share attributable to irrigation has held steady and the share attributable to fertilizer has gone up. Fertilizer was responsible for 40 percent of the increase in crop output realized between the early 1960's and the mid-1970's. In the same period the application of fertilizer in developing countries increased about fourfold, or at a rate of nearly 10 percent per year. Although there were worldwide shortages of fertilizer and rapidly rising prices for it in the mid-1970's, the annual increase since 1975 has actually exceeded 10 percent. Extrapolation of such growth rates in conjunction with Strout's yield estimates suggests that there could be crop surpluses in parts of the "third world" by the mid- or late 1980's.

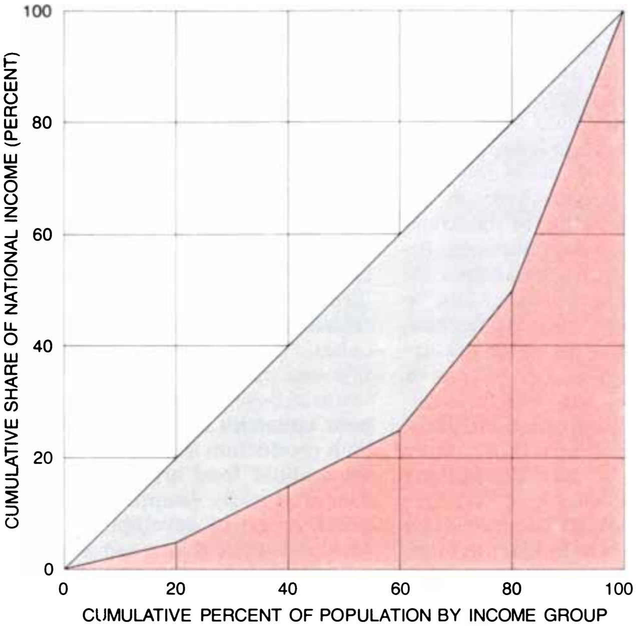
How widely the various means of increasing food production will be applied nationally and globally over the next two decades depends on countless decisions to be made by millions of farmers large and small, by their suppliers and by the people for whom they produce or to whom they sell. Obviously many of the decisions can and will be influenced by policies adopted by governments, by international agencies and research organizations and by the corporations that are playing an ever larger role in the production and distribution of agricultural raw materials and food.

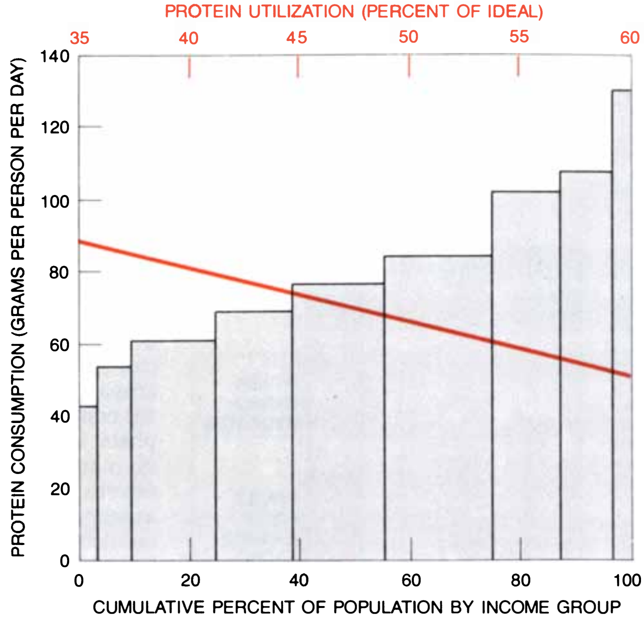
One of the major uncertainties is price policy. Food and agricultural decisions are by their very nature highly decentralized. The only way most consumers and producers can communicate is through the market or an equivalent bureaucracy. The mutual isolation of economic agents—producers on the one side and purchasers on the other—gets worse as development proceeds. Even in poor countries farm households where both production and consumption decisions about food are made under one roof are rapidly disappearing. As an inevitable part of development, decision making is guided increasingly either by government directives or by price signals from the market. In market economies the key question is how to make the best of a situation where a price change not only elicits an economic response but also can alter real income and the distribution of economic power.

An entire school of agricultural economists has followed the lead of Theodore W. Schultz of the University of Chicago in asserting that most farmers in developing countries are "poor but efficient." That is, they respond to price incentives and maximize profits within the limits of the available technology. One corollary of this view is that if the prices are manipulated by the government, they can easily be "wrong" and lead to a faulty allocation of resources. Examples are easy to cite. In Egypt the government controls the procurement prices of cotton and wheat but not the consumer price of meat. As a result crops have shifted from cotton and wheat toward clover, which is used in part to fatten animals for relatively well-to-do consumers in the towns. To take another case, the application of fertilizer responds almost everywhere to the ratio of fertilizer cost to the farm-gate price of the final crop; if the ratio goes up by 10 percent, fertilizer application per hectare drops by a percent or so.

Such observations suggest that price policy is a powerful tool and one that governments cannot afford to wield carelessly. It is now recognized that there were harmful "second generation" effects in the policy of setting high crop prices to hasten the green revolution. One effect was an increase in the displacement of farm labor by machines. Moreover, high government-supported prices and technically induced profit increases for grain production led to a drop in legume production. With legumes scarce and more expensive the already marginal diet of low-income groups declined further.

Farm price policies obviously have



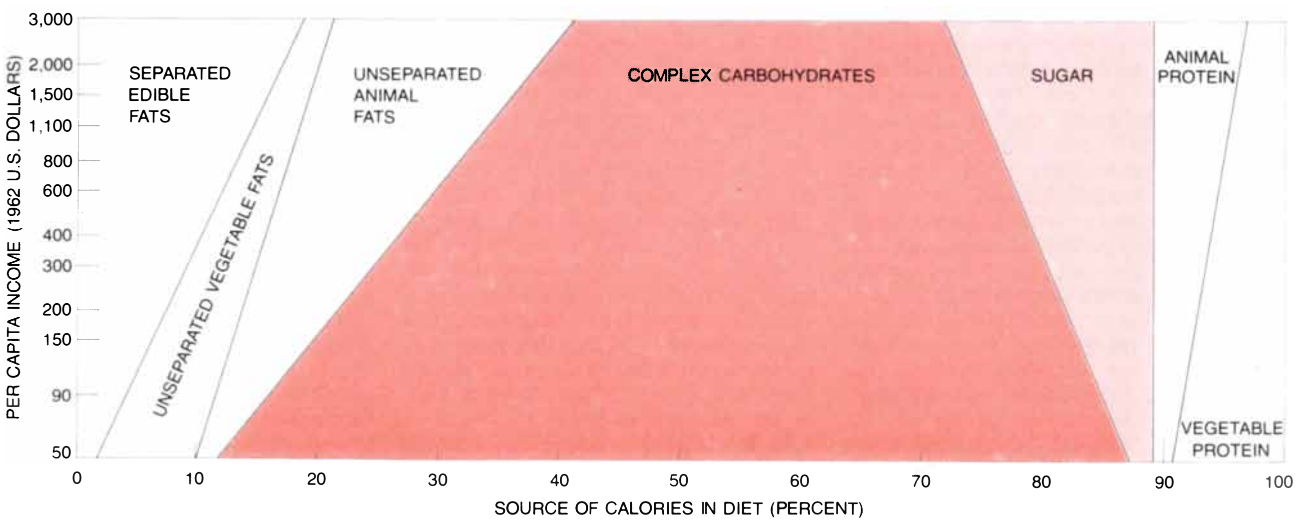


DISTRIBUTION OF HOUSEHOLD INCOME in a country can be summarized in the form of a Lorenz curve. Percentiles of the population, ordered by income level, are shown along the horizontal axis; percentage shares of the national income are represented on the vertical axis. In this Lorenz curve, which is typical of a fairly prosperous country, the poorest 20 percent of the population gets 5 percent of the income, the bottom 60 percent gets 25 percent and the bottom 80 percent gets 50 percent. A widely used measure of income inequality is the Gini coefficient, which is calculated as the ratio of the area (*gray*) lying between the diagonal line and the Lorenz curve to the area of the lower triangle. Here the ratio between the two areas is .4. The larger the ratio, the less equitable the distribution of income.

PROTEIN CONSUMPTION BY INCOME GROUP is a valuable index of the adequacy of a country's nutrition. A general finding is that total intake of calories and total intake of protein both increase with income. Unfortunately not only do poor people consume less protein than the more affluent but also their protein is low in quality, being deficient in legumes and particularly in animal products. The data for protein consumption by income group plotted here are based on the diets of 9,125 families in various parts of Brazil. The slanting line shows how much protein of the type actually consumed by families of different income levels would be needed to meet the FAO "safe level." One can see that the diets of the poor are even less adequate than would appear from total protein consumption alone.

long-term effects as well. The capital investment required for irrigation, land clearing and leveling, drainage and technical innovation in agriculture is substantial. In the recent FAO study *Agriculture: Toward 2000* it is estimated that the total agricultural investment in the 90 developing countries on the FAO list will be $52 billion by 1980, $78 billion by 1990 and $107 billion by 2000. Much of the investment will come from within the economies of those countries, but the above amounts include an increase in the share of foreign exchange devoted to agricultural investment from 16 percent in 1980 to 29 percent by 2000. These are huge sums compared with the few billions of dollars currently channeled to poor countries each year for agricultural purposes by the World Bank, the International Fund for Agricultural Development and similar institutions.

The implication is that the savings



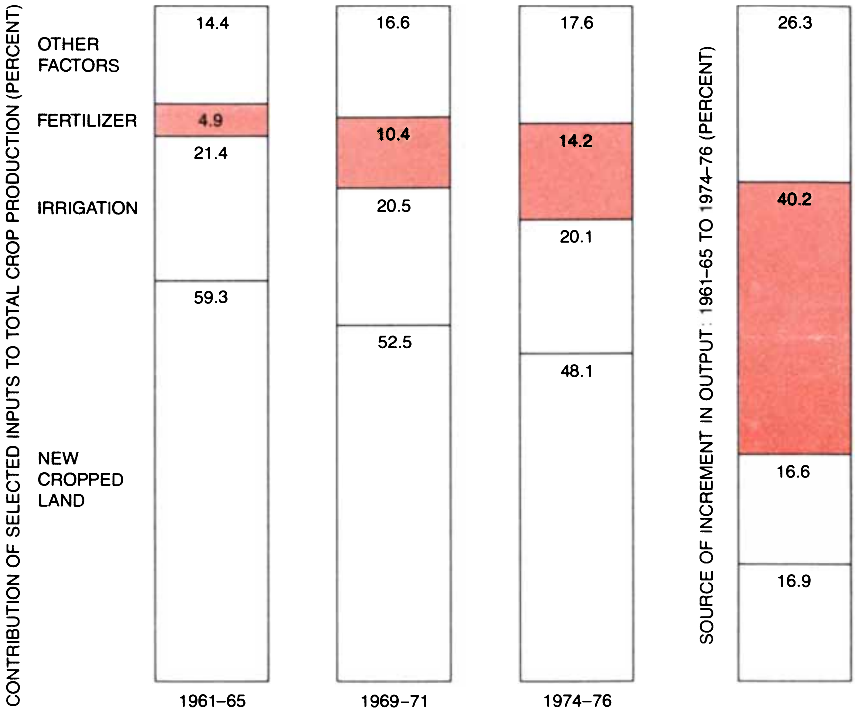
VARIATION OF DIET WITH INCOME exhibits a pattern that is remarkably consistent worldwide. At the lowest income level most calories in the diet are supplied by the country's main food group, usually a cereal, which contains small amounts of vegetable fats and proteins in addition to carbohydrates. With rising income calories from the main food group are supplanted by separated edible fats, by unseparated animal fats and proteins and by sugars. The diagram is based on the food balance sheets of 85 countries for 1960–62, which were analyzed by J. Perisse, F. Sizaret and P. François of the FAO. Not shown is that total calorie intake also rises sharply with income.

counterpart of this investment will have to be generated within the poor countries themselves. As Arthur Lewis of Princeton University has emphasized, in a capitalist system savings are generated by shifting the real-income distribution toward high savers, that is, the most prosperous groups in the society. Such a distributional change can be effected by raising food prices, which reduces the real income of the low-saving poor because food already absorbs much of the family budget. Unless remedial steps are taken one could well have the paradox that price changes designed to raise food output will harm precisely the poor families, particularly in the towns, who need the food most; the food will be priced beyond their reach.

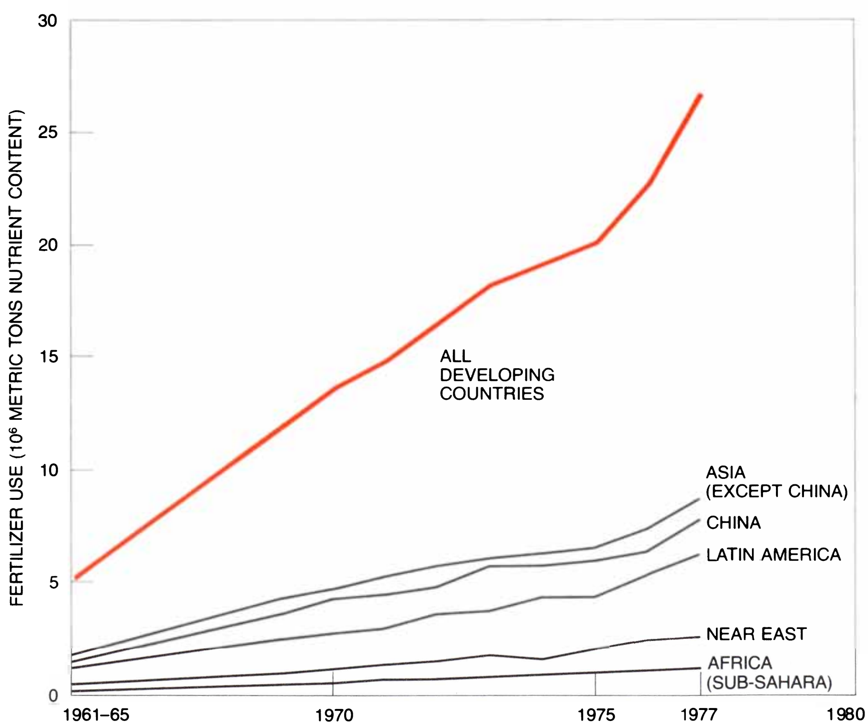
Experience in Sri Lanka, in the state of Kerala in India and in a few other places suggests that both producer incentives and consumer real incomes can be protected by a well-designed system of consumption subsidies for staple foods, as is also done in the U.S. and other developed countries. Many more schemes of this kind may become necessary if rapid agricultural growth is pursued in largely market-oriented economies. The World Food Council, one of the new UN organs created in response to the food crises of the 1970's, is now trying to encourage aid donors to support such programs.

At least as important as price policy in guiding and raising farm output is technology policy. What innovations should the government encourage? What kinds of agricultural research should it undertake? Almost superhuman judgment seems to be called for in the area of food, because it is just here that many promising initiatives have had unforeseen and unfavorable second-generation consequences, have not taken hold as widely as predicted, have failed disastrously or have simply been irrelevant. The technologies themselves may not have been at fault, but the policy environment in which they were applied did not always benefit the poorest groups. Still, without the technological advances the overall food situation could certainly have been much worse.

The widespread introduction into developing countries of Western concepts for rearing infants is a different but nonetheless instructive kind of example. The substitution of cow's milk or commercial infant-feeding formulas for breast-feeding by poor mothers living under adverse conditions has often been harmful for infants. The formula is often overdiluted because the mother is trying to eke out the costly supply of it, and it may be contaminated by dirty water and unsanitary preparation. Beyond that the infant is deprived of the factors in breast milk that can protect it from the ubiquitous pathogens in poor environments.



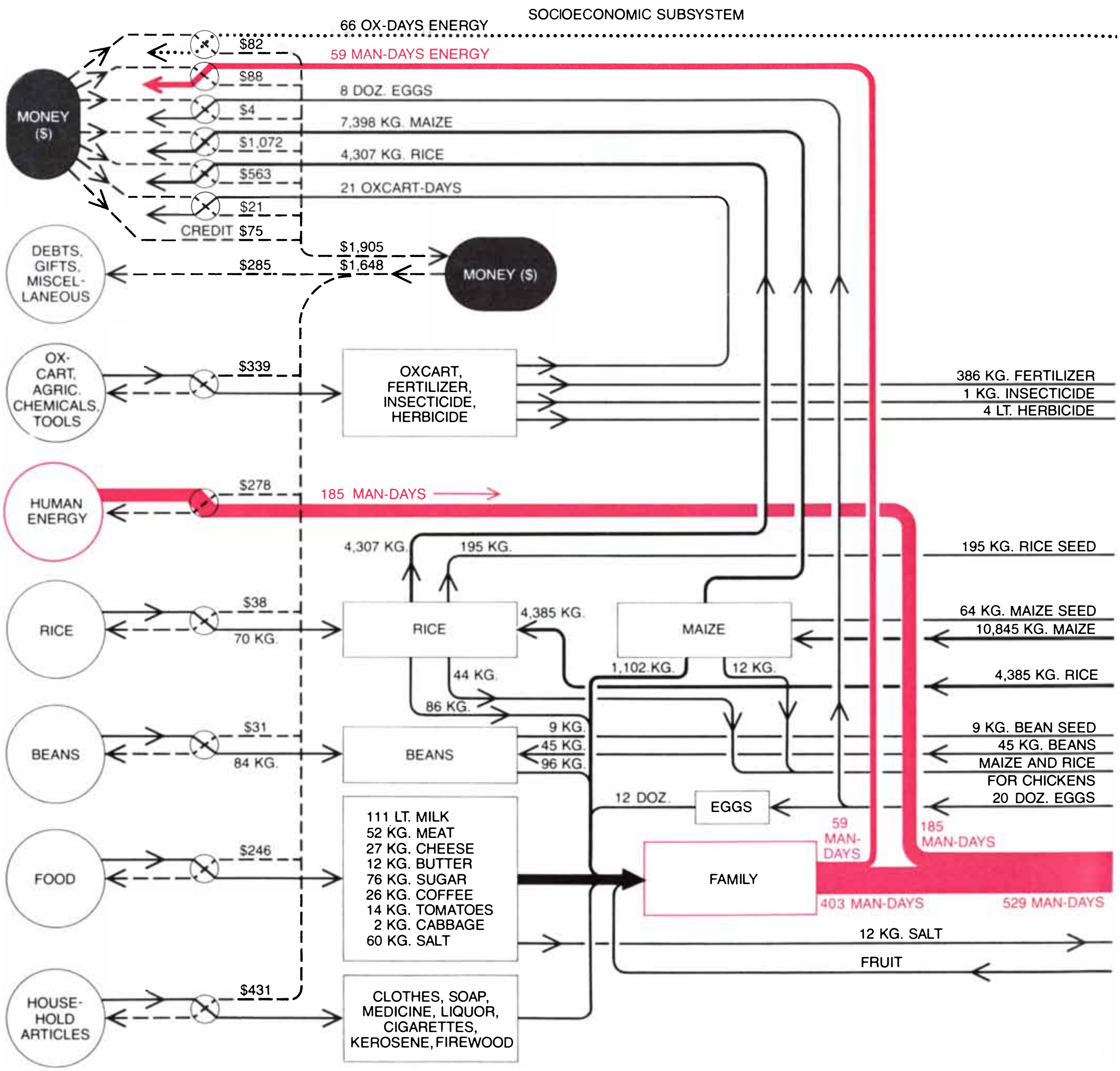
VALUE OF FERTILIZER in raising crop production is demonstrated in an analysis of factors contributing to total crop production in 90 developing countries in three periods between 1961 and 1976. The contribution made by bringing new land under the plow has declined since the early 1960's; the share attributable to irrigation and other factors has held fairly steady; the contribution attributable to fertilizer has risen sharply. The last bar shows that fertilizer was responsible for two-fifths of the increase between 1961–65 and 1974–76. The analysis was done by Alan Strout of the Massachusetts Institute of Technology on the basis of FAO data.



SHARP RISE IN FERTILIZER USE was reported in most developing regions of the world between 1961–65 and 1977. In spite of the slowdown due in part to oil shortages in 1974 and 1975 growth resumed strongly in 1976 and 1977. Over the 15-year period ending in 1977 the fastest annual rate of growth was in the Near East (12.4 percent), followed by Latin America (11.6 percent). In Africa, China and the rest of Asia the growth rates were respectively 8.3, 8.9 and 8.7 percent per year. The curves are again based on Strout's analysis of FAO data.

Among the innovations that were once heavily supported and publicized but that have since fallen by the wayside one may remember fish-protein concentrate for human consumption and protein from single-cell algae grown on petroleum substrates. The proposals themselves are technically feasible, but they proved not to be economically viable and also resulted in food products people did not like. Opaque-2 maize (which has a high content of the essential amino acids lysine and tryptophan), antarctic krill and the wheat-rye hybrid triticale all seem to hold promise, but it is too early to predict their success. In short, it would be unwise to bank on technological breakthroughs for the long-term solution to food shortages.

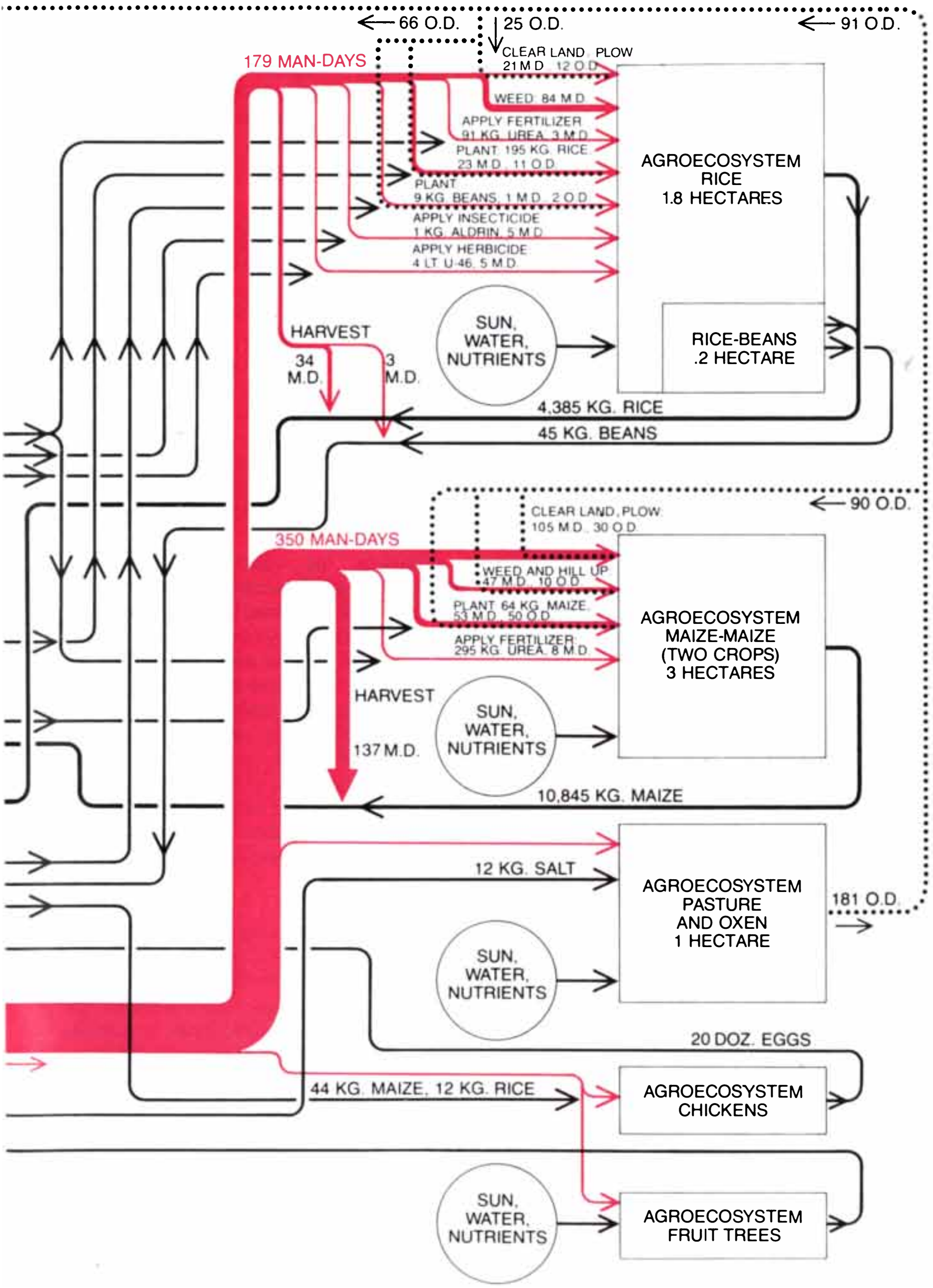
In retrospect one characteristic common to unsuccessful food innovations is that they were supported "from above" and had little relevance to the problems perceived by the people the innovations were supposed to help. A successful new technology has to fit the entire socioeconomic system in which it is to find a place. Security of crop yield, practicality of storage, palatability and costs are much more significant than the advocates of new technologies have recognized. For example, the better protein quality in tortillas made from opaque-2 maize is only a second-order benefit to a poor family on the margin of subsistence if the new maize does not match the yields of older varieties or is more vulnerable to insects. There is optimism that new high-yielding varieties of



INPUT-OUTPUT MODEL OF FARM SYSTEM in a small Honduran village, Yojoa, was constructed by Robert D. Hart, an agronomist with the Centro Agronómico Tropical de Investigación y Enseñanza in Costa Rica. For a year beginning in May, 1976, the owner of a typical small farm was interviewed weekly to record in detail all the flows of money, materials and energy on the farm. In the model money flows in a direction opposite to the flow of materials and energy. Most of the flows were associated with the flow of money. The farmer earned a total of $1,830 in the year by selling maize, rice, eggs and family labor and by renting out his oxen and an oxcart. His to-

opaque-2, with harder kernels to thwart insects, will be more widely accepted.

To such technical difficulties must be added a second set of complications: economic and political power relations strongly influence the outcome of those innovations that are put to use. In the Anglo-American tradition Schultz and most other economists stress private profitability as the key factor in guiding technical change. Actually profitability is neither a necessary nor a sufficient condition for a new technology to be adopted, let alone for it to benefit the poor. One example is the tendency for new methods to favor large landowners, as has been demonstrated in the case of Argentina by Alain de Janvry of the University of California at Berkeley. Amit Bhaduri of Jawaharlal Nehru University in New Delhi argues that efforts of peasants to break out of debt bondage by adopting more profitable rice-growing methods in West Bengal have been frustrated by village moneylenders who prefer things as they are.



tal expenditures for the year amounted to $1,648, leaving a net surplus of $182. There was a strong interaction among the "agroecosystems" represented by the farm. For example, the pasture-oxen system yielded 181 ox-days of energy, of which 90 were used in double-cropping the "maize-maize" system, 25 were used in the rice-bean system and 66 were rented for plowing and hauling. Some smaller labor inputs do not appear here because they were not recorded.

Innovations that carry high rewards for big agribusiness groups likewise may harm segments of the population and even reduce the availability of food in a country. For example, the production in some areas of Mexico of fresh vegetables for export to the U.S. worsens the food situation when the more profitable new crops take over land formerly used to grow staple foods. In Central America, to cite another example, modern beef-production operations have expanded greatly in recent years in response to a strong U.S. demand; not surprisingly the local price of meat has climbed steeply, further reducing consumption among the poor.

The details of any one of these examples can be debated but all of them contain an element of truth that most economists find necessary to accept. When a new technology promises to alter substantially the profits and losses associated with any production system, those who hold the balance of economic power will strive to maintain and improve their position. Since large segments of the population of many developing countries are close to the subsistence margin and essentially powerless, they tend to be the losers unless they are aided by a government policy that takes into account the needs of all sectors of the economy.

In spite of the above risks the sheer weight of growing population makes it essential that capital formation and technical change in the food system proceed. Moreover, the effort must be made in the third world itself. It is simply not feasible for the major grain-exporting countries (principally the U.S., Canada, Australia and Argentina) to create exportable surpluses large enough to meet the projected food needs of poor countries. Even if it were possible, there is no mechanism to ensure that poor people would have the money to acquire the grain that might be made available. External food aid is by its very nature incapable of solving distribution problems within the recipient country. Similarly, other proffered first-world contributions such as Western agricultural technology will fail or have harmful side effects unless they are redesigned to suit local circumstances. With all of that said, there are important areas in which agricultural research can be of decisive value.

One is the development of new ways to apply simple tools to the elimination of bottlenecks in food production. Readily utilizable energy is often a limiting input to agricultural production: energy for pumping water, threshing grain and tilling land for shortened crop intervals. Important work aimed at relieving this limitation is being done by a number of groups around the world. One broad goal of the work is the development of multiple-cropping systems for small farmers in the hope of increasing yields, reducing the need for fertilizer and pesticides, conserving soil and raising productivity on small plots of land. The widespread adoption of multiple cropping will require local research, effective instruction methods and access to necessary credit. The potential of multiple cropping is nonetheless quite promising because the technology is naturally labor-intensive and can contribute much to rural employment and development.

Effective land reform, which might be called social engineering if not technology, fits in nicely with small-farmer innovations such as multiple cropping. Yields per acre are usually far higher on small landholdings than they are on larger farms, since families use their many hands to exploit what we have described as the intensive margin. With appropriate support facilities and appropriate technology land distribution to favor small-holder agriculture has already played a large role, and it can play a much larger one in improving both agricultural production and rural-income distribution.

On another front food losses in developing countries often exceed 20 percent for cereals and legumes because of rodents, insects and molds. The losses for fruits and vegetables in tropical countries are likely to be more than twice as high. Badly needed are new techniques of food storage and preservation designed for poor households and villages. The problem is the focus of a major program of the United Nations University.

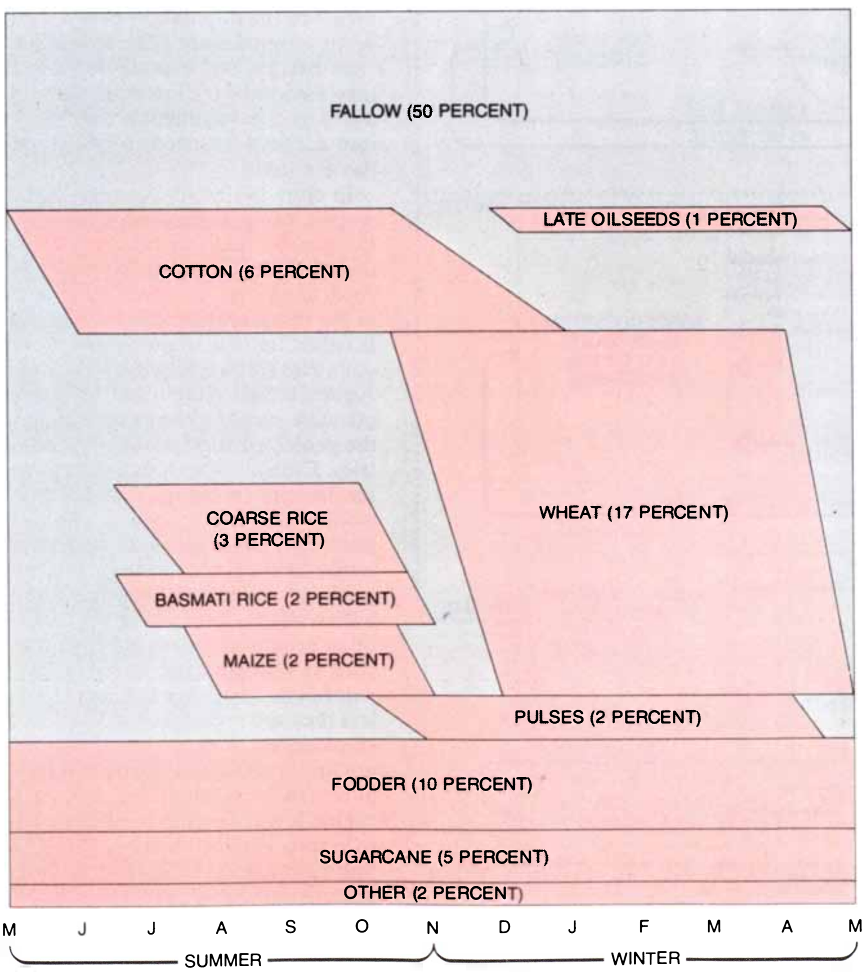
Western technology can also contribute greatly to the prevention and control of disease. The worldwide eradication of smallpox and the means to prevent measles and whooping cough by immunization are examples. The frequent episodes of diarrhea and other infectious diseases, coupled with the high prevalence of intestinal parasites in poor countries, decrease nutrient absorption and increase nutrient losses. The successful treatment of such afflictions requires health care that actually reaches down to individual poor families. A new program of the WHO has as its major purpose the delivery of primary health care [see "People," by Halfdan Mahler, page 66].

Finally, innovations in economic policy can be directed specifically to aid the rural and urban poor. Where land reform is politically feasible, it can secure both nutrition and employment for the poor. Food subsidies can substantially improve their nutritional status. Various methods have been employed, ranging from subsidized sales in special shops to food-for-work programs. A promising food-subsidy program is now being developed through the health-care system in Colombia. In Bangladesh the distribution of sorghum is being subsidized, and several countries are planning food-stamp systems for the poor. A more general redistribution of income would be even more valuable, but in many parts of the world that will not soon be achieved.

Producer incentives and technical imports can also be designed to help small landowners, sharecroppers and the rural landless. General price subsidies are usually not cost-effective because they are likely to benefit large producers and even industrialists rather than the low-income producers. Complex local power networks (often reflected at the higher level as well) may oppose or pervert price-subsidy policies for their own ends. Nevertheless, such programs should be instituted where they are needed.

Concern for macrolevel development, industrialization, advanced technology and transnational investment must be matched by concern and respect for the small farmer and for small food-production and food-processing activities. In some developing countries producer cooperatives are an important means of bringing increased resources and bargaining power to the small farmer. The result is not only improved food production but also higher incomes, less hunger and malnutrition and better overall health.

Food production and consumption are close to the core of all human cultures. Proper respect for what we do not understand about the operation of the food systems of individual countries and societies is needed to avoid mistakes. Programs should be tailored to regional and national circumstances. The final objective should be not only to ensure enough food to meet the effective demand (that is, food that someone will pay for) but also to see that human needs for food are met. This means that world food and nutrition problems cannot be solved by concentrating on production alone. Equivalent attention must be given to appropriate distribution and consumption. In most countries and most programs distribution has been slighted.



CROP CALENDAR OF A FARMER in the Punjab of Pakistan suggests the complexity of decisions he faces in choosing crops to maximize his return from a farm with a cultivable area of five hectares (12.5 acres). With irrigation he can obtain two crops per year, but at the same time he must allow for seasonal variations in supply and demand. Another major problem is having enough mechanical equipment and manpower available when he needs them. He must have enough of both on hand in November and December to plant wheat as he harvests cotton.

Keep this in your hand for good luck when speaking

There is more than one way of giving a paper. Some are appreciated more than others.

Everybody sitting in front of you is there for a somewhat different reason. You as the speaker have every right to ignore whatever their reasons may be and say what you want to say in whatever order you want to say it. Whether they like it or not, they'll be respectful. Perhaps that's all you expect.

Consider an alternative that might better justify the effort, the time, and the expense for you and them.*

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The rest of the slides in your tray are just as good, but which of them will be shown and in what order depends on what's on *their* minds. Why assail them with answers to questions that nobody present cares about?

But here comes a question that your Slides 23, 24, 37, and 39 answer beautifully. You know those numbers from your very brief notes. That's the reason for those notes, in fact. Just punch those numbers into the little device** in your hand. Only those you order come on, when you order them. The minutes so often consumed in a triangle of ill-concealed exasperation between speaker, operator, and projector ("No, not that one. Not that one either.") or in feverishly shuffling through your overhead-projection transparencies are saved for fielding the next question and the next. When the chair has to shut you off while the questions are still being well fielded, you know that you made no mistake in your choice of a career.

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*Warning: This alternative assumes you are very much on top of what you are talking about.

**Which, with its interconnect box, you have connected to the 7-conductor accessory receptacle to be found on most Kodak Ektagraphic and Carousel slide projectors. (It does not operate the model AF-3 or arc module, and has limited use with the Kodak pocket Carousel projectors.)

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Display—Keeps you informed of the slide number at the gate.

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SCIENCE AND THE CITIZEN

Vulnerable Science

In spite of financial uncertainty and continuing inflation, the level of Government support for basic research appears to be holding reasonably steady. On the other hand, the level is not rising as the Administration once hoped it would, and the President's revised budget for fiscal year 1981 offers signs that the support of basic research may be particularly vulnerable to economic pressures. In his original budget, presented in January, President Carter reaffirmed his commitment to the support of basic research: he proposed a 12 percent increase of $541 million over this year's total of $4.5 billion. That would have amounted to a real growth (after inflation had been taken into account) of 3.5 percent. By March, however, the Administration had cut the increase to 7.8 percent. This amount is almost certain to lag behind inflation and to mark fiscal year 1981 as the second consecutive year without a real increase in the support of basic research. Congress now seems likely to approve the March budget. Public support of basic research will therefore probably remain at 13 percent of the total research-and-development budget, about .75 percent of the total Federal budget and .16 percent of the gross national product.

The situation is reviewed in a publication of the American Association for the Advancement of Science, *Research & Development AAAS Report V,* by Willis H. Shapley, Albert H. Teich, Gail J. Breslow and Charles V. Kidd. According to the report, three of the agencies hardest hit by the March budget revisions were the National Science Foundation, the National Aeronautics and Space Administration and the National Institutes of Health. These three are traditionally regarded as being among the least "mission-oriented" of the Federal agencies that support basic research. The January figure for the NSF was reduced 5.1 percent and that for NASA by 10.5 percent. With these cuts the NSF shows a real growth of only 2 percent and NASA a real loss of more than 11 percent. Appropriations to the NIH, perennially the biggest disburser of basic-research funds, were reduced 2 percent in March, so that for the year the NIH shows a real loss of almost 4 percent.

One realm of basic research still seems to have the strong support of the Administration, namely research sponsored by the military. Research funds for the Department of Defense were reduced 2.8 percent in March, but because the department's increase in January was larger than that of the other agencies, it will show a real growth of almost 9 percent. Some nonmilitary agencies were also spared by the March revisions. Both the Department of Energy and the Department of Agriculture will register a real increase in basic-research funds of between 3 and 4 percent.

Even with real gains by certain agencies some workers in the physical sciences doubt that the support of basic research is keeping pace with increases in its true costs. "The nature of research has changed, with much more emphasis now on heavy instrumentation," comments Richard B. Miles of Princeton University. "The cost of doing the same piece of research has gone up faster than inflation."

Another concern of scientific workers is that basic research cannot be adequately supported on a cycle of annual grants. Most research projects take longer than a year, and although many grants are renewed, the longer-term investigations tend to be discriminated against. According to Leon M. Lederman, director of the Fermi National Accelerator Laboratory, interruptions and delays in funding not only have shut down some accelerators but also have made some projects in high-energy physics obsolete before they could be completed. President Carter has, however, endorsed legislation that would authorize multiyear research funding, and the House Committee on Science and Technology is urging the approval of such legislation by Congress. At a colloquium on the AAAS report held in June the President's science adviser, Frank Press, commented: "Nature does not yield her secrets on the basis of the annual budget cycle."

Continued economic pressures such as those that precipitated the March budget revisions will encourage Federal agencies to fund relatively short-term, low-risk research, perhaps not basic at all. Since World War II the mission-oriented agencies have put large sums into basic research but far larger ones into applied research and engineering development. Because their "mission" comes first, it may well encroach on basic research when the two are competing in a time of straitened resources. And since, according to the AAAS report, the more mission-oriented agencies, particularly the Department of Defense, are now likely to get a larger share of the basic-research funds, the amount available for basic research is increasingly vulnerable to such shifts in emphasis. If Congress has continued to support basic research so far, comments Shapley, it may have done so only because of "bureaucratic inertia." As Robert A. Zich of the Department of Energy said: "When times are hard, it is very, very tempting for people on the Hill to say, 'Let's take it out of basic research.' When you look around you and see poverty and the energy crisis, high-energy physics is a hard thing to justify."

Galilean Satellite

The discovery of Neptune in 1846 provoked one of the more florid controversies over scientific priority. The existence of the planet had been deduced and its position had been calculated by the English mathematician John Couch Adams, but no astronomer bothered to look where he directed. Meanwhile in France, Urbain Jean Joseph Leverrier, whose calculations were completed a little after Adams', persuaded Johann Gottfried Galle of the Berlin Observatory to undertake a search. Galle found the planet the first night he looked, and credit for the prediction went to Leverrier.

It has since been established that neither Galle nor Adams nor Leverrier has an absolute claim to priority. Neptune had been observed almost 55 years earlier by Joseph Lalande, although Lalande failed to identify it as a planet. Now there is compelling evidence that Neptune was first seen very early indeed in the history of telescopic astronomy. It was noted, but again not properly identified, by Galileo Galilei only three years after he trained the first telescope on the heavens and 234 years before Galle's work. Galileo's observation is more than a historical curiosity. It calls into question the accuracy of the calculated orbit of Neptune.

Galileo's early sighting of Neptune was discovered by Charles T. Kowal of the California Institute of Technology and Stillman Drake of the University of Toronto. Kowal was interested in Neptune because its orbit is not known with the same precision as the orbits of the inner planets are. With a period of revolution of 165 years, Neptune has not made a complete circuit of the sun since the time of its discovery, which might in part explain the theoretical uncertainty in its motion. Lalande's observation, however, fixes the position of Neptune in 1795, and it does not agree with the predicted value. The discrepancy is only seven arc seconds, but astronomical observations were quite accurate by the end of the 18th century, and so the difference cannot cavalierly be written off as observational error. Kowal hoped to find another record of an early sighting so that he could better evaluate the precision of the calculated orbit.

From an article in *Sky and Telescope* by Steven C. Albers, Kowal learned that Jupiter occulted Neptune in January, 1613. Galileo had been methodically charting Jupiter and its satellites since 1610, and Kowal wondered whether

WHAT'S NEWS IN PATENTS?

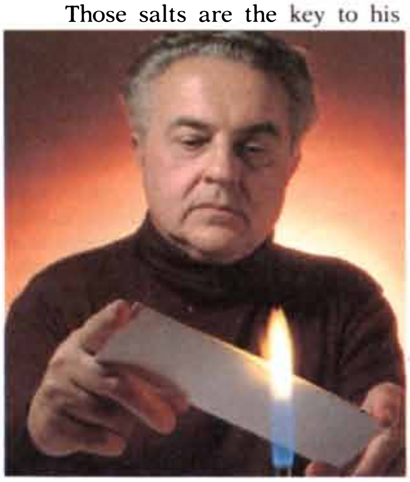
A continuing series on progress by GE inventors.

Last year, General Electric inventors were awarded over 600 patents, adding to GE's unsurpassed total of over fifty thousand U.S. patents, past and present. Here, GE reports on some recent patents—and on the inventors who won them.

Victor Mark: The firefighter.

GE's Victor Mark has learned how to fight fire, not with fire, but with sulfonic acid salts.

Those salts are the key to his



latest patent (Number 4,197,232—"Composition of a Flame-retardant Glass-reinforced Polycarbonate Resin").

Mark's discovery was that adding small amounts of sulfonic acid salts made a dramatic improvement in the flame-retardant properties of polycarbonates. The salts are thermally stable during processing and do not affect the performance characteristics of the polycarbonate resin.

The result is Lexan® 940 polycarbonate—a glass-reinforced version of one of the most popular GE engineering plastics. Its ability to retard flame is helping many manufacturers build increased safety into their products.

Mark's work in organic and polymer chemistry has won him over one hundred patents. And he has some fifty patents pending.

Beltran, Schilling and Muth: Taking the heat off turbine nozzles.

Raising the operating temperature of a gas turbine from 2000°F to 3000°F can raise the efficiency of a power-generating system by no less than 12 percent.

But turbine temperatures of 3000°F throw a chill into materials engineers. At 3000°F, the nozzles that

direct the hot gases at the turbine buckets must be liquid-cooled to keep them from disintegrating. A trio of GE engineers has now come up with a remarkable way to fabricate such nozzles. For their work, Adrian Beltran, Myron Muth and Bill Schilling have received patent number 4,183,456—"Method of Fabricating Liquid-cooled Gas Turbine Components."

Their method uses diffusion bonding with hot isostatic pressure to produce a nozzle with a copper core and stainless steel reinforcing, clad with a superalloy. A manifold system of tubing is built in for the liquid coolant.

The new nozzle is a crucial step along the way to more efficient turbine systems. Progress indeed.

Mike Byrne: Farewell to false alarms.

GE physicist Mike Byrne has truly built a better mousetrap with his work on home smoke detectors.

In the typical detector, alpha particles generate an ionization current between electrodes. When smoke particles enter the detector, current drops between the electrodes, and the alarm goes off.

Trouble was, even moderate currents of nonsmoky air could sweep out ionized particles, causing a false alarm.

Byrne's invention is patent number 4,185,196—"Ionization Smoke Detector Having Improved Stability and Sensitivity." It consists of a new electrode configuration that establishes a high-intensity field at the perimeter of the detector chamber; a low-intensity field at its center. The high speed of the ions at the perimeter stabilizes the device, while the reservoir of ions in the center increases the sensitivity.

Smoke detectors that cause fewer false alarms. That's true progress.

To learn more about GE research, write General Electric, Section 12, Fairfield, CT 06431.

We've got a patent on progress.

GENERAL ELECTRIC

Galileo might have seen Neptune just before the occultation. With Drake, Kowal studied Galileo's journal entries. They found that he saw Neptune on the night of December 27, 1612, and again on January 28, 1613. In spite of his primitive instruments and his simple measuring techniques, Galileo was able to determine the relative positions of Jupiter and Neptune with fair precision. The record of his observations leaves little doubt that Neptune was farther west than its theoretical orbit would put it.

On December 27 Galileo made a diagram of Jupiter and its moons and added to it the position of another object, which he took to be a fixed star but which turns out to have been Neptune. At that time the apparent motion of Neptune changed from direct to retrograde, so that the planet was virtually stationary with respect to the fixed stars. Neptune must have held some special interest for him because he rarely included a fixed star or any other object in his diagrams of the Jovian moons.

On January 28 Galileo detected an overnight change in the distance between Neptune and a nearby fixed star (now designated SAO 119234), but he could not tell which of the bodies had moved. In other cases Galileo followed up such a discovery with detailed observations on subsequent nights. Here he did not, and the reason is mysterious. Actually an explanation is wanting only for the next night, because after January 29 he could no longer have put Jupiter, Neptune and SAO 119234 in the 15-arc-minute field of his telescope. With no graduated mounting for the telescope, and without a bright object to serve as a guidepost, it is unlikely that he could have found a planet and a fixed star that are invisible to the unaided eye.

On January 29, however, Neptune and SAO 119234 must still have been in the same field as Jupiter. Perhaps the two planets were too close together then for Galileo to distinguish them. The reason he did not observe Neptune that night may become clear only with a more accurate calculation of its orbit.

The discrepancy between Galileo's record of Neptune's position and the theoretical orbit amounts to one arc minute. From the record of his observations of other objects and from knowledge of the structure of his telescope, Kowal and Drake have concluded that the difference cannot be charged to observational error. One possible explanation is that the orbit of Neptune has been perturbed by gravitational interactions with an undiscovered planet.

The 19th-century detection of Neptune itself was made possible by an orbital irregularity. Uranus, discovered in 1781, exhibited small departures from its predicted orbit that could not be accounted for by the gravitational forces of the known planets. It was by analyzing these small errors that Adams and Leverrier calculated the approximate position of Neptune.

Junk in the Genome

The fundamental biological function of DNA is clear enough: it is the genetic material. Hereditary information encoded in the sequences of its four chemical groups is transcribed into complementary sequences in the similar nucleic acid RNA and then is translated into the sequences of amino acids that constitute proteins; the proteins determine the shape and function of every living cell and organism. Not long after this central dogma of molecular biology was proclaimed, however, it became clear that not all DNA codes for proteins. There is much more DNA in the cells of most organisms than would be required to account for the probable number of genes, or functional coding sequences. Some of the DNA is not transcribed into RNA at all; much of the RNA is discarded and never appears as messenger RNA, the form that can be translated into protein; even some of the messenger RNA is not translated.

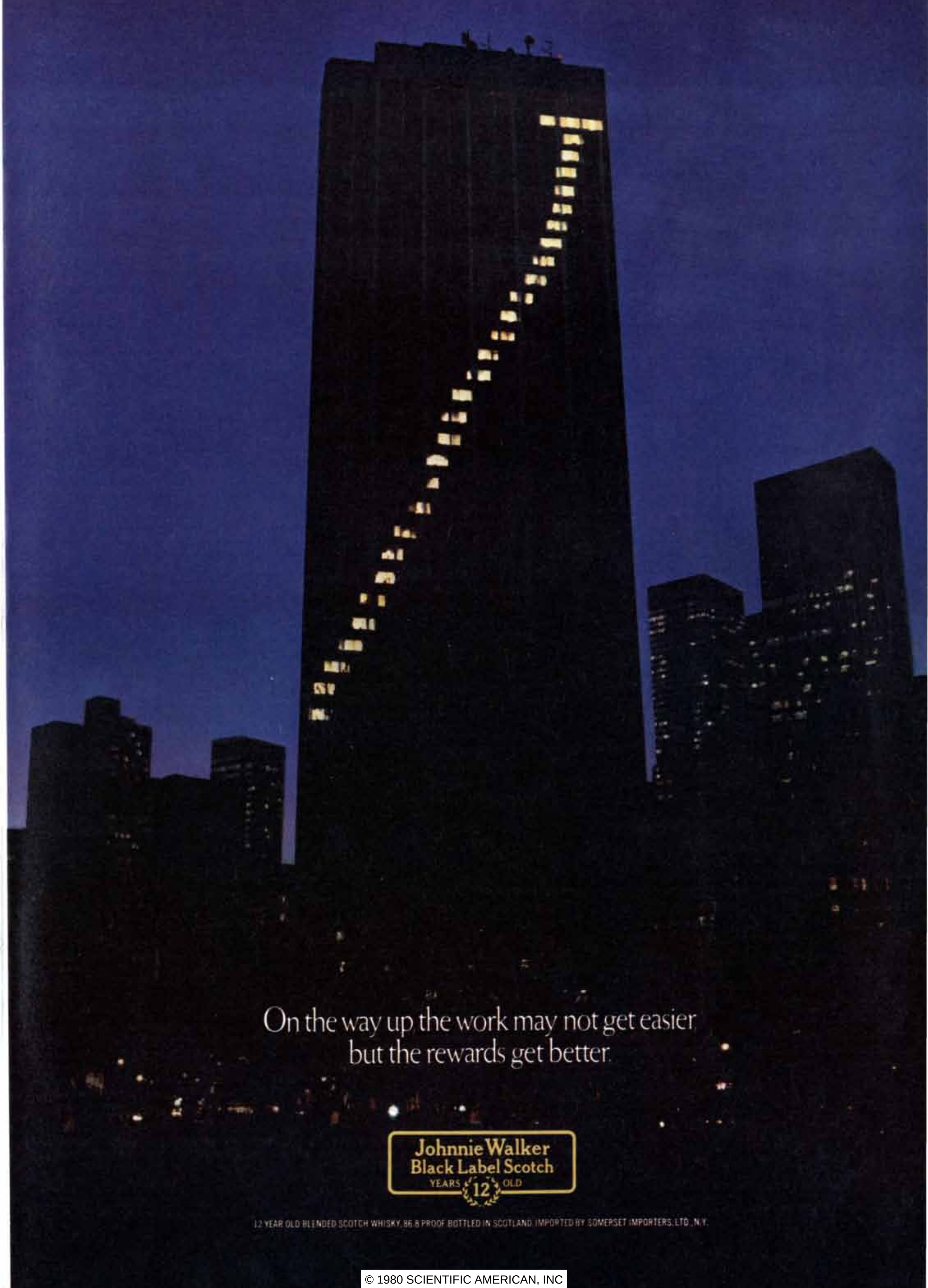
What, then, is all the DNA there for? Biologists try to avoid teleological reasoning, and so they tend to ask instead: How has all the extra DNA been preserved over evolutionary time? They assume that the genotype—the genetic makeup of an organism—is subject to natural selection. In that case, it has generally been held, those DNA sequences should be preserved that improve the fitness of the phenotype: the sum of the traits that characterize an organism. In other words, the extra DNA must have some phenotypic function or it would not be there. And so functions of presumed benefit to the phenotype are suggested. The various classes of noncoding DNA's are said to be present because they contribute to chromosome structure, are required for the splicing of messenger RNA or regulate transcription or translation, or else because over the long term they facilitate the recombination of DNA to form new coding genes or provide the raw material for such genes.

In two articles published in *Nature* a different view is put forward. W. Ford Doolittle and Carmen Sapienza of Dalhousie University in Nova Scotia suggest that "natural selection does not operate on DNA only through organismal phenotype," and that "sequences whose only 'function' is self-preservation" can arise and be maintained simply because they are successful in that endeavor. L. E. Orgel and F. H. C. Crick of the Salk Institute argue that "much DNA in higher organisms is little better than junk," spreading through the cell's genome, or total complement of DNA, much as a not too harmful parasite spreads in its host. For both sets of authors the genome is an environment in which a "molecular struggle for existence" is carried on among many DNA's. Success in the struggle comes not only to sequences that code for proteins improving the fitness of the organism but also to noncoding sequences that are simply effective in spreading themselves through the genome—to "selfish DNA."

The essence of the selfish-DNA hypothesis can be suggested by a few of the examples discussed. Doolittle and Sapienza cite transposons and insertion sequences: short stretches of DNA that move from one site to another in bacterial chromosomes and in the small extrachromosomal segments of bacterial DNA called plasmids. Some transposons carry genes for traits such as drug resistance that are clearly advantageous to a bacterial host under some circumstances. Others have harmful effects, and many transposable elements appear to have no genes affecting the phenotype. It has been proposed that transposable elements nonetheless enhance long-term phenotypic fitness by helping to shuffle bacterial and plasmid genes.

Doolittle and Sapienza give two reasons for doubting that transposable elements "arose or are maintained by selection pressures for such evolutionary functions." One reason is that a transposed element failing to confer an immediate benefit is of no immediate advantage to the host (and indeed is an energetic burden). "Evolution is not anticipatory," they write. "Structures do not evolve because they might later prove useful." The other reason is simply that no functional explanation is necessary: "transposability itself ensures the survival of the transposed element" unless the effect on the phenotype is strongly negative. These elements apparently spawn copies of themselves within the genome, which they would not have to do if they were maintained by selection acting on the cell. If some copies diverge in sequence, copies that transpose particularly successfully will increase in frequency.

Many reported characteristics of transposons and insertion elements suggest, Doolittle and Sapienza write, that "nonphenotypic selection may inevitably give rise" to just such elements. They propose, moreover, that the same qualities may explain the presence of a lot of other noncoding DNA: the "middle-repetitive DNA's" of eukaryotic cells (nonbacterial cells, with nuclei and more than one chromosome). These are stretches of DNA in which the same sequence is repeated from hundreds to many tens of thousands of times; their sprinkling through eukaryotic genomes makes "no particular phylogenetic or phenotypically functional sense." Perhaps they are (or once were) transposable elements. A similar explanation could account for introns, the noncod-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ing sequences that interrupt coding sequences in many eukaryotic genes.

Orgel and Crick maintain that natural selection within the genome favors the spreading of selfish DNA, whereas selection between genotypes tends to keep the selfish DNA to a level that is not metabolically disadvantageous to the organism. They argue that the energy cost of replicating a small amount of superfluous DNA must not be great, and that in any case the elimination of "a particular piece of junk from the genome may be a very slow process." And once the cell has evolved a way to restrict the spreading of that piece or to eliminate it, other selfish DNA's might arise and begin to multiply. In sum, selfish DNA can exist and proliferate because the replication of DNA is a necessity in the cellular environment; selfish DNA simply subverts essential mechanisms to its own purpose.

To be sure, Orgel and Crick point out, a host organism may occasionally find some use for a selfish-DNA sequence. The evolution of higher organisms may depend not so much on new proteins as on new mechanisms for controlling the expression of genes. Sequences of DNA would be particularly advantageous if they controlled as a unit sets of genes that had previously been controlled separately. This might come about if multiple copies of a repeated sequence were scattered through the genome in just the right positions to turn on or off together the new combination of genes. On statistical grounds, however, most repeated sequences would usually be in unsuitable positions. It therefore seems unlikely "that all selfish DNA has acquired a special function."

The two selfish-DNA articles elicited a voluminous response, a sampling of which has since been published in *Nature.* T. Cavalier-Smith of King's College, London, cites evidence that the total amount of DNA in a genome has effects on phenotypes "of profound adaptive significance," so that selection favoring larger genomes rather than smaller ones can sometimes be expected. The wide range of DNA content found in eukaryotic algae alone, he contends, suggests that "large cells actually require more DNA than do small ones."

Gabriel Dover of the University of Cambridge asks: "Are we yet in a position, in our ignorance of the mechanisms of so many fundamental biological processes, to strip the bulk of these sequences . . . of all biological activity?" He maintains that "when we enter the depths of the higher genome we should not abandon all hope of arriving at an understanding of the manner in which some sequences might affect the biology of organisms in completely novel and somewhat unconventional ways."

Temple F. Smith of Northern Michigan University welcomes the selfish-DNA hypothesis as being supported by "a variant on Occam's razor" as well as by considerable evidence, but he calls for more rigorous statistical analysis of such sequences as those of the transposable elements. He holds that it is not enough to prove there is a "potential for neutral parasitic sequences"; it is necessary to predict, on the basis of the selfish-DNA hypothesis, the statistical properties of particular genetic sequences.

The selfish-DNA controversy thus seems to be a matter of differing emphasis. The phenotypic-selectionists would assign to each newly discovered class of DNA's and to each new mechanism of replication a meaningful "biological activity," or at least they would keep the door open for such assignment. The proponents of the selfish-DNA hypothesis want to direct attention to the mechanisms by which DNA's that have no proved phenotypic function ensure their own survival in the genome. They think settling for selfishness can liberate investigators from a futile search for other ways to explain the existence of DNA's whose only function is survival.

III-V Electronics

For 20 years the intricate machines of microelectronics have been built almost entirely of a single material: silicon. Part of the reason has to do with the electrical properties of silicon. As an element in group IV of the periodic table it sits on the fence between metals and nonmetals, and small changes in its composition or in external conditions can convert it from a conductor of electricity into an insulator. There are other such semiconductors, however, and there is another explanation for the predominance of silicon: it is a peerless medium for the fabrication of small structures. Methods have been developed for inscribing on silicon the most precise of all manmade patterns.

In spite of these virtues, silicon may yet be displaced by another semiconductor. The likely successors are not elemental materials but are compounds made up of one element from group III of the periodic table and one element from group V; they are the III-V semiconductors. One such compound is indium phosphide, but its technological potential is highly uncertain. A better-known III-V semiconductor is gallium arsenide, which has been employed for some time in making solid-state lasers and light-emitting diodes. It now appears that gallium arsenide may also become the material of choice in electronic devices less specialized than these.

The particular advantage of gallium arsenide is speed. When electrons are accelerated by an applied voltage, they move faster in gallium arsenide than they do in silicon; typically the mobility of the electrons is from four to five times greater. As a result the time required to establish a current or to extinguish one, and hence to change the state of a circuit, can be much shorter.

In view of the higher electron mobility, another property of gallium arsenide may seem paradoxical: when it is prepared in an appropriate way, it makes a better insulator than silicon. Good insulation, or in other words high electrical resistance, can reduce the capacitance of an electronic device and improve the isolation of adjacent devices, so that they can be moved closer without interfering with one another.

The higher electron mobility and higher resistance of gallium arsenide combine to give it an appreciable advantage over silicon in the speed with which a signal can propagate through a network of transistors or other devices. The speed is measured in terms of the highest-frequency signal a circuit can handle without severe attenuation or distortion. For the fastest silicon devices the cutoff frequency is about two gigahertz, or two billion cycles per second. With gallium arsenide electronics there appears to be no fundamental impediment to speeds of from 10 to 20 gigahertz.

The high-speed capability of gallium arsenide semiconductors is not a recent discovery. The material has not been widely adopted up to now, however, because techniques for circuit fabrication comparable to those employed with silicon do not exist. The great complexity of modern electronic devices has been made economically feasible primarily through the process of large-scale integration: the packing together of thousands of circuit elements on a small chip of semiconductor substrate. For gallium arsenide technology to become practical it will have to be compressed in much the same way.

Until recently it was not possible even to grow the large single crystals of high-purity gallium arsenide that would serve as the raw material for a III-V semiconductor technology. Today the crystals can be grown, and the main difficulties lie in the need to preserve the chemical purity and structural integrity of the material during fabrication.

One problem arises in the course of doping, or introducing impurities to alter the electrical characteristics of the semiconductor. Some methods of doping disrupt the orderly structure of the crystal. In silicon the damage can be undone by annealing the doped material at high temperature. The same strategy cannot be followed with gallium arsenide because the compound dissociates at the annealing temperature. A still more troublesome difficulty involves the "passivating" layer of insulator that protects the surface of the chip and insulates the electronic devices from the overlying metallic traces that interconnect them. In silicon technologies the passivating layer consists of silicon dioxide, which is formed in place by heating the chip until the surface oxidizes.

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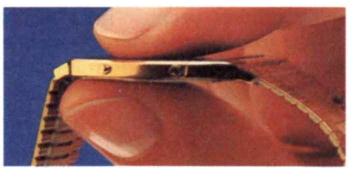

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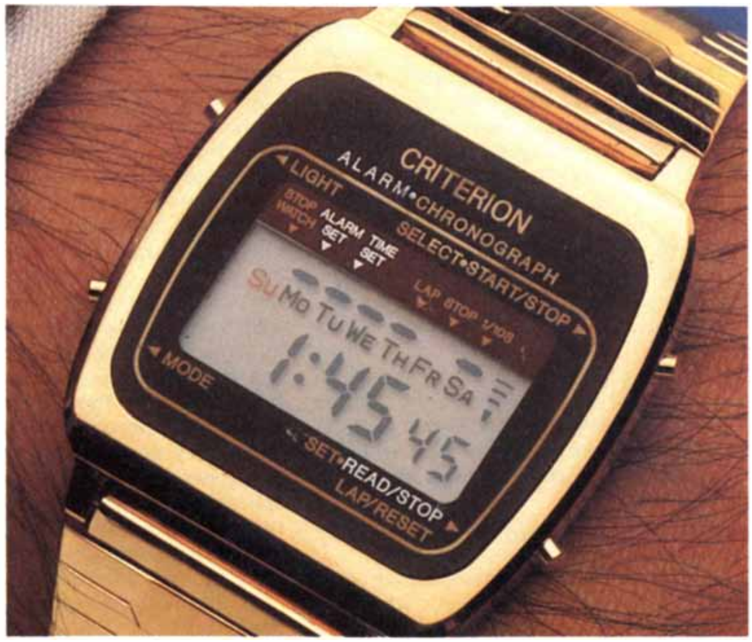

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That method will not work with gallium arsenide, in part because the oxide of the compound has an irregular structure, and instead of protecting the semiconductor it disturbs the surface region.

There is now much optimism that these obstacles to the development of gallium arsenide technology can be overcome. A few prototype chips that approach large-scale integration have been made, and some discrete components (as opposed to integrated circuits) are being manufactured commercially. The first applications will probably come where high speed is the prime desideratum and where high cost can be tolerated. One example is in telecommunications, where a shift to higher frequency can raise the capacity of a communications channel. Another is the processing and analysis of radar signals. If gallium arsenide technology is successful, it must eventually find its way into computers and other devices based on digital electronics. There the relation between speed and capability is particularly clear. If a computer runs 10 times as fast, it can do 10 times as much.

Dante's Dimensions

One of the most coherent and comprehensive expositions of medieval cosmology is to be found in the *Divine Comedy* of Dante Alighieri. Because Dante narrates a tour of the universe at first hand he cannot be vague about the details of its construction. On the contrary, from his description one could prepare topographic maps of Heaven, Hell and Purgatory. Of course, Dante's universe is a geocentric one, and it is organized largely according to theological principles; nevertheless, some of its imagined features seem remarkably well thought out. For example, Dante gives a plausible account of what it might be like to pass through the center of the earth, "the point to which all weights are drawn from every part," and he accurately describes the apparent motions of the sun and the planets as seen from the Southern Hemisphere.

An interpretation of Dante that ascribes a still greater sophistication to his cosmology has recently been proposed by Mark A. Peterson of Amherst College. From a reading of several stanzas in the *Paradiso* (the final book of the *Divine Comedy*) Peterson suggests that the overall topology of Dante's universe is that of a three-sphere, a three-dimensional "surface" of spherical form embedded in a four-dimensional space. It should be noted that in modern cosmologies a three-sphere is considered a possible configuration of the universe. It describes a "closed" universe, one that has a finite volume but no boundaries.

Even with the geometric intuitions gained through modern mathematics it is not easy to visualize a three-sphere. One aid to the imagination is to construct the sphere from sections, or slices, cut at various latitudes. For an ordinary sphere (a two-sphere in three-dimensional space) the slices are circles whose radius varies from zero at one pole through a maximum value at the equator and then returns to zero at the opposite pole. For a three-sphere the sections are ordinary two-spheres whose radius follows the same progression.

Another method of construction suspends a sphere from two poles in order to form the sphere of next-highest dimension. A circle can be suspended from a pole above the plane and a pole below the plane by connecting each of the poles with every point on the circumference of the circle. The result is a pair of hollow cones joined at their bases, which by smoothing and reshaping can be made into a two-sphere; the joined cones are said to be topologically equivalent to a sphere. The procedure can be repeated by choosing two more poles, one inside the two-sphere and one outside. Connecting each of these poles with every point on the surface of the two-sphere yields a topological three-sphere. In the simplest case, the original two-sphere becomes the equator of the three-sphere, equidistant at all points from the two poles.

In the *Divine Comedy* Peterson finds evidence for both of these conceptions. The passages in question come in Canto 28 of the *Paradiso*, where Dante's wayfarer has already climbed above the spheres of the planets and the fixed stars to reach the Primum Mobile, the ninth sphere, which was the mainspring of the medieval universe. From this vantage he observes the Empyrean, the realm of fire and the dwelling place of the angels. The Empyrean was a feature of Aristotle's *Metaphysics*, and it had been adapted to Christian cosmology by Thomas Aquinas, but it had generally been described in vague or abstract terms. Dante gave it an explicit structure.

What the wayfarer sees as he looks on the Empyrean is a further set of nine nested spheres. They are the dominions of the nine orders of angels, and they revolve about an infinitesimal point of luminosity at the center. There is a geometrical paradox in this arrangement. The Empyrean was generally thought to surround the material universe, and in the preceding canto Dante has endorsed this view. Beatrice, the wayfarer's guide in Paradise, says of the Primum Mobile, "Light and love enclose it in a circle, as it does the others." It is hard to see how the universe could be enclosed in a set of spheres whose diameters progressively diminish and culminate in a fixed point.

The wayfarer himself is puzzled by another aspect of the Empyrean: "in the world of sense," he points out, the spheres revolve faster as they grow larger, but in the Empyrean the smallest sphere moves fastest. He asks Beatrice to explain this apparent lack of symmetry, and she responds as follows (in a prose translation by Charles S. Singleton of Johns Hopkins University): "The material spheres are wide or narrow according to the more or less of virtue which is diffused through all their parts. Greater goodness must needs work greater weal; and the greater body, if it has its parts equally complete, contains the greater weal. Hence this sphere [the Primum Mobile], which sweeps along with it all the rest of the universe, corresponds to the circle which loves most and knows most. Wherefore, if you draw your measure round the virtue, not the semblance, of the substances which appear to you in circles, you will see a wondrous correspondence of greater to more and of smaller to less, in each heaven with respect to its Intelligence."

Peterson, writing in *American Journal of Physics*, offers a gloss on this passage. "The innermost angelic sphere turns faster than the other angelic spheres because it ranks higher, just as the Primum Mobile turns faster than the other heavenly spheres because it ranks higher. In other words, the spheres have a ranking, a 'greatness,' which does not necessarily correspond to their size (although for the first nine it does), but is rather indicated to the eye by their speed. This explanation strongly suggests our construction of the three-sphere as sliced up into two-spheres which first grow and then diminish in size, labeled by a fourth coordinate... which simply increases. Indeed Dante has actually introduced such a fourth coordinate to label the spheres as they grow and diminish, namely their speed.... His fourth dimension is speed of revolution."

Another stanza suggests the construction of the three-sphere by suspension from two poles. When the wayfarer first notices the central light, Beatrice says in explanation, "on that point the heavens and all nature are dependent." Singleton, in his commentary on the *Paradiso*, traces the source of the line to Aristotle, where the context suggests that the word translated as "dependent" (the Italian is *depende*) should probably be read as meaning "contingent" rather than "hanging." The more concrete and geometrical image must also come to mind, however, and indeed other translators have chosen to render the line with "hang." If that was Dante's intention, a three-sphere becomes a reasonable model for his universe. Indeed, there is no coherent method of suspending one set of nested spheres from another set except by adding a fourth dimension to space. The structure that results is notably symmetrical, and it even seems to be consistent with Dante's spiritual purpose. Each point on the surface of the earth acquires a direct connection with a pole in the interior, where Satan is fixed in ice, and with a pole at the Godhead. The earth is suspended between God and Satan.

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Water

An adequate supply for agriculture, industry and people depends on human intervention in the water cycle and the development of water resources not only on the surface but also in the ground

by Robert P. Ambroggi

The total quantity of fresh water on the earth exceeds all conceivable needs of the human population. Much of the water is inaccessible or otherwise unavailable, however, and the remainder is unevenly distributed both from place to place and from season to season. In most parts of the world, therefore, an adequate and reliable supply of water can be had only by active management of water resources. In order to meet the large demands of agriculture and industry and the small but imperative demand of domestic consumption, water must be collected, stored, allocated and distributed. The water itself falls from the heavens, but it is not free. Human intervention in the natural water cycle always entails some cost, and occasionally the cost is high.

By far the commonest method of controlling and augmenting the water supply is to build dams for impounding the seasonal floods of streams and rivers. Indeed, since the Neolithic period human settlements have been clustered in the major river basins precisely because water is readily available there. Today other techniques of water management are also possible, such as tapping underground reservoirs and diverting rivers from one basin into another. The importance of limiting demand and of improving the efficiency with which water is delivered to the site of ultimate use has also recently been recognized. A common element in almost all these methods of water management is a need for large capital investments. The capital requirement is inevitable: dams, canals and other devices for regulating the water cycle are among the largest of the works of man.

Even when geographic disparities in water resources are taken into account, there is no country whose economic development must be curtailed for lack of water. With proper management of supply and demand, and with sufficient investment, every country could meet the needs of its population for water, even under conditions of intrinsic water scarcity. It is therefore all the more inexcusable that some 30 countries face severe water shortages in the next 20 years. Because the lead time for large water-management projects is itself about 20 years, any efforts to make up these deficiencies must be got under way soon.

Global reserves of fresh water add up to more than 37 million cubic kilometers, enough to fill the Mediterranean 10 times over. More than three-fourths of this water is bound up in glaciers and polar ice, however, where it is largely beyond the reach of present technology. Almost all the rest consists of water in underground aquifers, which are not yet exploited intensively. The main sources of supply—the waters of lakes and rivers and the water vapor in the atmosphere—make up less than 1 percent of the total.

The ultimate source of fresh water is the continuous distillation of the oceans by solar radiation. The annual evaporation of water (including transpiration by plants) is roughly 500,000 cubic kilometers, of which 430,000 comes from the oceans and the remaining 70,000 from waters on the continents. Because the amount of water vapor in the atmosphere is essentially constant the same amount of water must fall back to the surface as rain and snow. It is of vital importance to terrestrial life that a disproportionate share of this precipitation falls on land. Whereas the continents lose 70,000 cubic kilometers of water to evaporation, they receive 110,000 from precipitation, so that the net effect of the hydrologic cycle is to transfer some 40,000 cubic kilometers of fresh water each year from the oceans to the continents.

Although the net continental influx is 40,000 cubic kilometers per year, not all of it is available for man's use. Much is lost through floods or is held in the soil or in swamps. The maximum that might reasonably be applied to human purposes is about 14,000 cubic kilometers per year, which is the base flow, or stable runoff excluding flood waters, of all the world's rivers and streams and of those isolated underground aquifers that discharge directly through evaporation. Of this volume about 5,000 cubic kilometers flows in regions that are uninhabited and are likely to remain so because they are climatically unsuited to human settlement. Hence the effective world water resource, from which all needs will have to be met for some years to come, is about 9,000 cubic kilometers per year.

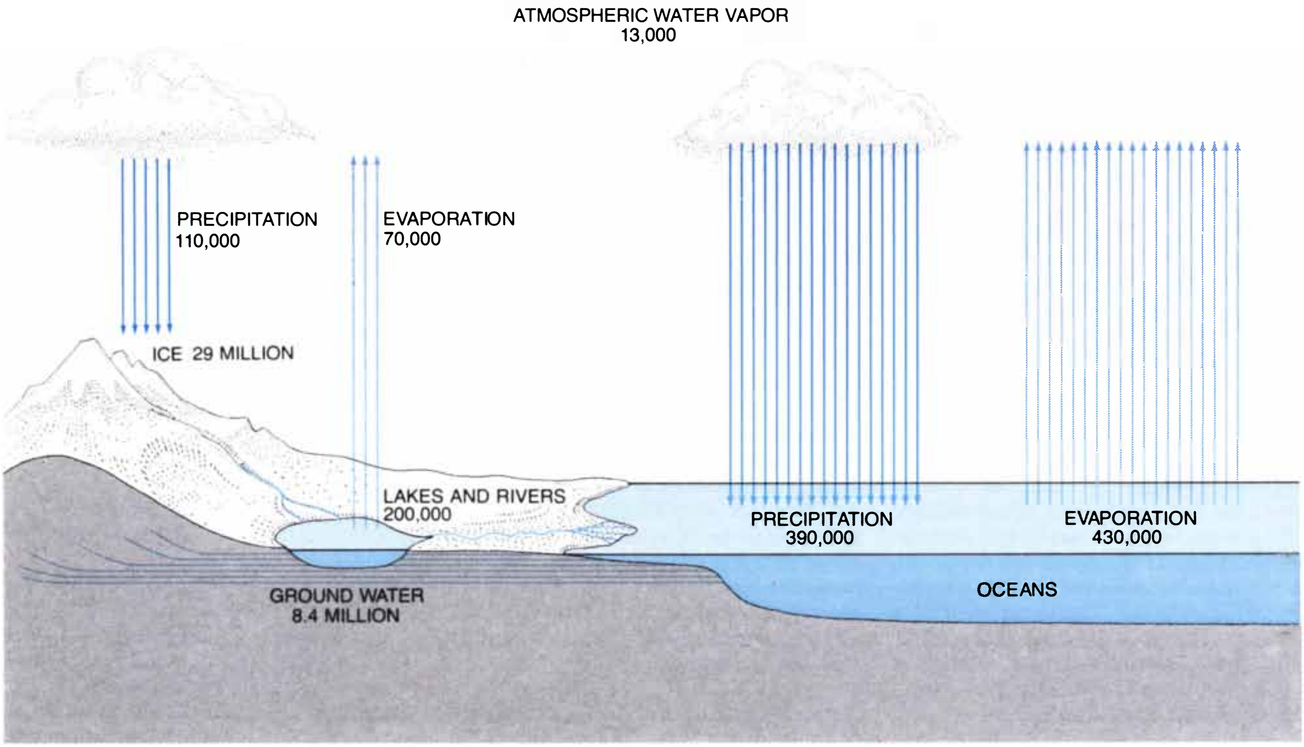
The adequacy of this overall supply can be gauged through a simple analysis of the per capita need for water. For this purpose it is convenient to measure volumes of water in smaller units: cubic meters rather than cubic kilometers. (One cubic kilometer is equal to a billion cubic meters.) To sustain an acceptable quality of life a society must provide its people with about 30 cubic meters of water per person per year for direct domestic consumption. Of this allotment less than one cubic meter is for drinking. (If the quantity of drinking water is small, however, it should be remembered that the need is an absolute one, which cannot be deferred; moreover, the water must be of the highest purity.)

Outside the highly industrialized countries, industry claims about 20 cu-

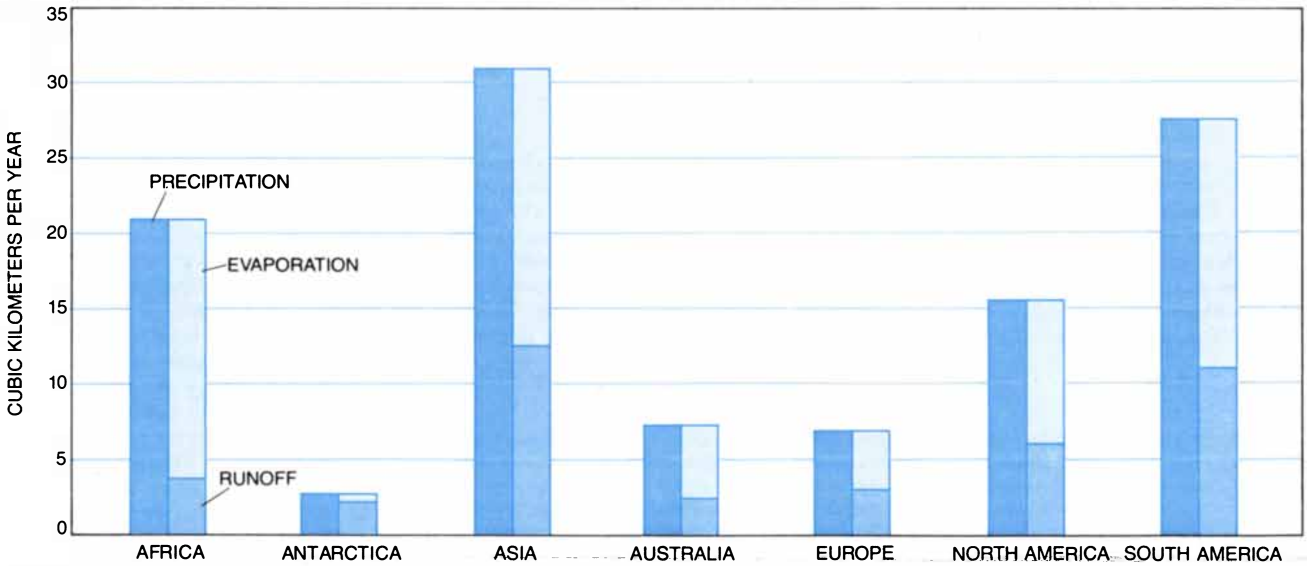
RIBBON OF CULTIVATED LAND bisecting the desert is the valley of the Nile, where a successful agrarian economy depends on the almost complete utilization of the river's waters. The Nile has supported irrigated agriculture since 3400 B.C., but until about 100 years ago most of the fields were watered only by the seasonal inundation of the floodplain. The land is now under perennial irrigation: water is impounded behind the Aswan High Dam, released on a regular schedule for downstream use and distributed by a network of canals. Some of the largest canals are visible in the false-color Landsat picture on the opposite page, which shows the region surrounding Luxor (Al-Uqsur) in eastern central Egypt, about 200 kilometers downstream from Aswan. The transition to perennial irrigation has greatly improved the efficiency of Egyptian agriculture: crop yields have almost doubled, and two or more crops a year can now be grown. The river itself is fully exploited in that essentially no water is discharged into the sea.

bic meters of water per person per year. By far the largest share of the supply goes to agriculture. To maintain a diet of 2,500 calories per day requires 300 cubic meters of water per year. In the wealthier nations, where the diet is commonly more than 3,000 calories per day, the agricultural water requirement is 400 cubic meters per year. In practice much of the agricultural demand is supplied directly by rainfall, so that it remains outside the water economy. Even if all farming were entirely dependent on irrigation, however, the total demand for water, including domestic, industrial and agricultural needs, would be only from 350 to 450 cubic meters per person per year. Given that average rate of consumption, the global water supply of 9,000 cubic kilometers per year (equal to nine trillion cubic meters) could support a world population of between 20 and 25 billion.

The flaw in this analysis is the implic-



HYDROLOGIC CYCLE of evaporation followed by precipitation is the ultimate source of all fresh water on the earth. Land areas receive a disproportionate share of the rainfall and snowfall, and as a result the continents have a net influx of 40,000 cubic kilometers of water per year. Reserves of fresh water greatly exceed this annual input, but most of the reserves consist of ice (in glaciers and the polar ice caps) and ground water. Lakes, streams and other surface waters, which are the main human supply, make up less than 1 percent of the total.



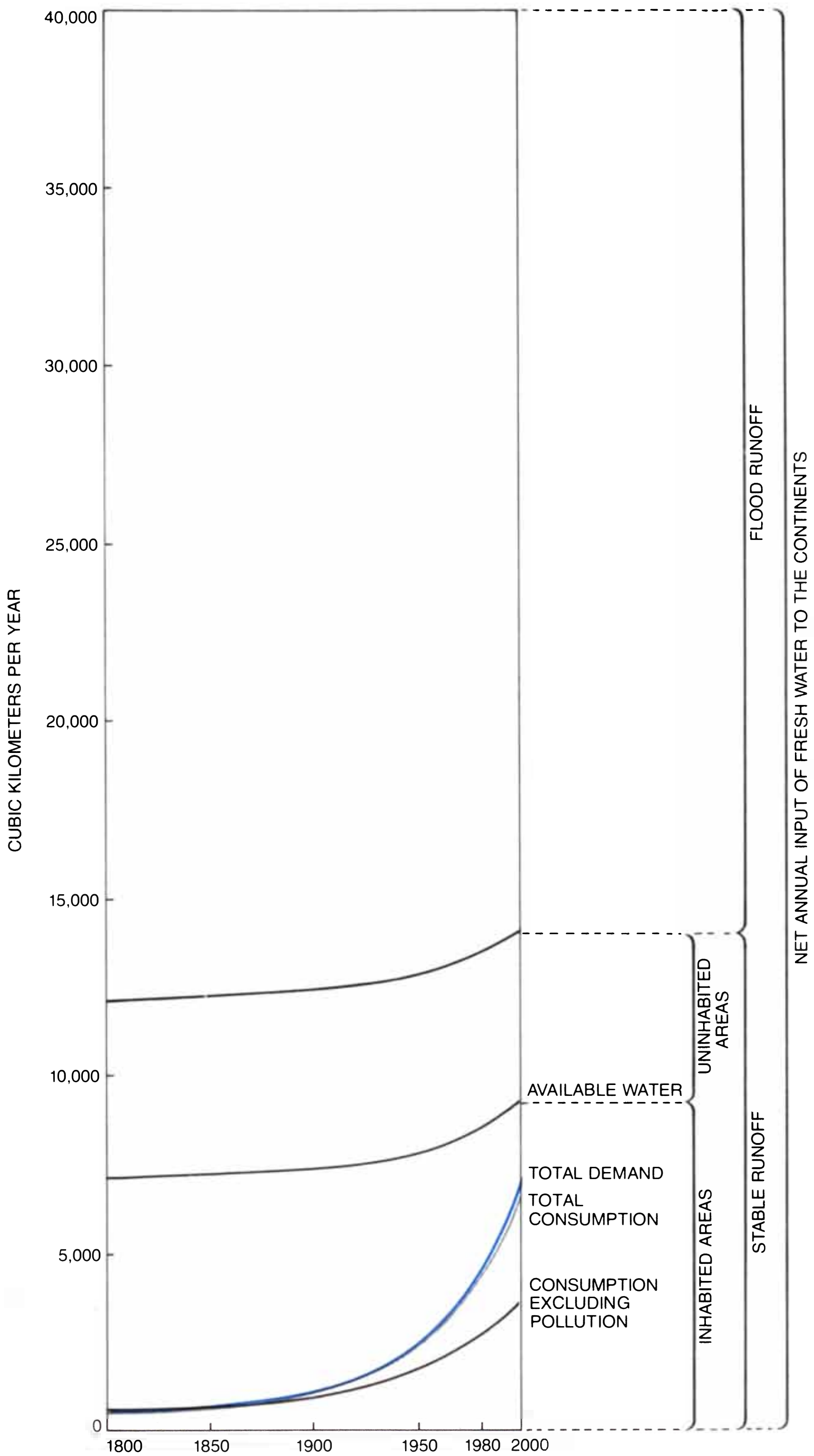
DISTRIBUTION OF WATER RESOURCES on the continents is determined by the balance of precipitation and evaporation. The difference between these quantities is the runoff carried by streams. Although the available quantity of water could support several times the present human population, the geographic distribution of water resources is uneven and there are seasonal variations in the supply.

it assumption that water is distributed over the earth in the same way as the human population. The actual distribution is quite different. The rural residents in the southwest of the Malagasy Republic survive on less than two cubic meters of water per person per year, which is little more than the biological minimum. For this marginal water supply, which is of poor quality, they pay $20 per cubic meter. In the U.S. and in other developed countries, in contrast, the urban population consumes 180 cubic meters per person per year and pays only $.10 to $.25 per cubic meter. Correcting such inequities is one of the goals of economic development.

Agriculture, which represents the largest demand for fresh water, is also the most sensitive to variations in the supply. More than 85 percent of the world's cultivated land is watered exclusively by rainfall. These rain-fed crops take advantage of an enormous volume of water, obtained at essentially no cost, much of which would not otherwise be of any benefit to man. In 1970 rain-fed agriculture consumed 11,500 cubic kilometers of water; in the same year 2,600 cubic kilometers were employed in irrigated agriculture on 12 percent of the world's cultivated land.

Considering the quantities of water required, irrigation obviously could not be extended to all the world's farmed land, even if that were desirable. Where irrigation is economically feasible, however, it brings at least four potential benefits. It often brings an absolute increase in the area under cultivation, particularly on arid lands that could not be farmed at all without irrigation. It can also increase the yield of a crop: the amount of grain, say, obtained per hectare planted. When irrigation is combined with other practices for increasing the efficiency of agriculture, such as the planting of improved crop varieties and the application of fertilizer and pesticide, yields can be increased by a factor of three or four.

A third way in which irrigation can augment total food production is by making it possible to grow more than one crop per year on a given tract of land. The raising of such multiple crops has the same effect on the food supply as an increase in the area under cultivation. Indeed, in measuring the harvested area of land the effects of multiple cropping are included by counting twice those areas that yield two crops and counting three times those that yield three. This procedure gives a simple measure of cropping intensity: the ratio of harvested area to the total area under cultivation. Because part of the land can be harvested more than once each year, the ratio can exceed 1. In rain-fed agriculture the cropping intensity worldwide is now .71, and it is expected to reach .76 by the end of the century. Under irriga-



GLOBAL WATER SUPPLY consists mainly of the base flow, or stable runoff, of rivers and streams. Of the net continental influx of 40,000 cubic kilometers per year all but about 12,000 cubic kilometers runs directly to the sea in floods. A small fraction of the flood water can now be captured by dams, so that by the end of the century the stable and regulated runoff will amount to 14,000 cubic kilometers. Of this amount, however, some 5,000 cubic kilometers flows in sparsely inhabited regions, such as rain forests; hence the total volume of water readily available at the end of the century will be about 9,000 cubic kilometers per year. Actual consumption then will be about 3,500 cubic kilometers, but water made unusable by pollution will effectively add another 3,000. Total demand, which includes requirements for water that is not consumed but must still be made available, will reach almost 7,000 cubic kilometers per year.

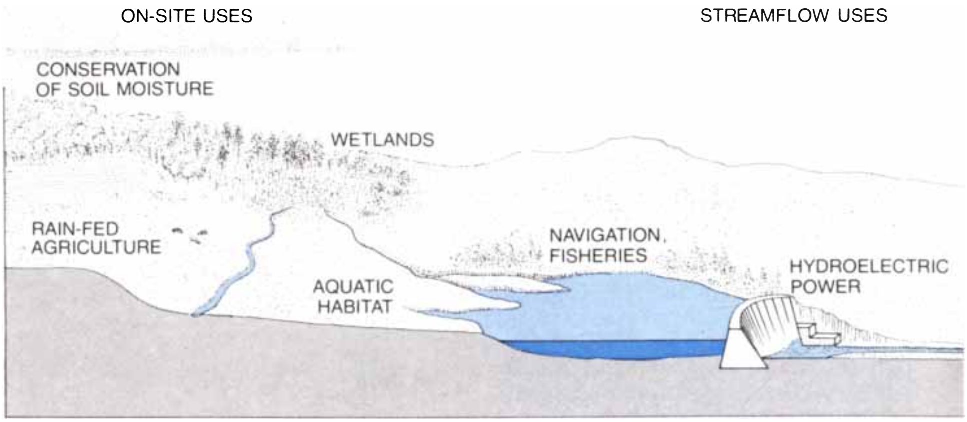
tion the cropping intensity is now 1.11, and an increase to 1.29 is expected by the year 2000. In three countries, Bangladesh, China and Egypt, where arable land is at a premium and there is a long tradition of intensive cultivation, the cropping intensity already exceeds 1.5. At the end of the century irrigated land will make up only 13 percent of the area cultivated, but because of differences in cropping intensity it will account for 22 percent of the harvested area.

A fourth benefit of irrigation is enhanced security for the farmer. Seasonal rainfall cannot be predicted with any reliability, and so there is a risk in rain-fed agriculture that after a crop is planted there will not be enough moisture for it to reach its full yield. Such a crop failure over a large area can lead to famine, but even when it is isolated, it is an economic disaster for the farmer. An irrigation system with a large reserve of water, either impounded behind a dam or in an underground aquifer, eliminates much of the risk. Years in which rainfall is scant need not curtail production, since the reserve accumulates over several years or many years. Knowing that an adequate supply of water is assured, the farmer may be more inclined to plant high-yield varieties (which tend to be intolerant of drought) and to invest in fertilizer, pesticides and farm machinery.

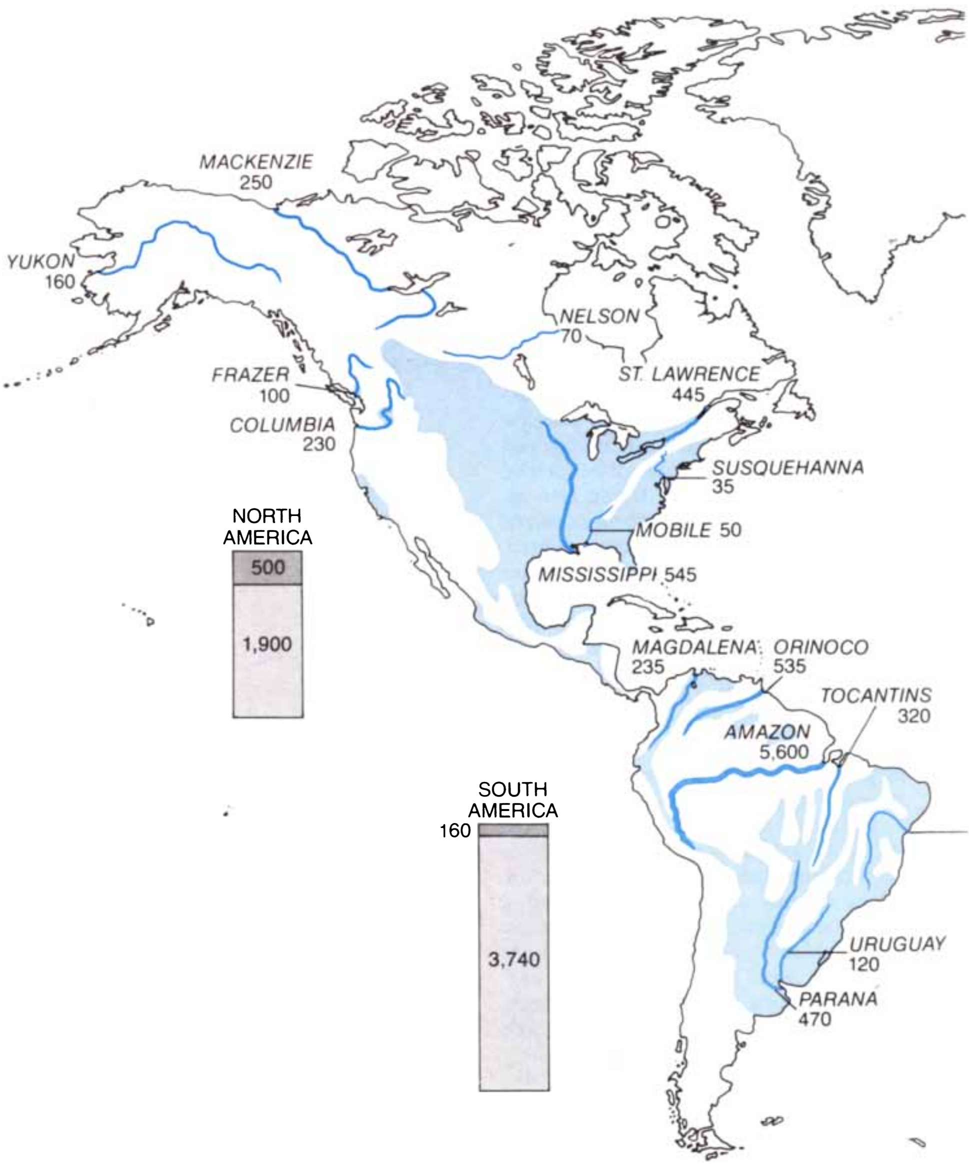
The great successes of irrigated agriculture are found mainly in Asia; indeed, 63 percent of the world's irrigation capacity is in southern Asia. In much of this region yields of rice and wheat have doubled and the cropping intensity has almost doubled too, reaching an average value of 1.3. As a result total production has increased almost fourfold. The most efficient agricultural system in the world is an Asian one and is almost entirely under irrigation. It is the system of Japanese rice culture, where .045 hectare of land suffices to provide 2,500 calories per day for one person. In the U.S. twice as much land is needed to provide the same diet, and under the Indian system of agriculture almost seven times as much land is needed.

Irrigation projects elsewhere in the world have been notably less effective in raising total food production. In Africa, Latin America and the Near East the cropping intensity of irrigated land ranges from .77 to 1.07, and there have been few significant gains in yield over the values that can be achieved with rain-fed agriculture. Africa is a particularly instructive case in that an ambitious plan to regulate water resources has been undertaken there, and yet the effects on agriculture (except on the Nile) have so far been disappointing.

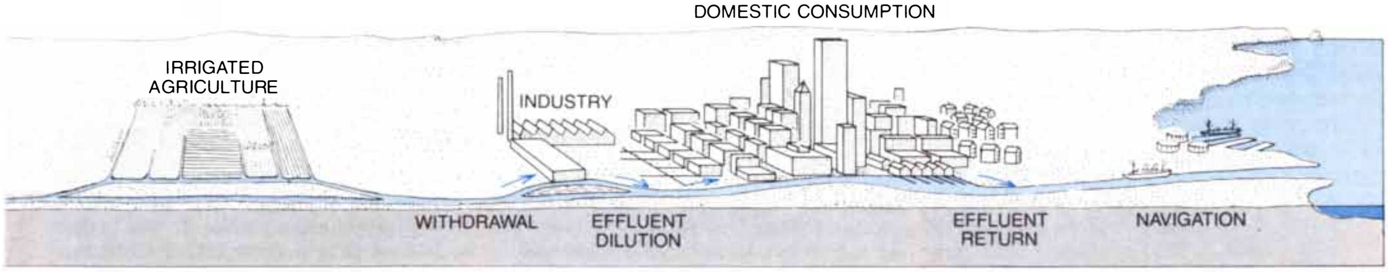
What feature of irrigated agriculture in southern Asia distinguishes it from that in the rest of the developing world? It is unlikely that any single factor can



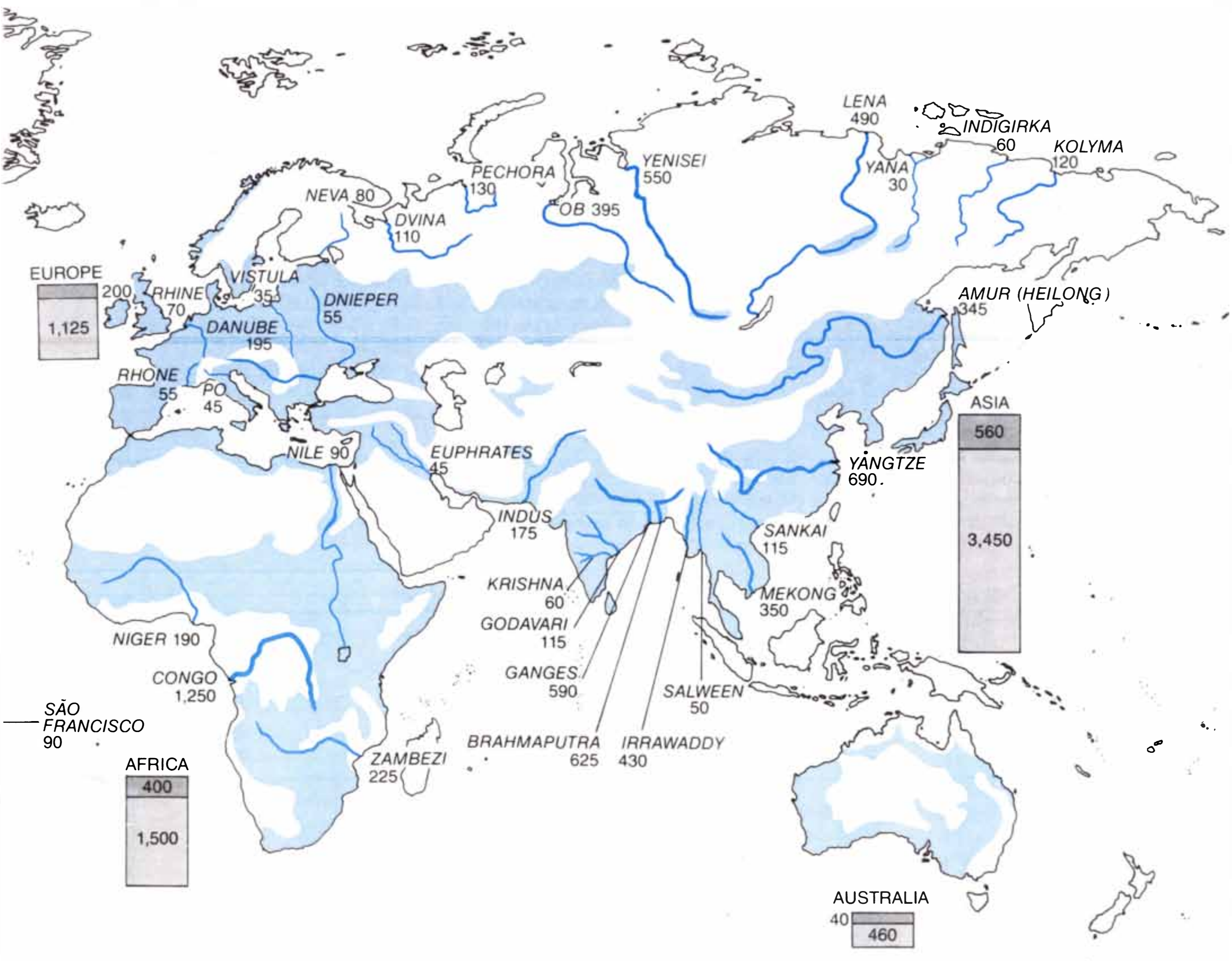
MULTIPLE FUNCTIONS can be served by a single volume of water in a well-managed watershed. On-site uses, the most important of which is rain-fed agriculture, benefit from water that in most cases would not otherwise enter the economy. Streamflow uses are often nonconsumptive in that the water remains available for further exploitation downstream, but they



MAJOR RIVER BASINS have long been the main focus of human societies, and they remain the most favorable sites for irrigated agriculture, for industry and for large cities. All rivers with an average annual discharge greater than 30 cubic kilometers are shown. The bar graphs give the stable runoff (in cubic kilometers) of all rivers on each continent, including the many small-



must still be counted among the demands made on the total supply. For example, maintaining sufficient river depth for navigation may require the release of water from a dam. Withdrawn water is sometimes consumed directly, as in irrigated agriculture, where much of the water supplied is lost through evaporation and through transpiration by plants. Withdrawals can also give rise to indirect demands: when water that carries pollutants is returned to a stream, additional water must be provided to dilute the effluent to an acceptable level.



er rivers that are not shown. The runoff is regulated by natural underground reservoirs (*light gray*) and by dams (*dark gray*). Some of the largest rivers are virtually unexploited because they flow through regions (*white areas*) where the terrain or climate is unsuited to large settlements. The Amazon and the Congo, which have the largest flows of all rivers, fall into this category. In the more densely populated parts of the world (*colored areas*) a number of smaller rivers (such as the Nile, the Indus and the Yangtze) have been intensively developed.

account for all the difference, but a plausible analysis might begin with an examination of the economic circumstances of the individual farmer. In most of southern Asia, where population density is high, arable land is scarce and expensive. A farmer who seeks to increase his production generally cannot do so by acquiring more land. He therefore has a strong incentive to adopt methods that promise higher yields or higher cropping intensity. In Africa and in Latin America the shortage of arable land is much less severe, and the successful farmer who finds he has surplus capital may conclude that additional land represents a more secure investment than improved agricultural techniques. It is worth noting that this situation can be expected to change in the coming decades. As population increases, a larger proportion of the arable land will be brought under cultivation, so that intensive agriculture may become more attractive economically.

It is apparent from the highly nonuniform results of irrigation projects undertaken in the past 20 years that there is more to the development of agricultural water resources than building dams and delivering water to the fields. Indeed, if the needs and the practices of the farmer are not taken into account, or if the hydrology of the soil is not understood, irrigation can occasionally do more harm than good. An example is the waterlogging of soil that results when large volumes of water are applied over a long period to flat land with poor drainage. Because the water cannot drain away it percolates through the soil and raises the level of the underground water table. When the ground water reaches the surface, the soil is said to be waterlogged and it becomes unsuitable for agriculture. If the water at the surface is allowed to evaporate, it leaves behind a residue of salts that further impair the fertility of the land. On the floodplain of the Indus in Pakistan some two million hectares of irrigated land has been rendered useless by this process.

The disaster of waterlogging and salinity buildup in Pakistan might have been avoided by improving the drainage of the soil and by pumping the ground water itself for irrigation instead of employing river water. Now that an extensive area has already been damaged, the remedy is straightforward but expensive and time-consuming. Water must be pumped from the ground over a wide area in order to lower the water table, and some of the extracted water must be recycled through the affected soil repeatedly to leach out the salts.

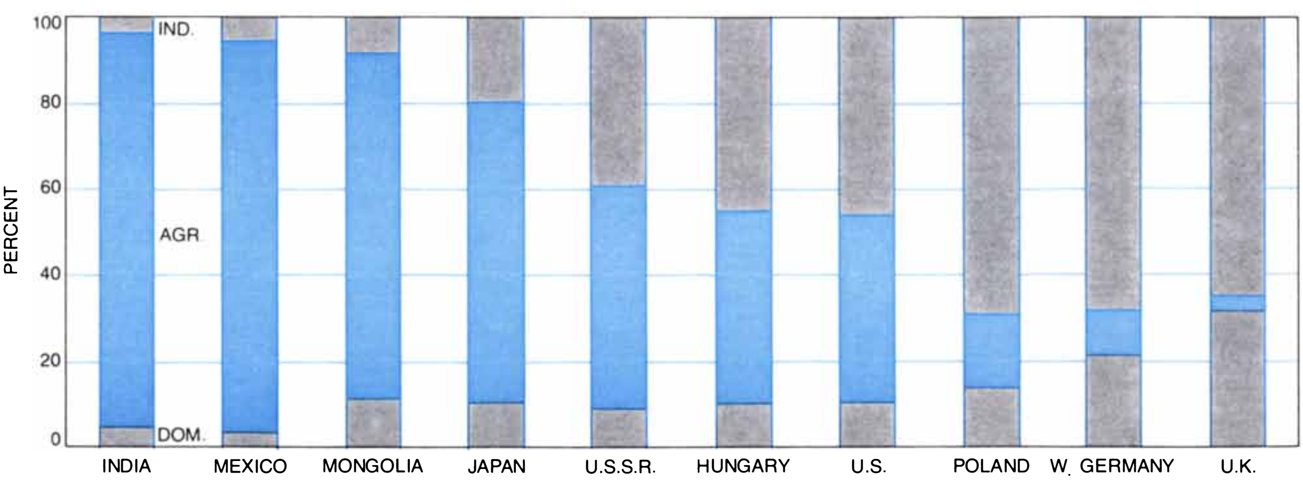
Another hazard of irrigation is the inadvertent propagation of waterborne diseases and parasites [see "People," by Halfdan Mahler, page 66]. Perhaps the most notorious of these diseases is schistosomiasis, a chronic, debilitating infestation with the blood flukes called schistosomes. The schistosomes spend part of their life cycle as parasites of certain aquatic snails, which thrive only in a stable, year-round supply of water. The mature schistosomes infect people who enter the water, and their eggs return to the water through human excreta. Schistosomiasis has been called a man-made disease because of its frequent association with public waterworks. The attribution is no doubt exaggerated, but the recent spread of the disease through Africa, Asia and South America is indeed correlated with the completion of large irrigation projects.

The rising incidence of schistosomiasis is particularly well documented in Egypt and the Sudan. The disease has been prevalent in communities on the Nile for millenniums. (Schistosome eggs have been found in mummies dated to 2800 B.C.) As long as the land was irrigated only by seasonal floods, however, the incidence remained low. With the recent transition to perennial irrigation a much larger proportion of the population has become infested—more than half in some regions—and one of every five deaths in Egypt is now attributed to schistosomiasis.

Under the conditions prevailing in rural areas of the developing countries schistosomiasis can rarely be cured. Schemes for prevention based on control of the snail population have also had disappointing results. In the Sudan a 10-year plan for combating schistosomiasis along the Blue Nile was recently begun; it will emphasize sanitation and regulation of surface water. Ultimately the most effective remedy for endemic schistosomiasis seems to be an improvement in the standard of living; that, of course, is precisely what irrigation itself is intended to bring.

In the developing countries agriculture often claims almost all the available water. In India and Mexico, for example, the share going to farming amounts to more than 90 percent of the total. In the U.S., on the other hand, industry and agriculture make about equal demands. Actually a more careful analysis might show that the same volume of water is put to use repeatedly in industry and agriculture and for such other purposes as navigation and the generation of hydroelectric power before it is discharged to the sea.

The industrial demand for water in the developing countries is generally from 20 to 40 cubic meters per person per year, comparable to the volume of domestic consumption. Industrial demand in the U.S. is roughly 100 times greater: 2,300 cubic meters per person per year. A few industries account for



ALLOCATION OF WATER to agriculture, industry and domestic consumption is influenced most strongly by the importance of irrigated agriculture in a nation's economy. Worldwide, irrigation claims more than three-fourths of the available water supply, but in such countries as India and Mexico the proportion is higher still. In Japan farming is a much smaller segment of the economy, but the agricultural demand for water remains high because almost all crops are grown under irrigation. The quite different allocation characteristic of the U.S., Poland, West Germany and the U.K. reflects not only a larger industrial need but also more extensive rain-fed agriculture.

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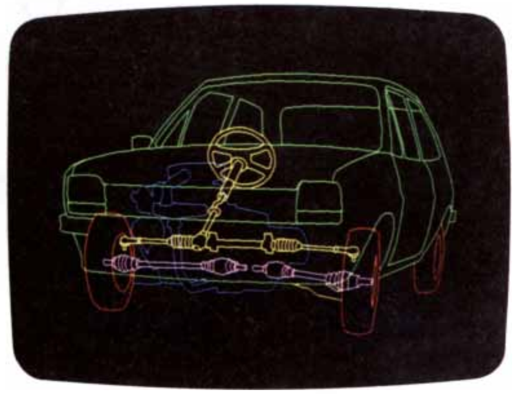

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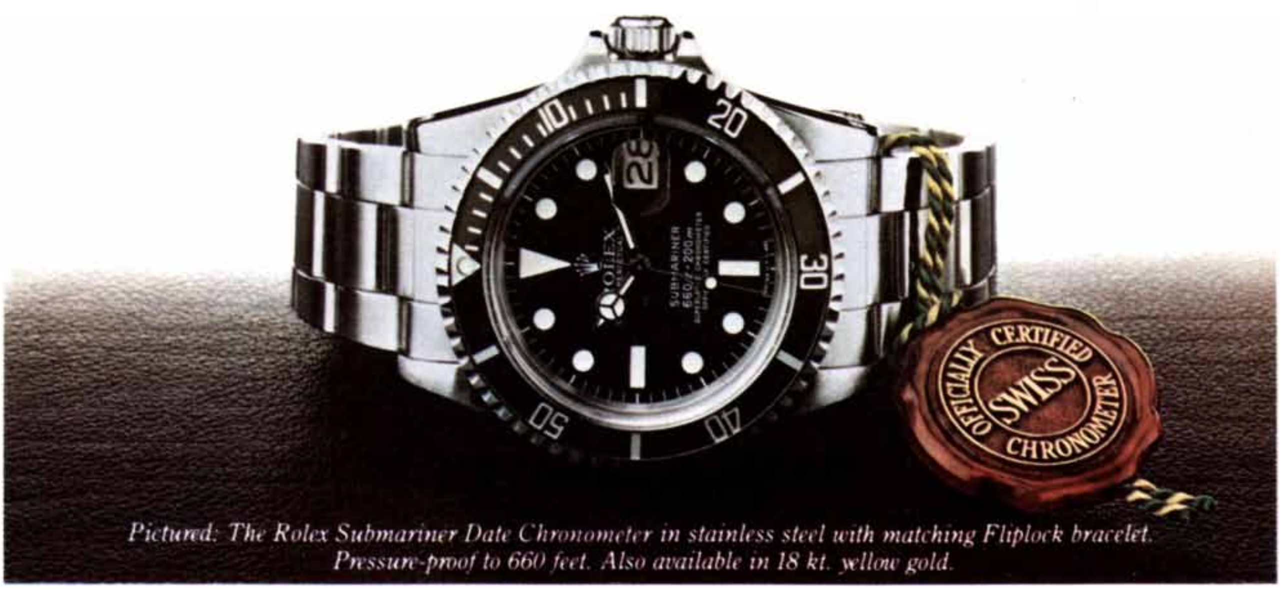

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some two-thirds of all the demand: they are metals, chemicals and petroleum refining, pulp and paper manufacturing and food processing.

Much of the water used is not "consumed" in the usual sense. From 60 to 80 percent of the industrial demand is for cooling water, mainly in electric-power generation. Almost all the water withdrawn for cooling is subsequently returned to the streamflow, unchanged except for a rise in temperature. Even so, it is important to recognize that the demand for this water is not thereby eliminated from the water budget. If a generating plant is built downstream from a dam, enough water to supply the cooling needs of the plant will have to be released continuously from the reservoir and will therefore be lost to further use upstream.

Often industrial water is returned to the streamflow bearing a load of pollutants. In that case the total demand must include not only the water actually withdrawn but also a streamflow volume sufficient to dilute the pollutants to an acceptable level. The same calculation should be applied to water for domestic consumption, which is also returned to the streamflow bearing wastes. The pollution load of a lake or a river is usually measured in terms of the dissolved oxygen consumed in the biological degradation of the wastes. If the process of degradation is to be a continuous one, the concentration of dissolved oxygen must not be allowed to fall below the level needed to support aerobic forms of life. Toxic pollutants require special handling, since they can make water unfit for all further use.

The generation of hydroelectric power is a distinctive industrial use of water in that it is entirely nonconsumptive. Of course the water must be released from a reservoir in order to generate electric power, so that the hydroelectric generation must be counted among the demands made on the supply. Usually, however, water would have to be released anyway in order to serve the needs of downstream industries and communities; if it is released, the falling water may as well give up its potential energy usefully in a turbine. As it happens, the economics of hydroelectric-power generation are so appealing that almost all the best sites have already been exploited. For those sites that remain the question is whether the energy extracted can repay the capital costs of construction. Sites of smaller capacity may become competitive with other energy sources as the price of fossil fuels continues to rise.

Navigation of inland waterways is a nonconsumptive use that nonetheless makes a large demand on water resources. Behind a dam the maintenance of a high water level in order to make navigation possible enlarges the surface area of the reservoir and thereby increases the loss of water through evaporation. Below a dam, maintaining the navigability of a river usually requires the release of large volumes of water. A controlled waterway, with locks for changes in level, can reduce this demand somewhat, but the locks themselves need water for their operation.

In a comprehensive plan for water management certain other uses of the water, such as fisheries, cannot be neglected. The maintenance of swamps and wetlands for wildlife represents a large demand on water resources because the rate of evaporation and of transpiration through plants is exceptionally high in such environments. In some circumstances water may also have a scenic, ornamental or recreational value. The fact that some of these demands for water are not incompatible and can be met by recycling the same water several times complicates the task of planning and allocation. By exploiting all such opportunities for multiple or successive use, however, the water supply is effectively enlarged.

The principal method of regulating the water supply—the damming of rivers—has the significant advantage of satisfying several needs at once. By controlling floods a dam can make safely habitable some of the world's most fertile land, that in the floodplains of major river valleys. By capturing flood waters that would otherwise run direct to the sea a dam actually augments the total water supply available to man, unlike other techniques that merely tap existing reserves. In regions subject to a monsoon, where almost all the yearly rainfall comes in a few weeks, such water management is imperative: the flood must be impounded and measured out over the course of the year. By raising the water level a dam also aids in the delivery of water to gravity-fed irrigation systems, and of course it holds the potential for generating hydroelectric power.

The preeminent system of dam building in the 20th century is that of China, where some 70,000 dams and reservoirs have been completed in the past 30 years. They are mainly small dams, but they have an aggregate storage capacity of more than 300 cubic kilometers. If construction continues at the present rate, another 50,000 reservoirs will be created in the coming decade, adding another 150 cubic kilometers to the total capacity. China has emphasized small dams in order to reduce the costs of construction. The technology employed is simple, so that almost all the work can be done by the local population.

Construction costs of larger dams have been rising steeply. For each cubic kilometer of capacity in the reservoir formed by a large dam the capital expenditure is now estimated to be $120 million. A cubic kilometer of water will irrigate an average harvested area of 85,000 hectares. Even at this price large dams and the associated irrigation system may be the technology of choice in some cases. In estimating the economic benefits of an irrigation project, however, the question to be answered is whether the value added to the agricultural produce of the region will pay back the investment. Today there is a good possibility that water from some other source will provide the same added value at a smaller initial cost.

Another economic and technological issue in dam construction is the deposition of silt in reservoirs. The silt is picked up by streams from the soil of the watershed, and it remains in suspension as long as the water is moving. In the still waters of an artificial lake the silt settles to the bottom. If the accumulated sediments are not removed, and if nothing is done to arrest their deposition, the entire reservoir will eventually be filled with silt. Depending on the quantity of solids suspended in the streamflow, the time required for the process ranges from a few decades to several centuries.

There are solutions to the silting problem, but they are costly. The dam can be heightened to enlarge the reservoir; the sediments can be dredged; a second dam and reservoir can be built upstream to serve as a silt trap. In the long run the most effective solution may be the adoption of soil-conservation practices in the watershed. If any of these measures are taken, their projected cost should be included in the cost of the irrigation project; if silting is not controlled, it must be recognized that the reservoir is a finite resource that will be exhausted and require replacement in a period of years. The value of the dam should therefore be depreciated over that period.

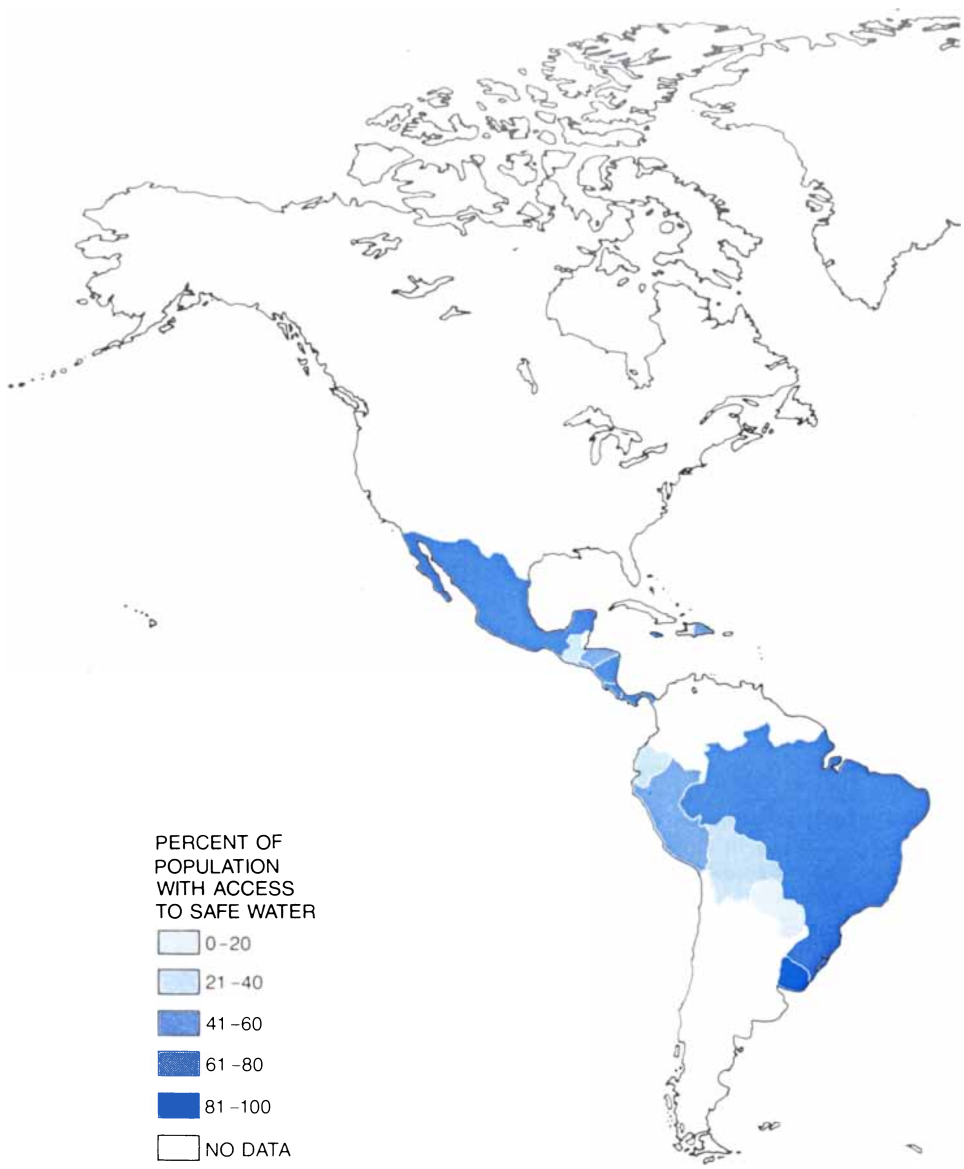
In spite of these costs the major river valleys will surely remain the primary focus of human civilization, as they have been for 6,000 years. They supply both the land and the water resources needed for irrigated agriculture. Moreover, because the rivers offer abundant water both for consumption and for transport they are also the logical site of major industrial development; cities have grown up on the riverbanks for the same reasons.

The resources of the world's rivers are in widely varying stages of development. The two rivers with the largest annual flows, the Amazon (5,600 cubic kilometers) and the Congo (1,250 cubic kilometers), are almost entirely unexploited because they flow through inhospitable rain forests. Large rivers draining into the Arctic Ocean, such as the Mackenzie in Canada and the Ob and Yenisei in the U.S.S.R., are also virtually unutilized. At the opposite extreme the Nile, which has a natural flow of only 90 cubic kilometers per year, is completely developed: since the mid-1970's, when the reservoir behind the Aswan High Dam was filled, the Nile has ceased entirely to flow into the sea. Its waters now serve one of the largest irrigated areas in the world, amounting to five million hectares. Elsewhere in Africa the Volta and the Zambezi have both been dammed to create large reservoirs; indeed, Kariba Lake on the Zambezi is the largest artificial reservoir in the world. The management of the Niger and Senegal basins and of the several rivers flowing into Lake Chad is being planned by commissions of the countries bordering those rivers.

Asia has the largest volume of dam-regulated streamflow of all the continents: 560 cubic kilometers per year, most of it dedicated to irrigation. All the large rivers in southern and southeastern Asia, such as the Yangtze, the Mekong, the Irrawaddy, the Brahmaputra, the Ganges and the Indus, have been developed to some extent, but much capacity remains unexploited.

In Europe and the U.S. a few rivers support large irrigation works; notable among them are the Colorado and the Tisza, a tributary of the Danube where development began in the mid-19th century and is expected to achieve complete regulation by about the year 2050. A number of other rivers have been dammed for extensive flood-control and hydroelectric projects; examples are the Columbia and the Tennessee. For the most part, however, another pattern of river-basin development has prevailed, emphasizing industry, navigation and waste disposal. Many of the rivers in Europe and the U.S., such as the Rhine, the Ruhr and the Mississippi, function mainly as commercial thoroughfares.

Although regulation of natural rivers and streams by dams will remain the



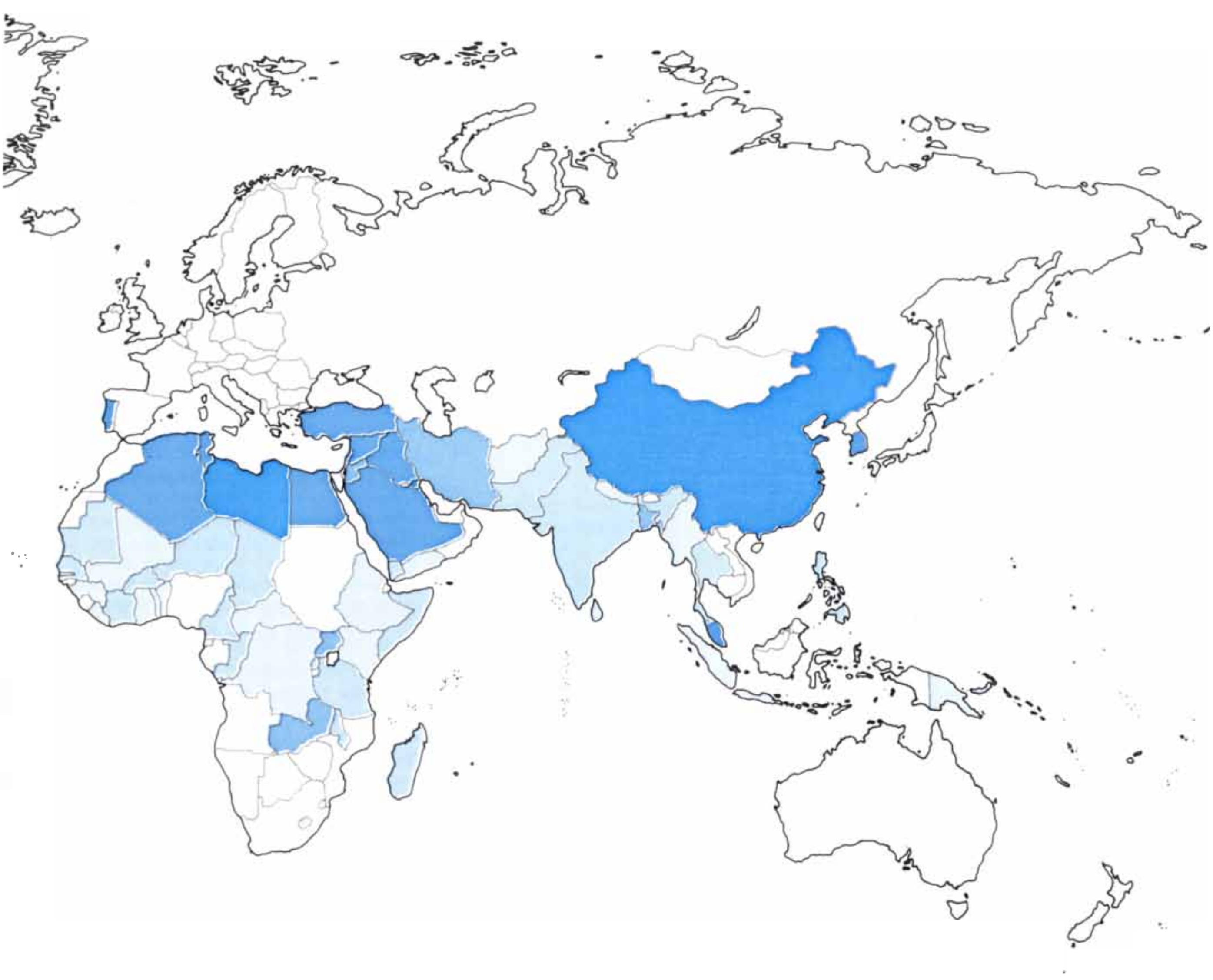
ACCESS TO POTABLE WATER is a basic index of economic development, and through its influence on the health of a population it can help to determine the pace of development. In more than half of the developing countries less than 50 percent of the population has a source

predominant method of water management for many decades, other sources of supply also deserve consideration. The most important of these sources is ground water, which constitutes the major part of the world's reserves of fresh water outside the polar regions. In arid countries, where evaporation generally exceeds precipitation, ground water is usually the only stable indigenous supply. Even where surface water is available, however, it is occasionally cheaper or otherwise preferable to pump out ground water.

In the Libyan Desert the Sarir project has tapped a natural underground reservoir to irrigate 15,000 hectares of desert land. The water is delivered to the crops by the technique of center-pivot irrigation, in which a circular field is watered by a long, pivoting sprinkler arm, fed by a submersible pump at the center. In 1976 a pilot area of 4,000 hectares produced 12,000 metric tons of grain by extracting 40 million cubic meters of water from the aquifer.

Although the Sarir program is a high-cost and high-technology one, an appealing feature of ground-water development is that in some instances it can be done cheaply. Whereas obtaining a cubic kilometer of water by building a large dam costs $120 million, the same volume of water could be extracted from underground reservoirs for a capital cost of between $30 and $50 million. In Bangladesh, where a high water table and soft alluvial soil favor ground-water development, underground reserves are being tapped by simple case wells, or tube wells, with an installed cost of about $100 each. A three-man crew can sink the well and assemble a hand pump in about three hours. Bangladesh now has 450,000 such wells, which provide drinking water for 70 percent of the rural population. The goal is to serve the entire rural population with 700,000 wells by 1985.

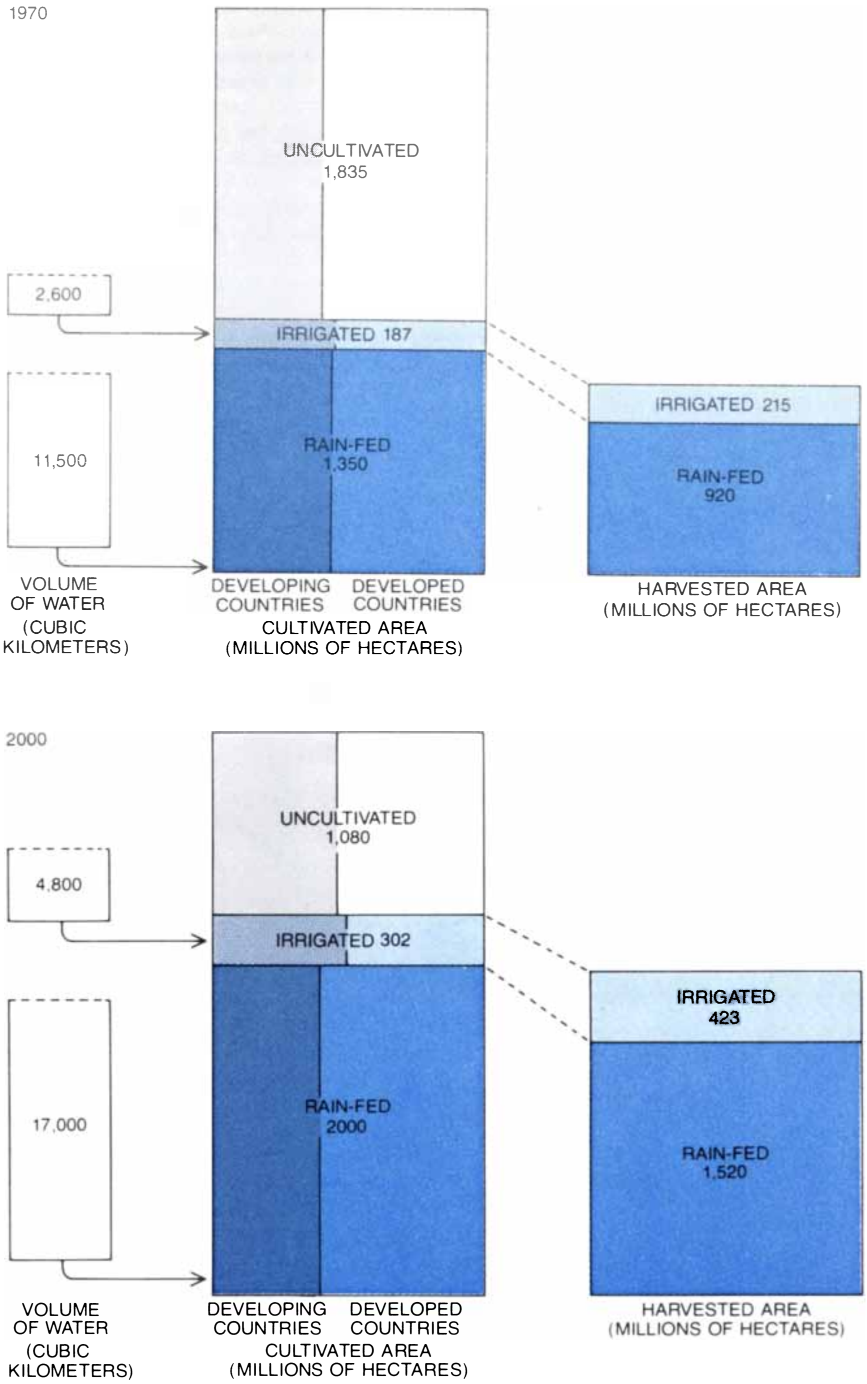
One of the most ambitious of all water projects would divert from their natural course the two largest rivers in northern Asia, the Ob and the Yenisei. The rivers now cross thousands of kilometers of sparsely inhabited permafrost and drain into the Arctic Ocean. The plan calls for a series of immense dams and canals to carry the water instead to the southwest, across warmer and potentially arable territory, discharging into the Aral Sea. A similar proposal would divert the Mackenzie River from its present channel across the Canadian Arctic. It is not yet known what effect such large-scale intervention in the wa-



of safe drinking water or facilities for sewage disposal. In rural areas the proportion without such access is generally higher. A plan conceived in 1976 calls for building standpipes, latrines and sewers to ensure a safe community supply throughout the world by 1990. The amount of water needed is comparatively small, but the cost of $200 billion greatly exceeds the recent rate of investment in such facilities.

ter cycle might have on the arctic environment or on global climate.

In areas of severe and sustained shortage, where water becomes the limiting factor in economic development, more exotic measures may be considered. The distribution of precipitation might be altered by cloud seeding or by other techniques of weather modification. Evaporation loss from reservoirs, which is the major cause of depletion in dry climates, might be reduced by spreading oil or some other substance on the surface of the water. Waste water might be reclaimed, and underground reservoirs might be recharged from surface supplies, including supplies of treated waste water. Desalination of seawater is an established technology, although it is expensive and likely to become more so as the price of fuel goes up. An idea that deserves serious consideration is the hauling of water by supertankers. Saudi Arabia has examined the possibility of towing icebergs to the Persian Gulf from arctic or antarctic waters.



AVAILABILITY OF WATER FOR AGRICULTURE is often the determining factor in the productivity of the land. Of an estimated world total of 3.4 billion hectares of potentially arable land less than half was cultivated in 1970, and only about 5 percent was under irrigation. The irrigated land makes a disproportionate contribution, however, to the total harvested area (which is defined as the actual area of land multiplied by the cropping intensity, or the number of crops harvested per year). In irrigated agriculture the cropping intensity is often greater than 1, whereas on land watered exclusively by rain it is almost always less than 1. By the end of the century irrigated land will make up more than a fifth of the world's harvested area. Much of the newly irrigated area will be in the developing countries, where the need for food is greatest. The water requirements for irrigation, given here in cubic kilometers, will almost double.

A few of these schemes hold some promise, but they are not likely to be adopted by any but the richest countries, and even there they can make only a marginal contribution. For example, in the past decade Saudi Arabia has installed plants capable of desalinating 150 million cubic meters of seawater per year; in the same period, however, the country's demand for water has increased by 900 million cubic meters.

By the end of the century some 30 countries are expected to have a demand for water that exceeds their maximum sustainable supply. For a time the demand could be met by depleting accumulated reserves (such as ground water), but overdrafts on a natural resource cannot continue indefinitely. It then becomes necessary to manage the demand as well as the supply, so that the available water can be allocated to those who need it most and to those uses promising the greatest economic return.

In this respect the experience of Israel is instructive. Israel already exploits 95 percent of its natural water resources and has begun to employ extraordinary means of stretching the supply, including desalination and the artificial recharging of aquifers. The reclamation of waste water makes an important contribution to the water budget: 20 percent of industrial and domestic waste water is recovered, mainly for use in irrigation. Further increases in the supply are certainly possible, but the wisdom of investing in them is questionable if the cost of the water obtained is greater than the economic return to be derived from it. Better results have been achieved by regulating consumption to increase the efficiency with which water is employed. Because of such policies the value of crops harvested per unit of water supplied has been increasing by 7 percent per year. In industry the amount of water consumed per $100 of production dropped from 20 cubic meters in 1962 to 7.8 in 1975. (These amounts have been adjusted for inflation and are expressed in constant 1975 dollars.)

In the Canary Islands water consumption already greatly exceeds all renewable supplies, and the deficit is being made up by mining ground water. The economy of the islands is based on irrigated cultivation of tomatoes and bananas and on a growing tourist indus-

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try. In recent years, however, the most important market commodity has been water, the bulk of which is privately owned. Sales of water amount to $200 million a year, which is comparable to the value of the agricultural product, but the return on investment is 50 percent for water and only 1.5 percent for agriculture, even with government subsidies. At the present rate of extraction all the available water will have been exhausted within two decades. If agriculture is to survive in the Canary Islands, drastic changes in water policy will be needed. Perhaps the most important of them will be the cultivation of crops that require less water and have a higher cash value.

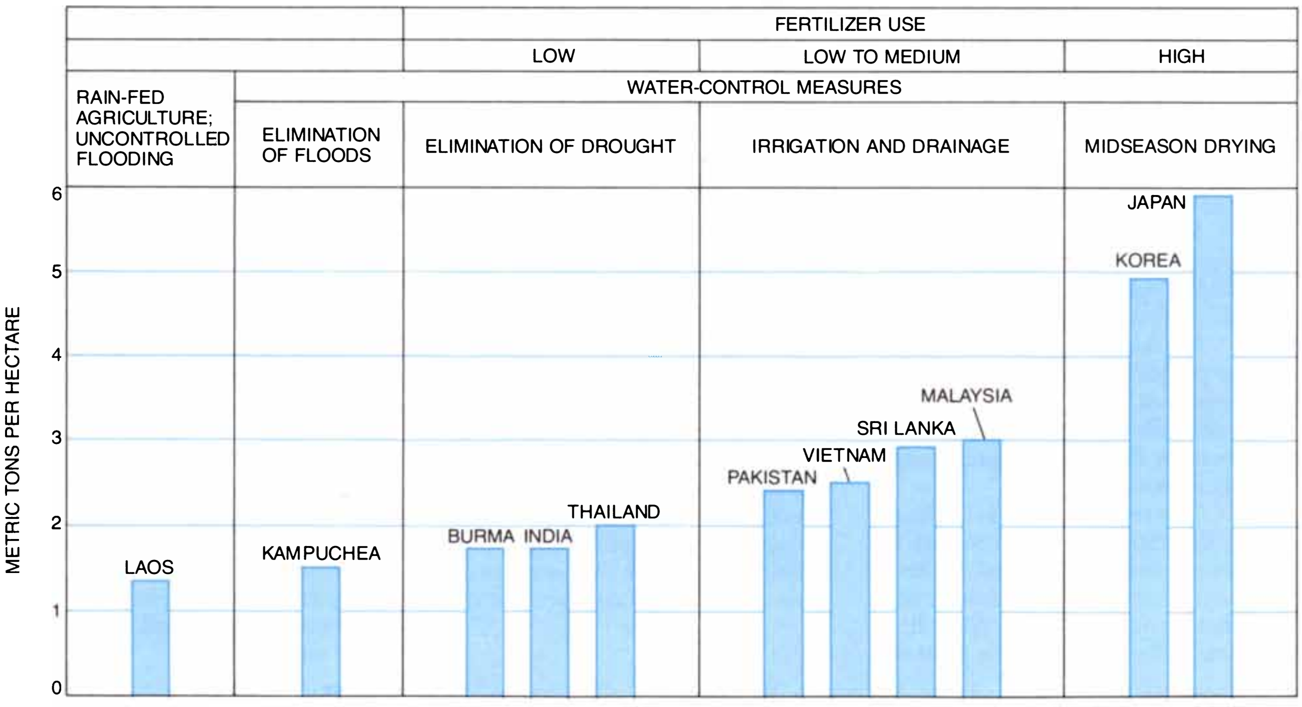
A chronic shortage of water is also in prospect for the state of California, where the present consumption of 41.3 cubic kilometers per year exceeds the renewable supply by 12 percent. Even if there were no further growth in the economy of California, demand would continue to increase, reaching 43.8 cubic kilometers per year by the year 2000. Practical sources of supply remain untapped but any program to exploit them will itself have a lead time of about 20 years. On economic criteria alone the best strategy of water use in California may be a shift from irrigated agriculture, where the value added is $75 million per cubic kilometer of water, to industry, with a value added of $5 billion per cubic kilometer.

Investments in the development of water resources have rarely exceeded 1 or 2 percent of the gross national product. In most countries they cannot be raised much above that level without causing hardship elsewhere in the economy. Capital is a resource in shorter supply than water, and the same strategies must be adopted for its conservation. Just as water is allocated to those uses for which it provides the greatest economic return, so investment in water technology should be made where it yields the greatest improvement in the quantity or the quality of water.

In agriculture the rehabilitation of existing irrigation works promises far greater benefits for a given rate of investment than the extension of irrigation to new lands. Renovation of reservoirs and distribution canals in the developing countries is estimated to cost $680 per hectare, and improvement of drainage and correction of the salt balance of the soil would add another $240 per hectare. The Food and Agriculture Organization of the United Nations has assigned such rehabilitation a high priority for the coming decades. Constructing new irrigation works of the same kind, including a drainage system, would cost $3,800 per hectare. For irrigation based on large high-technology dams the cost might reach $8,000.

In many of the developing countries, particularly in rural areas, the most urgent need is for safe drinking water and for waste-disposal facilities. By 1990 more than a billion people will have no reasonable access to potable water of acceptable quality. The amount needed is not large compared with the demands of agriculture, but the per capita cost of distribution can be very high. An ambitious plan to meet these needs was formulated in 1976 at the HABITAT Conference in Vancouver, and it was endorsed the following year by the World Water Conference, which met at Mar del Plata in Argentina. The plan calls for building standpipes, latrines, sewers and other facilities in order to ensure an adequate community water supply everywhere in the world by 1990. The goal is exemplary, but it is unlikely to be attained. The cost would approach $200 billion, which could be paid only by doubling the rate of investment in urban areas and quadrupling it in rural areas. A more realistic plan, based on less elaborate technology and calling for greater participation by the local population, might bring a significant improvement in water quality at a cost of $30 billion.

Although the projected global demand for water will remain well below the total amount potentially available for many years to come, the global surplus offers no consolation to those countries and regions facing a chronic water shortage. For such areas only two strategies are available: to increase the supply by investing in dams and other measures for the control of the water cycle, and to manage the demand, so that the available water is applied to the most urgent needs and utilized with optimum efficiency. Both approaches may be necessary, but with the increasing cost of investment capital, particularly for the developing countries, the latter approach is becoming the more attractive one.



EFFECTS OF IRRIGATION and other measures of water control on crop yields also enhance agricultural productivity. Yields of rice per hectare of land are given here for 11 Asian countries with diverse agricultural technologies. By doubling the yield and almost doubling the harvested area, irrigation and associated practices (such as the application of fertilizer) result in a fourfold increase in productivity.

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Energy

The future growth in the global demand for energy will come mainly from the less developed countries. If the demand is to be satisfied, the transfer of technology from the developed countries is essential

by Wolfgang Sassin

The world economy entered a new era in 1973, when the Organization of Petroleum Exporting Countries (OPEC) announced the first in a series of sharp increases in the price of crude oil sold on the world market. The sudden, widespread recognition of the finiteness of the earth's liquid fossil-fuel resources, brought on largely by the OPEC action, has left the majority of petroleum-importing countries—developed and less developed alike—in a continuing state of shock and uncertainty, which has come to be epitomized as the "energy crisis." It is not possible to predict with any confidence how long the transition to a stabler world energy perspective will last or exactly what its outcome will be. What is clear is the need, more urgent now than ever, to reevaluate the role of energy consumption as both the prime mover and the key indicator of economic development.

For the past six years my colleagues and I in the Energy Systems Program of the International Institute for Applied Systems Analysis (IIASA) at Laxenburg in Austria have been conducting just such a reevaluation, with a view to projecting a range of possible future trends in the world's energy supply and demand. In this article I shall draw heavily on the results obtained so far in that continuing study.

From the beginning of the Industrial Revolution, dating at least from James Watt's steam engine of the 1760's, energy conservation has been an integral part of the strategy of development. Various lines of technological progress, ranging from the invention of new mechanical devices to the development of industrial chemical processes, are characterized by a steady improvement in performance measured in terms of energy efficiency [*see top illustration on next page*]. The success of the basic engineering doctrine of "doing more with less" has resulted in a proliferation of "technical slaves" capable of substituting for human labor or animal power. The food the slaves consume is energy.

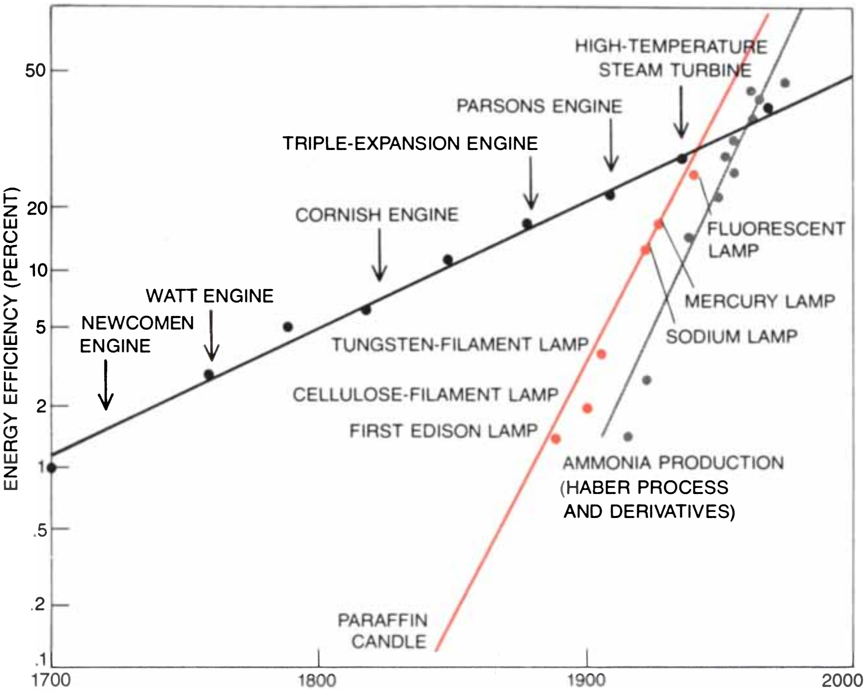
The acceleration of modern technology, fueled by a seemingly limitless supply of cheap oil, was particularly rapid in the already industrialized countries of the capitalist and communist blocs (respectively the "first world" and "second world") in the first decades after World War II. Recently the trend toward ever greater energy efficiency and hence greater opportunity for economically feasible energy use has been augmented in these countries by the advent of automatic information-handling systems to help supervise the work of the technical slaves. The result is a world in which the distribution of energy consumption is grossly uneven.

As of 1975 the average rate of energy consumption in the world was approximately two kilowatt-years per person per year, or in simpler terms two kilowatts of quasi-continuous power per person. The average American consumed some 11 kilowatts, however, whereas the average inhabitant of the less developed "third world" consumed less than a kilowatt. (The average European accounted for about five kilowatts.) Since there is a well-established correlation between the energy input to a national economy and its economic output, measured in monetary units such as dollars, a graph representing the worldwide distribution of the consumption of energy also serves as a fair approximation of the spectrum of economic activity [*see bottom illustration on next page*].

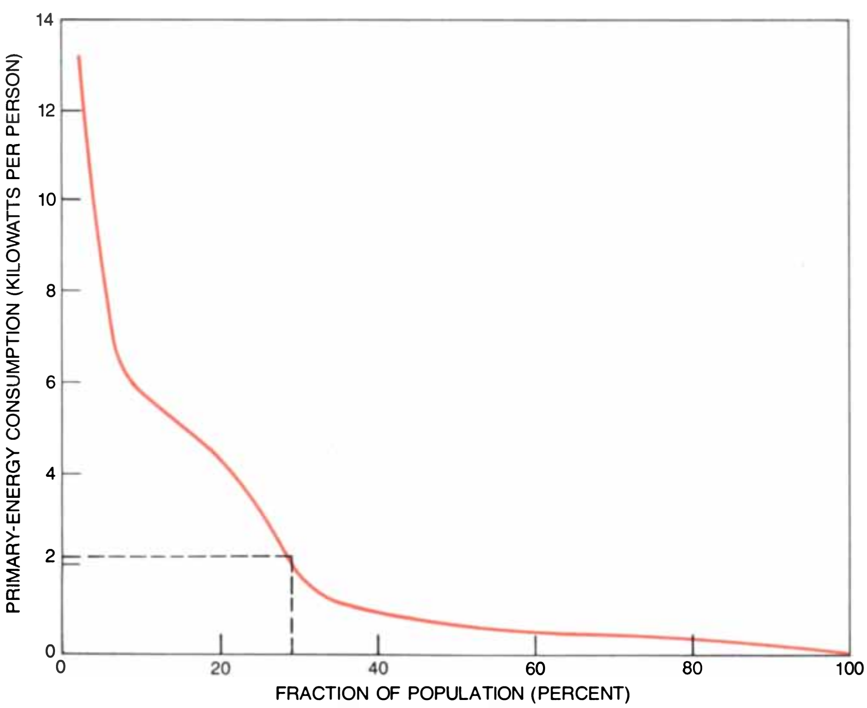
There is no doubt that the further spread of modern technology to the less developed parts of the world will result in a greatly increased demand for energy, aggravating the energy crisis. The only real uncertainties concern the rate and the ultimate extent of the growth in energy demand, and the makeup of the energy resources that will be called on to meet it. In order to investigate the potential future evolution of the global energy balance under these circumstances the IIASA Energy Systems Program has sought first of all to quantify as many as possible of the variables that have a bearing on this vital issue.

The task of quantification is complicated by many factors, among them the difficulty of determining the energy efficiency of a nation's productive capital stock (as technical slaves are usually called by economists). Normally one adds the theoretical heating values of the various forms of energy entering an economy and then compares this primary input with the designed output of the productive capital stock. Alternative primary forms of energy can differ widely, however, in their actual utilization. Some can be easily transported,

TSAIDAM BASIN, an extremely large interior sedimentary basin occupying much of northwestern Qinghai Province in the sparsely inhabited western part of China, is potentially a major energy-resource basin. Formed during the Mesozoic and Cenozoic eras, the basin covers an area of approximately 100,000 square kilometers. Exploration for evidence of fossil-fuel deposits began here in the mid-1950's, and several oil and gas fields have since been discovered and opened for production. Exploratory drilling is currently centered in the westernmost part of the basin, including the area shown in the enhanced false-color Landsat mosaic on the opposite page, made by digitally merging two consecutive Landsat scenes acquired as the satellite moved along its roughly north-south polar orbit. The mosaic was prepared by staff scientists at the U.S. Geological Survey's EROS Data Center who are participating with researchers from China's Ministry of Petroleum Industry in a joint program to investigate the applicability of remote sensing by satellite to petroleum exploration. Members of the U.S. team who visited the arid, perennially windswept site last year reported seeing numerous drill rigs operating in the area just north and east of the lake near the center of this image, particularly in the vicinity of an outcropping known to the Chinese as Yushashan (Tar Sand Hill). Before the establishment of the People's Republic in 1948 China was a net importer of petroleum; today its petroleum industry satisfies most domestic needs and provides a minor surplus for export.



INCREASING ENERGY EFFICIENCY characterizes three different lines of technological progress: the improvement in the performance of various steam engines (*black line*), the development of superior forms of lighting (*colored line*) and the refinement of industrial methods for producing ammonia (*gray line*). Energy efficiency is defined for this purpose as the ratio between the output and the input of thermodynamically "free" energy to a conversion process. When the energy efficiencies in each category are plotted on a logistic scale, as they are here, the data points lie along a straight line; on a linear scale the lines would be *S*-shaped curves.



DISTRIBUTION OF ENERGY CONSUMPTION in the world varies widely, as this graph for the year 1975 indicates. The total amount of primary energy generated commercially that year was on the order of 8.2 terawatts (trillions of watts), and the world population was about four billion. The average rate of energy consumption was therefore approximately 2.1 kilowatts per person (*broken-line scale markers*). The top 5 percent of the world's population in terms of energy consumption, however, averaged more than 10 kilowatts per person, whereas the bottom 50 percent averaged less than a kilowatt. An average energy-consumption rate of a kilowatt corresponds to the combustion of about a metric ton of coal per person per year.

stored and converted; others cannot. Such limitations may entail significant losses, since part of the original energy must be reinvested to "step up" the quality of the final-energy form. The success of any energy industry is ultimately dependent on its ability to produce final-energy forms that are attractive in terms of both low cost and (normally) low primary-energy losses.

Toward that end the established energy industries in the developed countries have over the years tapped ever more versatile forms of primary energy, that is, forms requiring less upgrading. Thus the industrialized countries have passed in a rational progression from wood through coal to oil, natural gas and uranium. This powerful trend in the direction of greater overall energy efficiency is manifested in the historical record of the relative shares of the major primary-energy forms in the global energy balance [*see illustration on opposite page*]. Switching from abundant coal resources to more efficient, if less abundant, oil and natural-gas resources has led to economic gains in excess of the costs involved in setting up worldwide distribution systems for oil and gas. A crucial question for the future is whether this traditional cost-minimizing strategy will continue to serve the common good.

The research at IIASA has focused on the medium-term (to the year 2000) and long-term (to 2030) aspects of energy and its interaction with other constituents of an economy. A major objective has been to analyze the possibilities of extending the supply of energy to provide more oil, gas, coal, nuclear fuel and other forms of energy, including new ones. Any such exercise would be meaningless, however, without a simultaneous evaluation of the future energy demand, the force driving any extension of the supply.

Our approach is based on the assumption of a cooperating world, free of major wars or social disruptions. This assumption is in turn a prerequisite for several other operating assumptions: the guarantee of open access by all nations to the world's energy resources, the universal availability of effective means of energy production and conversion, and the widespread adoption of energy-efficient consumer technologies. It goes without saying that this may not be the way of the future. Nevertheless, quantifications based on such assumptions serve a useful purpose: they establish the minimum technological and economic effort required to balance energy supply and demand.

The potential evolution of the world energy balance is analyzed at IIASA in the form of scenarios. Such scenarios are not merely extrapolations of past trends. They contain an element of judgment, insofar as inconsistencies arising

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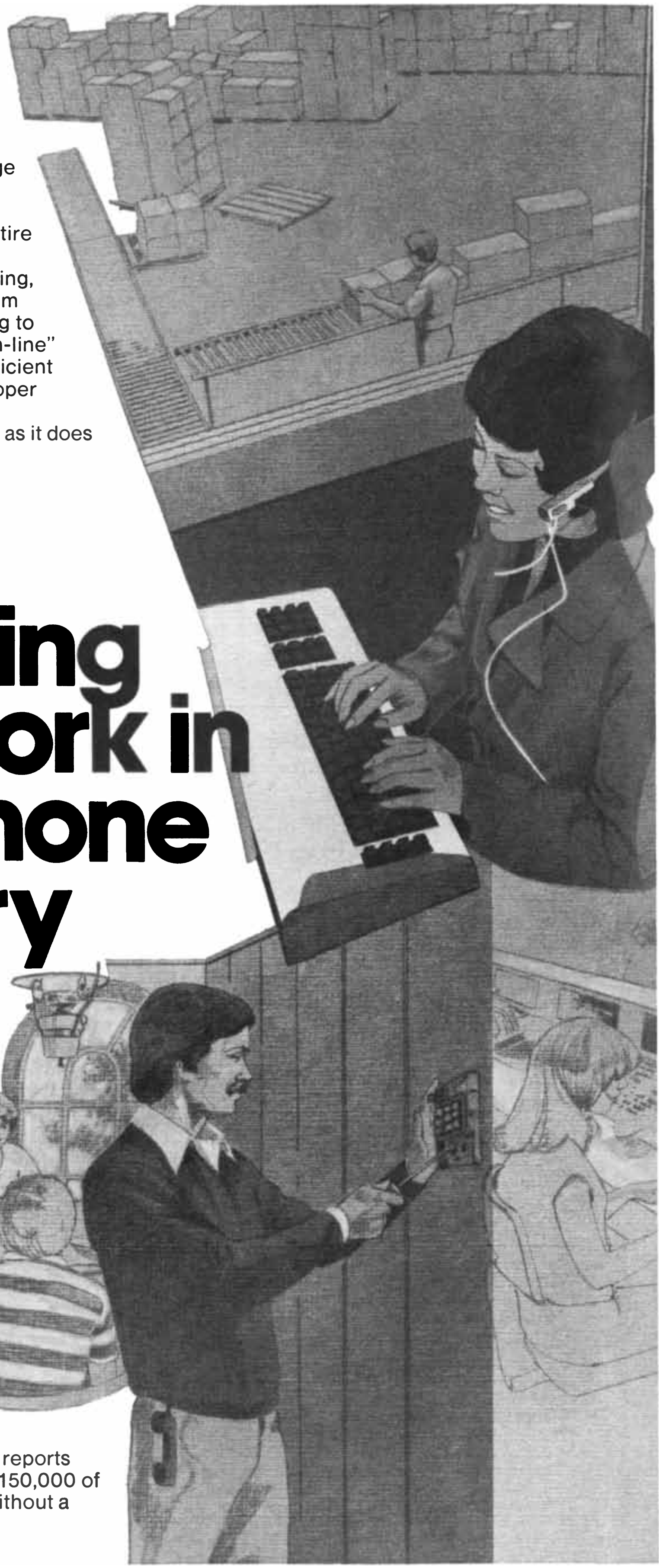

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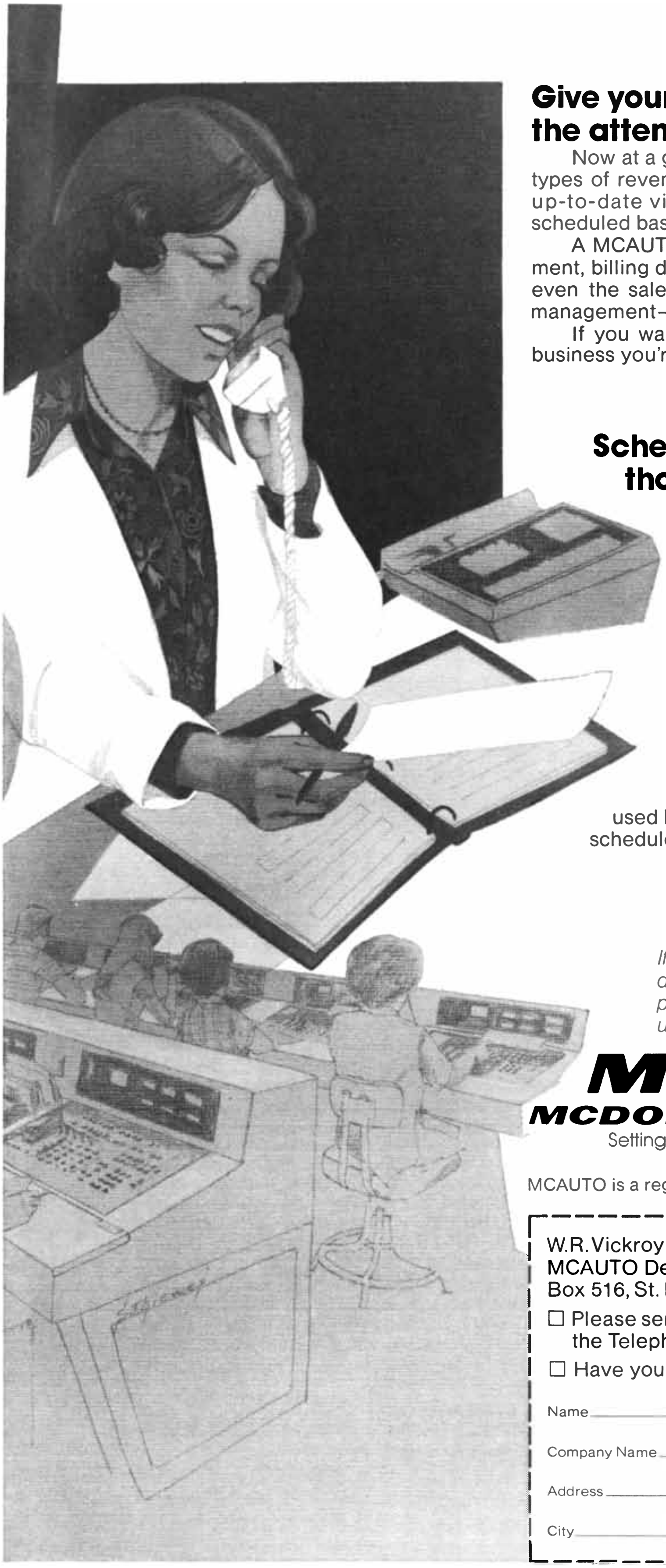

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from conflicting trends have to be resolved. Carefully constructed scenarios can be seen as ways of describing potential futures. They are not predictions. Instead they take into account both fond aspirations and realistic expectations. The results presented in the remainder of this article refer to the picture of the future world energy balance that emerges from the IIASA scenarios.

The transition from a stable world population of about a billion people in 1800 to one of perhaps 10 billion is already well under way. By a conservative estimate the world's population will double, from four billion to eight billion, within the next 50 years. Whereas the growth of energy demand in the period after World War II stemmed mainly from industrial development in the northern countries, where the population was already fairly stable, the future energy demand will be generated mainly by the demographic growth of the southern countries. In order to take into account the large differences between countries in their levels of economic development, their population dynamics, their energy resources and other pertinent factors the IIASA has divided the world into seven major regions [*see illustration on next page*]. A complex set of computer models serves to project the economic and technological development of each of these regions.

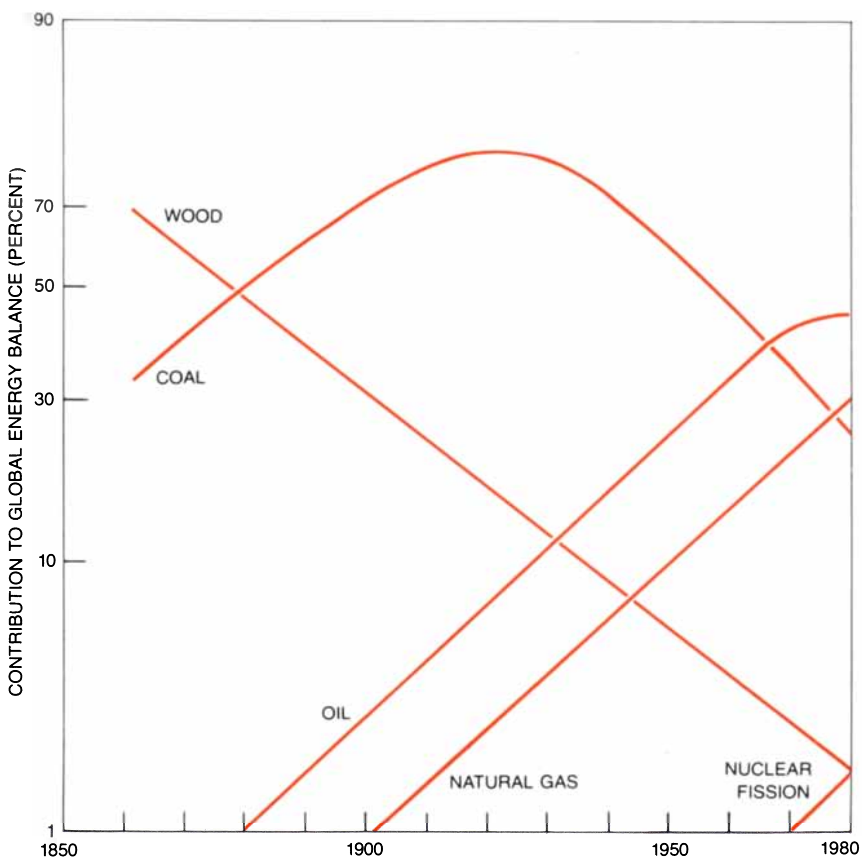
It was found fairly early that a simple extrapolation of the trends established in the period from 1950 to 1975 would lead to a growing discrepancy between global energy supply and global energy demand. Only by postulating a considerable reduction in the projected rate of economic growth in all the regions and a parallel sharp increase in the global energy supply—in terms of both estimated reserves and production capacities—was it possible to bring the future supply and demand totals into anything like a reasonable balance. In view of the uncertainties of such a dual "solution" to the world energy problem, two scenarios were developed. These models, termed the low-growth scenario and the high-growth scenario, were then applied to each of the seven major regions.

Both of the IIASA scenarios imply a dramatic break with past economic trends. The low-growth scenario in particular entails much lower rates of economic development than those of the period 1950–75. Although the projected growth rate in this scenario would be generally higher in the developing regions than in the developed ones, it would still not be high enough for an adequate technological infrastructure to be built up in most of the developing countries for many decades to come.

In addition to the modest economic projections built into these scenarios both of them incorporate optimistic estimates of the potential for energy conservation. They also reflect current trends toward an increase in the contribution to the gross national product made by the services sector of the economy, toward a substantial improvement in energy efficiency in all sectors and toward early "saturation" effects in certain energy-intensive activities, such as transportation. This approach has enabled us to obtain quite detailed projections, reflecting various ways of life and technological conditions, of the specific demand for energy required for a given amount of economic output, measured as a function of the level of economic activity achieved in a particular region [*see illustration on page 128*]. It is evident from such projections that "decoupling" energy and economic growth in an advanced economy is quite different from doing so in a subsistence economy. In view of the rudimentary industrialization achieved so far in the developing countries it seems clear that in the decades ahead it will be harder for them to limit their growth in energy-intensive technology than it will be for the developed countries to reduce theirs.

Complementary to the effort made to reduce the energy-demand figures in the IIASA scenarios has been the attempt to increase estimates of potential future energy supplies. The escalating price of crude oil, the form of primary energy now at the top of the world price scale, is bringing into the marketplace energy resources that were formerly not considered economically competitive. Our study ranks potentially recoverable resources of coal, oil, natural gas and uranium as a function of increasing production costs [*see top illustration on page 129*]. The totals we get in this way are much higher than the "proved" reserves identified as economic at present. Our figures nonetheless represent a reasonable hope; they suggest that with the help of vigorous exploration and advanced production technologies (either already in existence or yet to be developed) the world could roughly triple its present energy reserves by 2030.

By this accounting fossil-fuel reserves would amount at that time to the energy equivalent of 3,000 terawatt-years within production-cost ranges at or even below current market prices. (A terawatt-year is the standard energy unit in the IIASA studies; it is 10^{12}, or a trillion,



SUBSTITUTION OF PRIMARY-ENERGY FORMS has historically been in the direction of greater overall energy efficiency. In effect this trend has manifested itself in the movement toward ever more versatile forms of primary energy, that is, forms that require less upgrading to provide final-energy forms. In this graph of the substitution of primary-energy forms in the U.S. the colored lines are averages of the historical data. The data are again plotted on a logistic scale, which represents *S*-shaped functions as straight lines. The lines are remarkably regular.

watts supplied or consumed for a year.) Divided by a global energy demand of about 30 terawatt-years per year, which is what we estimate as the annual rate of energy consumption in 2030, this projection translates into an energy reserve with an exhaustion time of roughly a century. It is imperative, however, that such optimistic resource estimates be interpreted within the correct framework.

First, the economic evaluation of energy resources (measured, for example, by the price/cost ratio) in an evolutionary process leading to ever cheaper energy supplies does not apply to the uphill fight in costs that confronts the world in the years ahead. Second, the 3,000 terawatt-years' worth of oil, gas and coal we have projected will be qualitatively different from the reserves associated with these forms of energy today. The rise in production costs from one category to another reflects important changes that will further constrain the usefulness of such energy resources. For example, the oil in the IIASA production-cost Category 3 consists primarily of tar sands and oil shales, both resources that are accessible only by mining and retorting, not by drilling. The transportation and refining of a barrel of oil produced in this way will be considerably more costly than they are for a barrel of today's Saudi Arabian light crude. Moreover, environmental limitations quickly enter the picture if these resources are to be recovered and processed not in desert areas but close to heavily populated consuming ones.

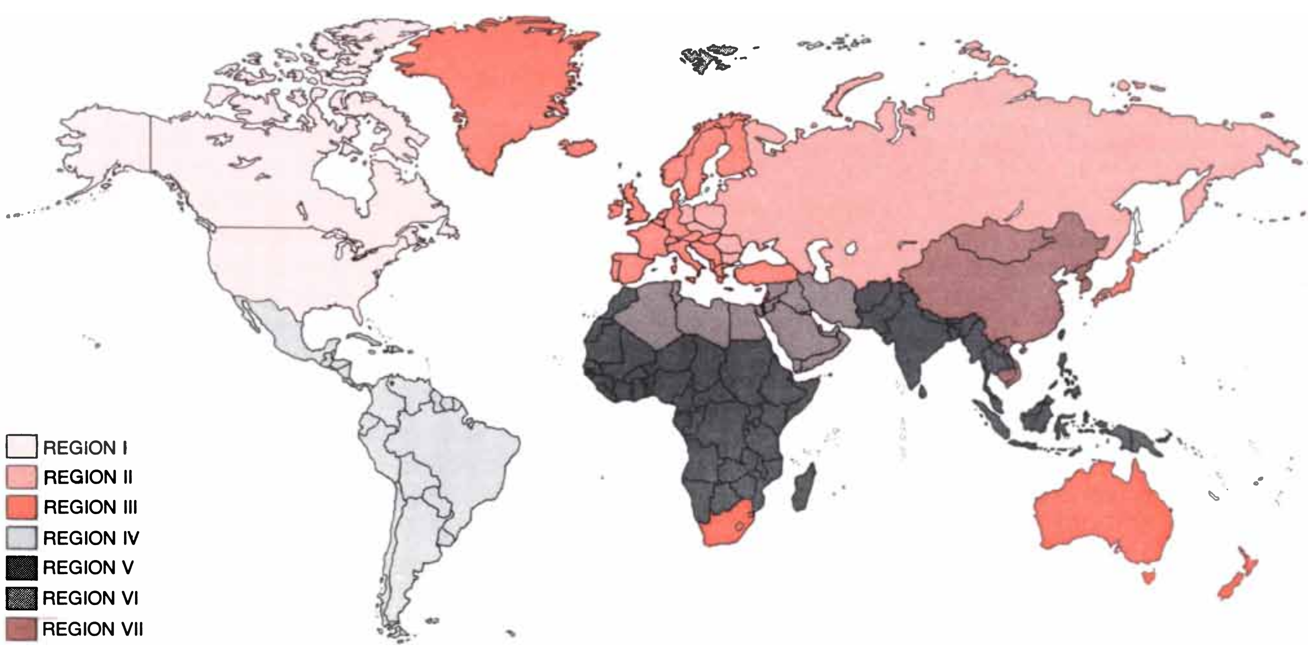
In short, tapping a major fraction of the resources projected in the IIASA models implies a difficult transition, not only from cheap fuels to expensive ones but also from comparatively clean and easy-to-handle fossil fuels to dirty and less versatile ones. Such a transition will also call for important adjustments outside the narrowly defined energy sector of the world economy, and it will take time.

What is true of fossil-fuel power systems applies even more to advanced, non-fossil-fuel systems such as fission reactors that "breed" their own fuel, solar-power generators and fusion reactors. Since the fuel resources in these systems are in effect unlimited, the resource base does not influence the achievable levels of deployment. "Infinite" energy resources of this type can be said to substitute capital for the finite natural resources that are depleted in fossil-fuel systems. Hence the rate at which an economy can afford to expand its fixed energy-generating capital stock will determine the price of these quasi-permanent power sources and accordingly their potential share of the world energy market.

A satisfactory determination of this price cannot yet be made. It would presumably balance the capital investments that would have to be diverted from general productivity with the benefits that would accrue to a national economy from adding a quasi-permanent power source. There is a striking similarity between the ambiguities inherent in determining a "fair" price for scarce fossil-fuel resources and those inherent in determining the price of "infinite" energy endowments such as breeder reactors and solar-power generators.

In the absence of long-term price estimates a projected balance between energy supply and demand must rely on considerations of cost and other constraints. In the IIASA analysis such constraints were imposed by a specific assortment of final energy requirements that would have to be met by the energy-supply sector of the economy; other possible constraints include the maximum deployment rates of new energy technologies and limitations imposed by the exhaustion of certain categories of resources.

Within such constraints primary-energy-supply scenarios were constructed that correspond to the high-growth and low-growth economic-development scenarios discussed above. The relative shares of primary-energy resources could then be calculated for the high-



WORLD IS DIVIDED into seven major energy-related regions in the scenarios constructed by the author and his colleagues in the Energy Systems Program of the International Institute for Applied Systems Analysis (IIASA). The regions were selected mainly on the basis of economic factors rather than geographic proximity. Region I, North America, has a highly developed market economy and is comparatively rich in energy resources. Region II, the U.S.S.R. and the rest of eastern Europe, has a developed planned economy and is also quite rich in energy resources. Region III, a far-flung entity consisting of western Europe, Japan, Australia, New Zealand, South Africa and Israel, is highly developed economically but rather poor in energy resources. Region IV, Latin America, is a developing region that is fairly rich in energy resources. Region V, which encompasses central Africa, southern Asia and parts of southeastern Asia, is made up typically of less developed countries with scarce energy resources. Region VI includes the oil-rich developing countries of the Middle East and northern Africa. Region VII, China and the other centrally planned Asian economies, is a less developed area that is generally self-sufficient in energy. The seven IIASA regions are not to be confused with different groupings discussed elsewhere in this issue.

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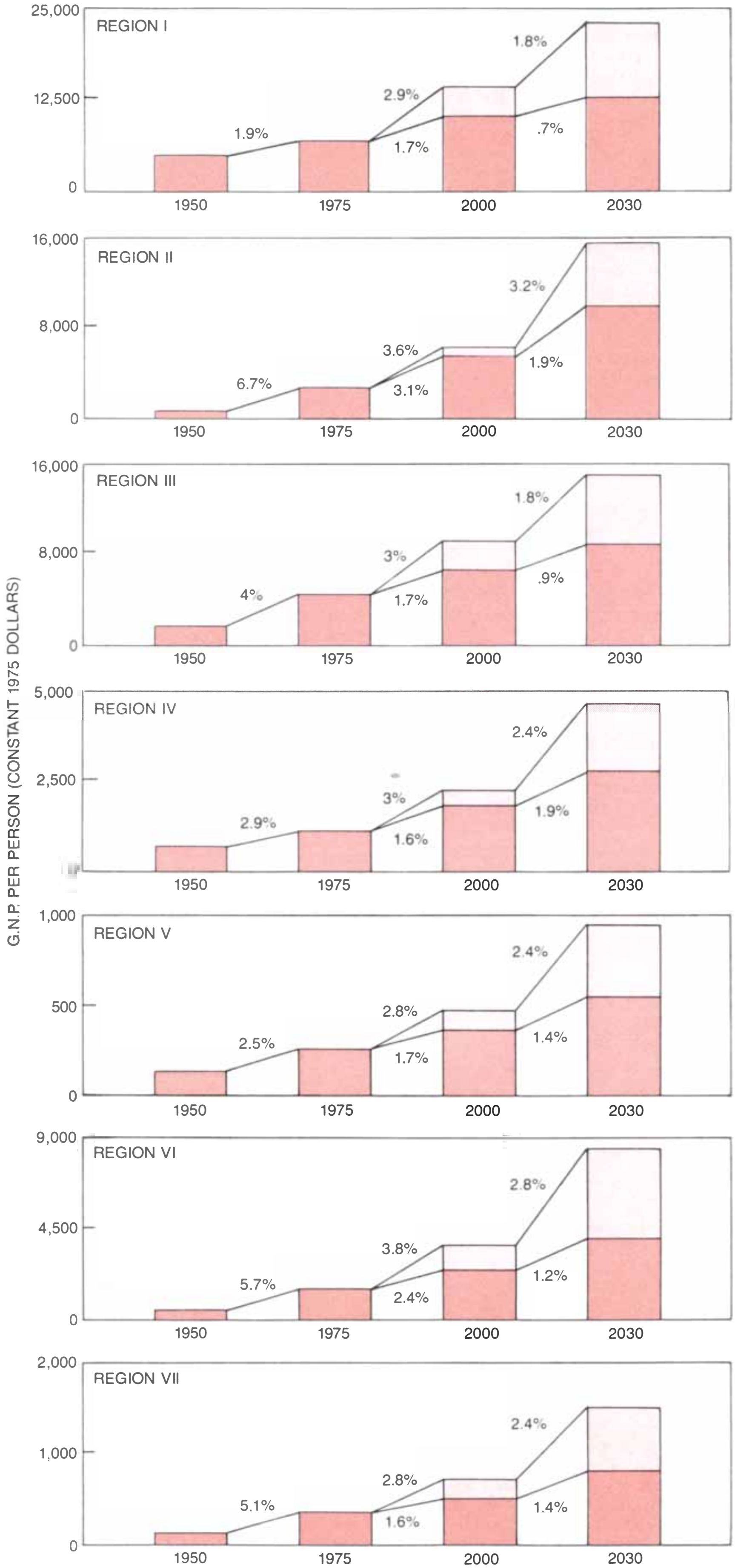
growth scenario, say, as a function of time, aggregating the separate calculations for each of the seven major IIASA regions. Although the patterns of primary-energy deployment were somewhat different at the regional level for the low-growth scenario, the aggregate supply structure for the entire world turned out to be practically the same as in the high-growth scenario.

The projected figures for the high-growth scenario show that over the 50-year span of the IIASA study natural gas will maintain its present share of approximately 20 percent of the world energy market but that oil will gradually decline, from 40 percent in 1980 to 20 percent in 2030. To make up for this shortfall and, what is equally important, to meet the demand for liquid secondary-energy forms an increasing amount of coal will have to be converted into synthetic fuels. The diversion of this much coal from electric-power generation will in turn have to be partly compensated for by the further penetration of nuclear power into the market for generating electricity. Because of anticipated resource limits on the supply of natural uranium, breeder reactors will assume an ever increasing share of the world energy-supply market from the year 2000 on. Renewable energy sources, hydroelectric power and geothermal power will add up to a fairly constant share of somewhat less than 10 percent of the total energy supply, an estimate that implies a substantial increase in the absolute power-generation levels for all these comparatively minor supply categories. From the base year of the IIASA study (1975) to 2030 the total primary-energy consumption rate is projected to rise from 8.2 terawatt-years per year to 36 terawatt-years per year in the high-growth scenario and to 22 terawatt-years per year in the low-growth one.

The size of the industrial operations postulated as achievable in the two energy-supply scenarios can be gauged by comparing present and future rates of deployment of the various primary-



MODEST ECONOMIC GROWTH projected in both the high-growth and the low-growth energy-demand scenarios constructed by the IIASA analysts is presented in this set of bar charts for each of the seven major world divisions considered in their study. The percent figures on the connecting lines give the historical and projected rates of economic growth for each region in terms of the annual growth in the gross national product per person in that region for three different time intervals between 1950 and 2030. All the figures are average annual growth rates (rounded to the nearest tenth of a percent) over the interval in question; actual projections in the IIASA scenarios assumed decreasing growth rates. Light-colored parts of bars show the difference between high- and low-growth scenarios.

energy sources [*see bottom illustration on opposite page*]. In the high-growth case oil production would have to double by 2030 and coal production would have to quintuple. The challenges facing the energy-supply industries in the low-growth scenario also appear to be formidable.

The tension in the two IIASA scenarios between prodigious energy-consumption figures and modest economic-development prospects is symptomatic of the long-term global energy problem. To put the present trends and future challenges of the energy market in perspective it will be helpful to recall at this point several of the more detailed conditions underlying the IIASA scenarios. These conditions are as follows. (1) The energy resources to be consumed within each IIASA region will have to be made available at production-cost prices. With the exception of oil this rule will also apply to exports to other regions. (2) Oil production in Region VI (the Middle East and northern Africa) will have a ceiling of 33 million barrels per day. In addition Region II (the U.S.S.R. and its allies in eastern Europe) and Region VII (China and the other centrally planned Asian economies) will not participate in the oil trade between regions. (3) Each of the seven major world regions will build up a cost-minimizing energy-supply system of its own to meet regional demands for final energy. (4) Each region will in addition assume for itself the burden of switching to a more expensive energy infrastructure when the time comes.

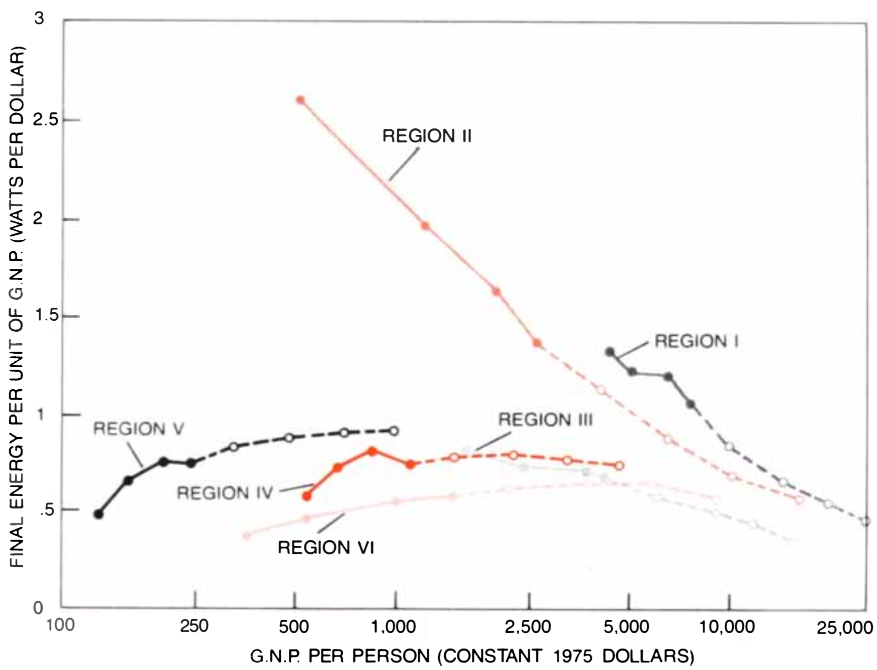
Together with various other methodological provisos these four conditions enable us to project a viable, if not entirely satisfying, solution to the global energy problem. The cheapest energy resources would be used up gradually, and no region would be forced to pay exceptionally high energy costs long before the others would have to follow. Except for the oil trade originating in the Middle East and northern Africa, such a world would abstain from using energy as leverage for the redistribution of general economic productivity.

Both the high-growth and the low-growth scenarios are put forward as possible long-term evolutionary processes. As such they imply a number of actions and achievements, both technical and institutional, over the next 50 years. What are the crucial checkpoints that must be passed for these global evolutionary scenarios to be realized?

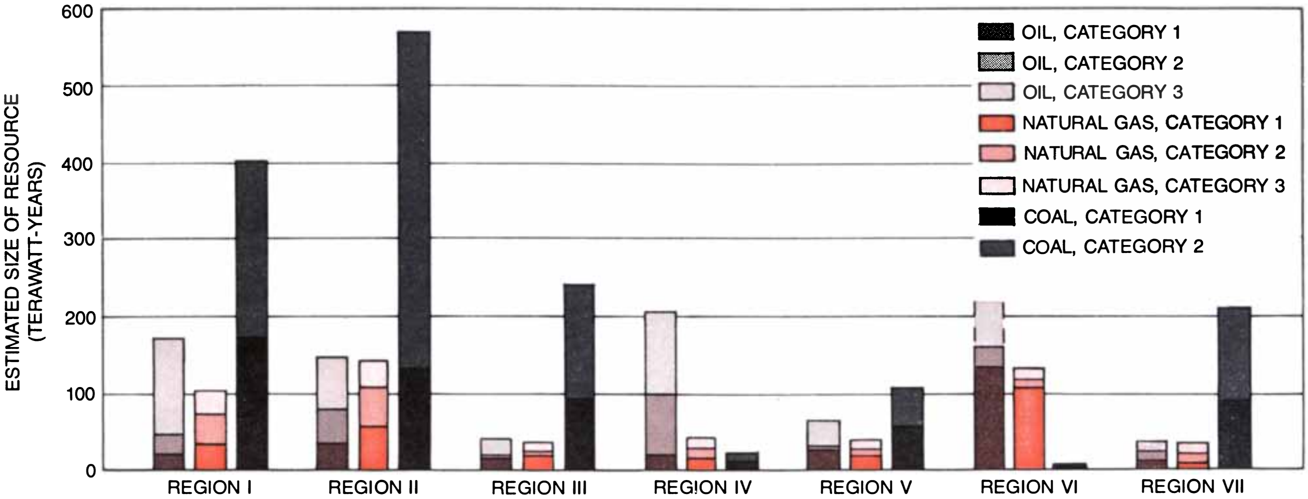
A particularly difficult problem within the general energy puzzle is how to ensure an adequate supply of liquid fuels through roughly the year 2000. It appears from our analysis that if one excludes from consideration the centrally planned economies (which need not be driven into the tightening international oil trade, since they have comparatively ample oil resources of their own), the world will continue for some time to depend on oil exports from the Middle East and northern Africa. Outside this region new reserves will have to come on stream very quickly, from both proved and unproved fields, including those in deep offshore areas and polar areas. The large contributions projected from such sources by 1990 will require that enormous effort be put into exploration and development. It is questionable whether such a pace will actually be achieved; accordingly it seems all the more important to prepare in plenty of time for the large-scale production of oil from unconventional sources beginning in about 1990. Substantial shortfalls in the production of oil by either conventional or unconventional means below the volumes projected in the IIASA high-growth scenario would require the introduction of coal liquefaction on a globally significant scale before the year 2000. Except for a possible delay of 10 years in the production of synthetic liquid fuels from coal the low-growth scenario leads to an oil shortfall that is almost identical with that in the high-growth scenario.

The short-term and medium-term liquid-fuel problem is a tremendous challenge to technology, but there is an even more pressing aspect of the problem, which is related to the quick shift that is bound to take place in the energy-trade relations between and within developed and developing regions in about the year 2000 [*see top illustration on page 130*]. At that time two important turning points will have been reached. First, the three major developing regions that are now net oil exporters will divide into two subcategories: two that will continue to be net oil exporters, namely Region VI (the Middle East and northern Africa) and Region IV (Latin America), and one that will abruptly become a major oil importer, namely Region V (central Africa, southern Asia and parts of southeastern Asia). Second, the oil-buying competition between Region I (North America) and Region III (western Europe, Japan, Australia, New Zealand, South Africa and Israel) will be succeeded by a competition between Region III and the energy-poor group of developing countries in Region V. If Region I is not able to reduce its oil imports significantly by the year 2000, the competition for imported oil among developed and developing countries beyond 2000 will become even sharper. What institutional arrangements would be able to manage these two likely transitions in the terms of the energy trade among major world regions around the year 2000?

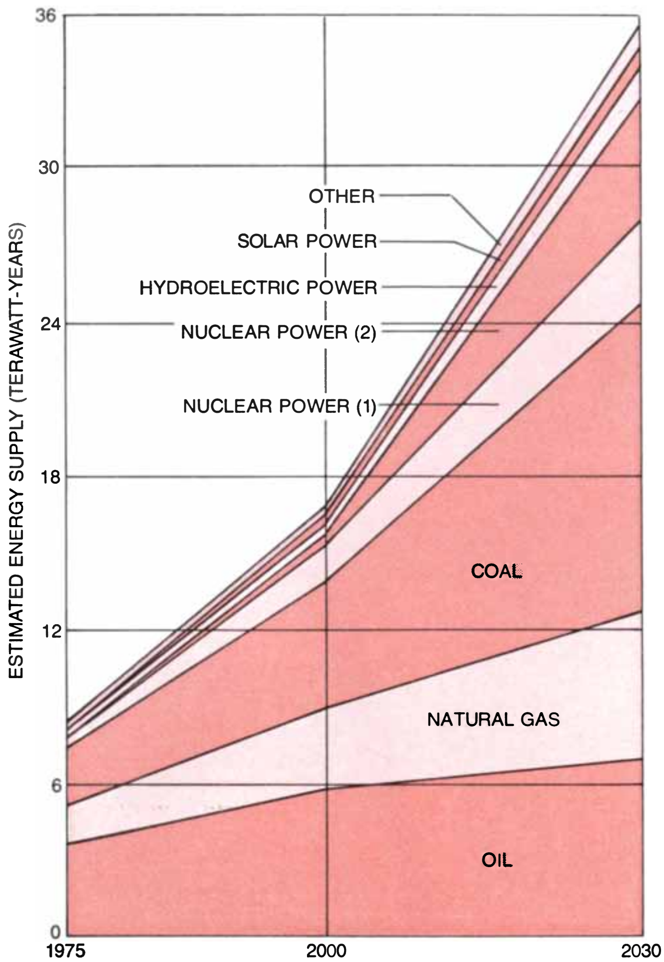
The full weight of such questions of energy-related medium-term economic stability will be felt in western Europe and Japan. In the high-growth scenario the dependence on imported oil in the Region III countries could be reduced by increasing imports of coal (or coal products) and natural gas. The low-

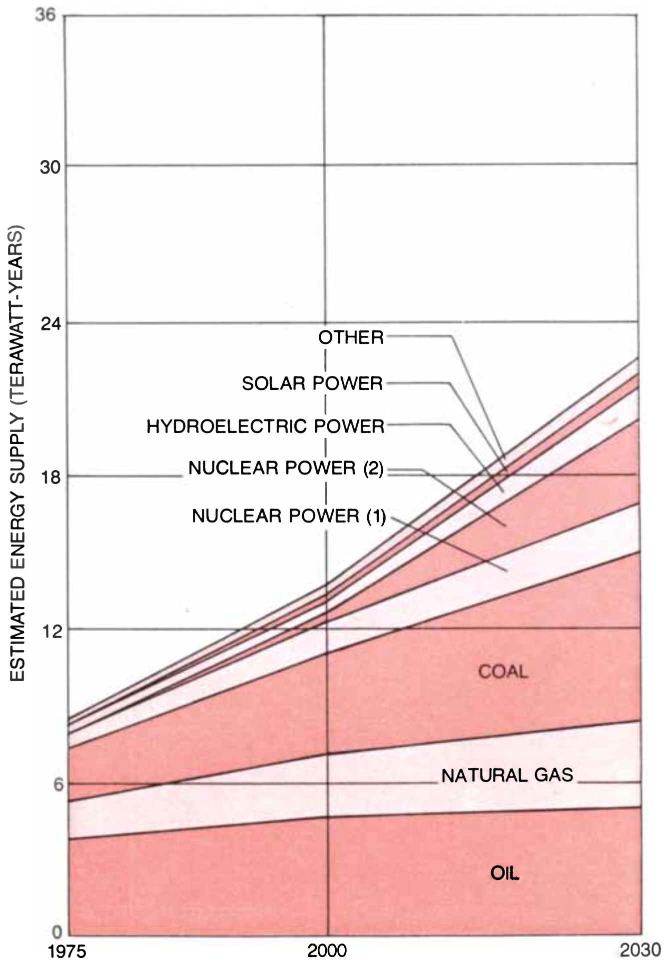


SPECIFIC DEMAND FOR FINAL ENERGY required to produce a given unit of economic output was projected in the IIASA low-growth energy-demand scenario as a function of the average level of economic activity achieved in six of the seven regions in the study. The dots give the historical data for the years 1950, 1960, 1970 and 1975; the open circles indicate the projected figures for 1985, 2000, 2015 and 2030. According to the author, the graph suggests that in the decades ahead it will be harder for the developing countries to limit their growth in energy-intensive technology than it will be for the developed countries to reduce theirs.

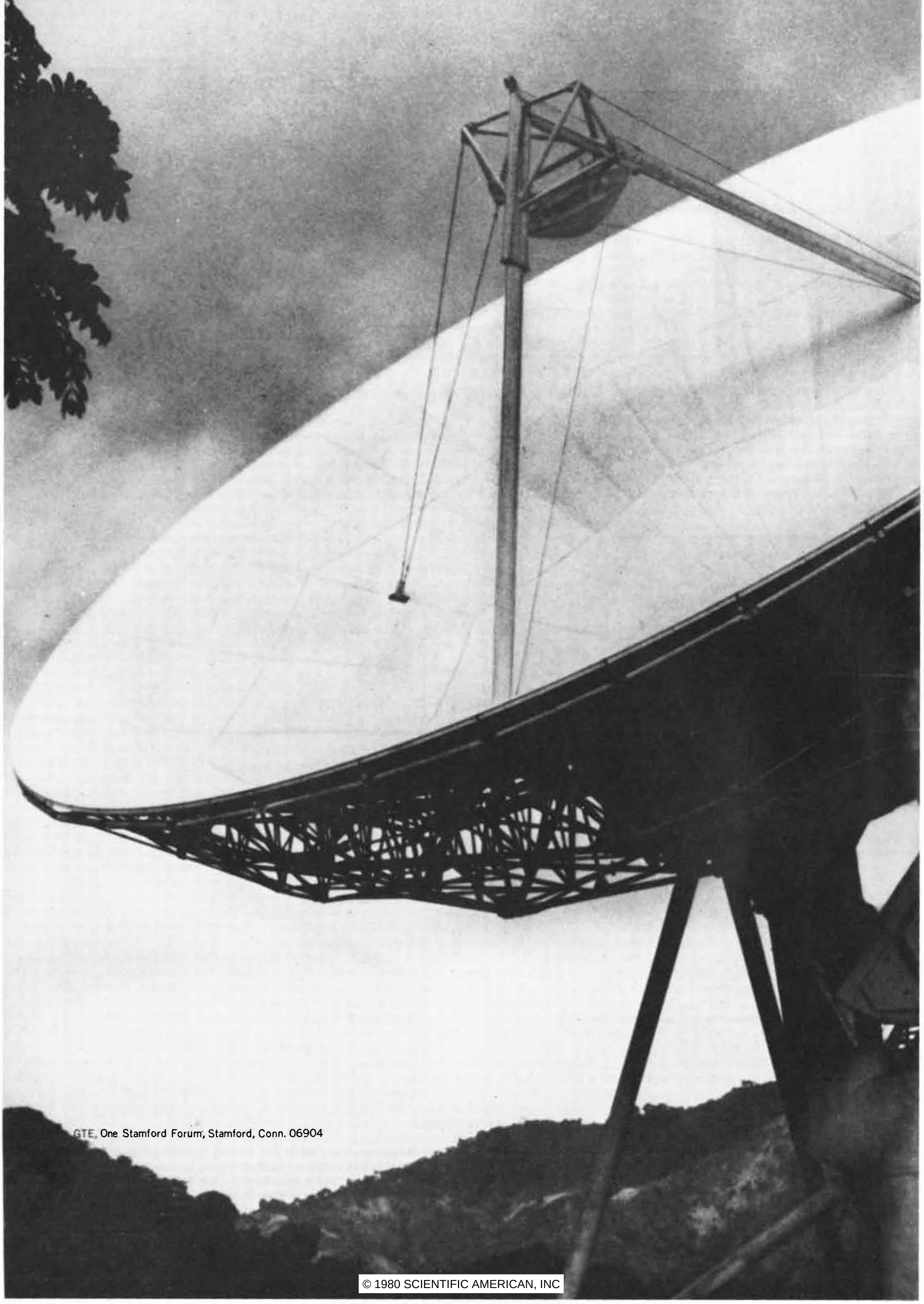


FOSSIL-FUEL RESOURCES judged to be ultimately recoverable in each of the seven regions considered in the IIASA scenarios are categorized according to increasing production costs. The cost categories represent estimates of costs at or below the stated volume of recoverable resources (in constant 1975 dollars). For oil and natural gas production-cost Category 1 includes all resources recoverable at a price equivalent to $12 per barrel of oil; Category 2 covers the range from $12 to $20 per equivalent barrel of oil, and Category 3 covers the range from $20 to $25 per equivalent barrel of oil. For coal Category 1 includes all resources recoverable at or below $25 per metric ton; Category 2 covers the range between $25 and $50 per metric ton. In the case of coal only a part of the ultimate resource (about 15 percent) was included, because the figures were already large and because many uncertainties surround long-term coal resources and production technologies. No estimate was made of recoverable Category 3 oil resources of the Middle East and northern Africa (Region VI).





GLOBAL CONSUMPTION RATE of a variety of primary-energy forms is projected to rise from a total of 8.2 terawatt-years per year in the base year of the IIASA study (1975) to 36 terawatt-years per year in 2030 according to the high-growth scenario (*left*) and to 22 terawatt-years per year in 2030 according to the low-growth one (*right*). Nuclear-power sources are divided in these projections into conventional fission reactors (*Nuclear 1*) and advanced breeder-type fission reactors plus fusion reactors (*Nuclear 2*). The projections for direct solar power and other forms of primary energy, such as "biomass" conversion, are considered optimistic by the IIASA analysts.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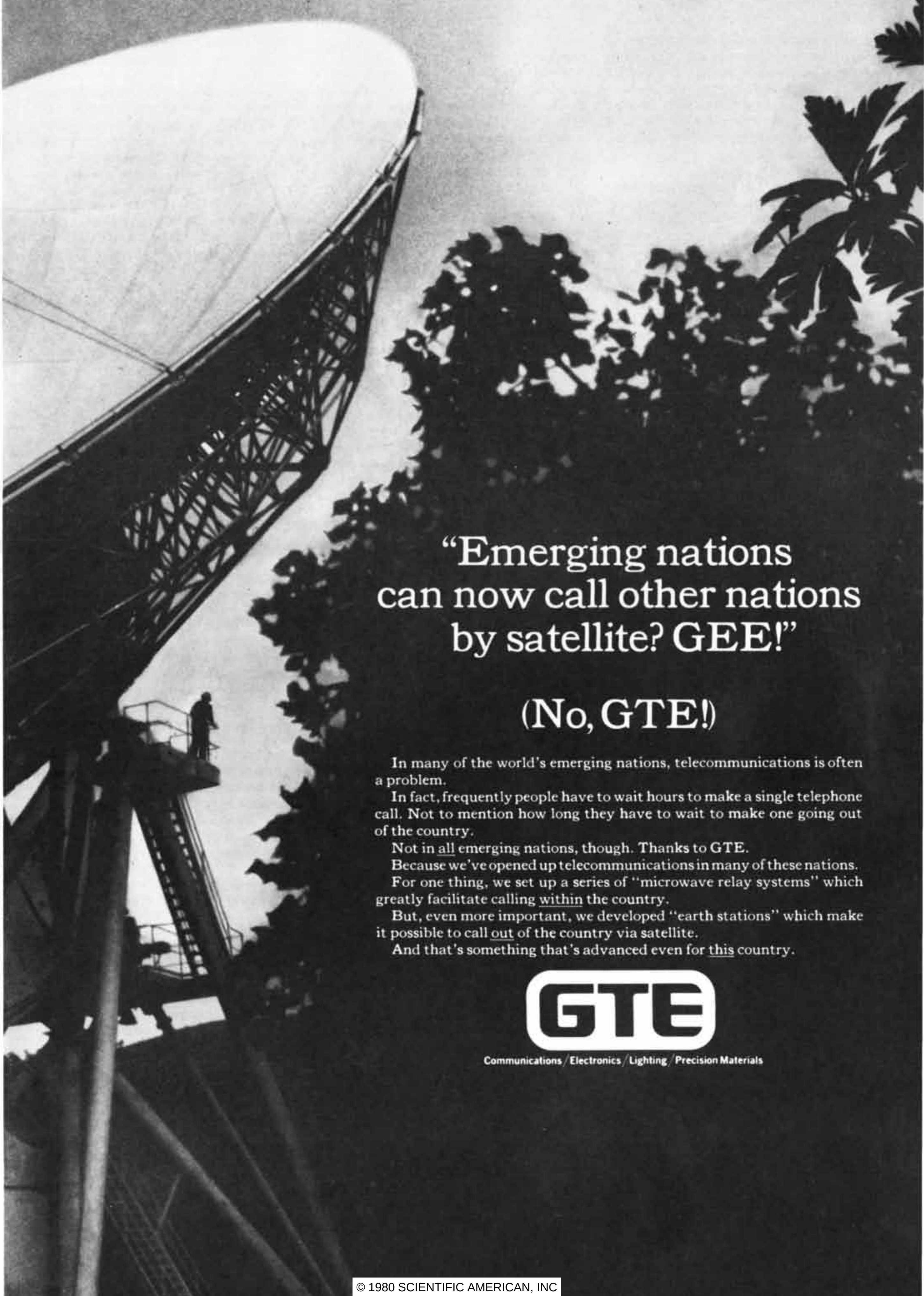
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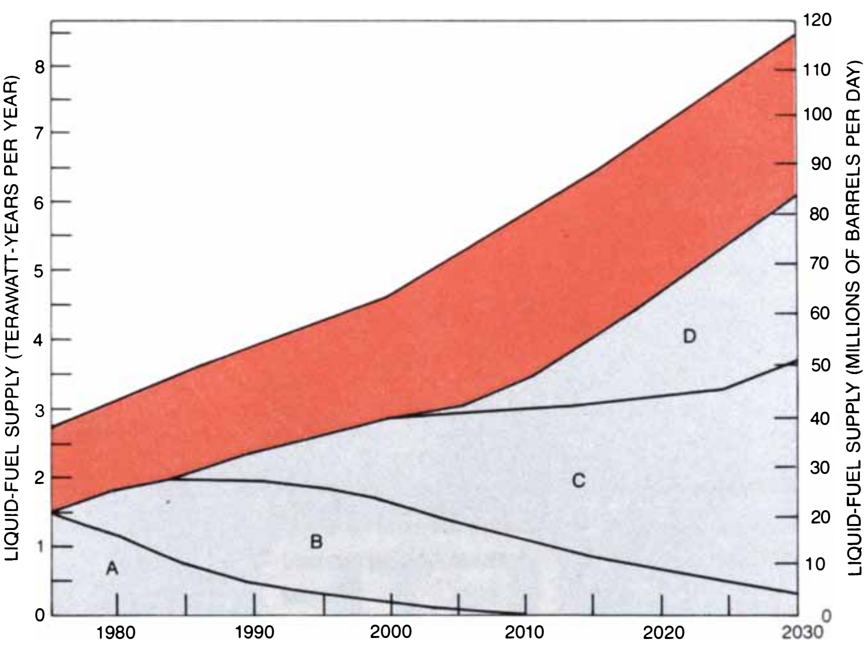
growth scenario avoids such additional fossil-fuel imports, but like the high-growth scenario it pushes Region III into an extended competition for imported oil at a crucial time: beyond 2000, when very expensive oil will have to be shared with the much needier developing regions.

The imminent need to switch to large-scale substitutes for conventional oil, evident in both of the IIASA scenarios, raises some important environmental questions. Deep offshore oil, heavy crude oil, tar sands and oil shales will all have to be exploited vigorously beginning in about 2000. Apart from the deep offshore oil deposits and those in polar areas most of the recoverable hydrocarbons in this category are in nondrillable formations in a few large geological basins. By 2000 these basins will come to play a role analogous to that of the giant oil fields of the Middle East today. The IIASA high-growth scenario envisions an energy-production rate of a terawatt-year per year from this "minable" hydrocarbon group in about 20 years, most of which would have to come from three places: the Athabasca tar sands of northern Alberta in Canada, the Orinoco heavy crudes of Venezuela and the Green River oil shales of Colorado, Utah and Wyoming in the U.S. The local environmental consequences of such large operations cannot yet be adequately assessed on the basis of past or present experience.

When one computes the energy ratio (defined as the net useful energy output divided by the energy invested in production) for alternative schemes for the production of unconventional liquid fuels, one finds that an output on the order of .3 or .4 terawatt-year per year per basin would call for the combustion of more than .1 terawatt-year per year of low-grade fossil fuel. In addition to the huge quantities of waste heat and chemical pollutants that would be liberated the water-supply problems would be prodigious. Depending on the extraction process, the production of several tenths of a terawatt-year per year of synthetic liquid fuel would consume on the order of tens of cubic meters of water per second. Significant problems are already encountered with wet cooling towers in areas such as the valley of the Rhine and its tributaries, where the water requirements are much smaller. Major problems related to land use, soil erosion and water pollution are likely to place further limits on the recovery of these nonconventional oil resources. The same limitations apply to the production of synthetic liquid fuels from comparatively cheap open-pit-mined coal, for example in the vast coal basins of the northern Rocky Mountain states in the U.S. and of the Kansk-Achinsk region in south-central Siberia.



LIQUID-FUEL SUPPLY is projected according to the IIASA high-growth scenario for the world excluding the centrally planned economies (Region II and Region VII). The top line gives the estimated demand for liquid primary-energy forms in the five regions that are expected to participate in the international liquid-fuel trade through 2030. The gray area includes various kinds of liquid fuel produced outside the Middle East and northern Africa (Region VI); the fuel sources represented include known reserves of conventional oil (*A*), new reserves of conventional oil (*B*), unconventional forms of oil, such as tar sands, oil shales, heavy crudes and other products of enhanced-recovery techniques (*C*), and synthetic fuels made by the liquefaction of coal (*D*). Gap between supply and demand is filled by oil produced in Region VI (*colored area*), which is expected to reach a peak output of 33 million barrels per day in 2010.

Over and above the local and regional problems that are likely to be encountered in recovering such additional fossil-fuel resources, both of the IIASA scenarios would lead to a worldwide risk that cannot be adequately quantified at present. It is the risk arising from the release of the carbon contained in such fuels, which would be largely in the form of carbon dioxide. Significant increases in the atmospheric concentration of carbon dioxide have been monitored for the past two decades. The possible consequences of the two IIASA primary-energy-supply scenarios have been estimated on the basis of various physical models, which describe the effects of increased atmospheric carbon dioxide on the carbon cycle in the environment and on the exchange of radiation between the earth and space. The reliability of these models is not yet well enough known, but research and monitoring programs are under way to improve the scientific basis for judging the global carbon dioxide issue.

Finally, there is another potential economic constraint on the world's future energy supply, arising from the rather heterogeneous geographic distribution of all fossil-fuel resources. A large fraction of the world's aggregate G.N.P. must be invested to build up the energy-production infrastructure in both of the IIASA scenarios. It is conceivable that adequate rates of investment can be achieved, but it will surely be difficult for the developing countries. Averaging energy investments over regions as we have done tends to obscure the increase in the amounts of capital that will have to be transferred across national boundaries to develop the great resource basins for the purpose of producing more fossil-fuel power. The development within the next two decades of any one of the major energy-resource basins will require not billions of dollars but hundreds of billions. Problems associated with the accumulation and control of that much capital are likely to lead to fiscal complexities that are unknown at present even to the largest of the world's national economies.

The developing countries, in view of their difficult situation, are likely to extend their use of local renewable energy sources as far as is practical. Excluding the large-scale direct use of sunlight, which under the most favorable circumstances will remain economically infeasible for decades to come, the largest potential renewable energy source is wood and similar solid biological matter ("biomass"). Wood is still widely burned as a fuel in the developing countries, where it supplies a significant fraction of present energy needs.

The limitations on such renewable energy sources can be demonstrated by comparing natural energy-supply densi-

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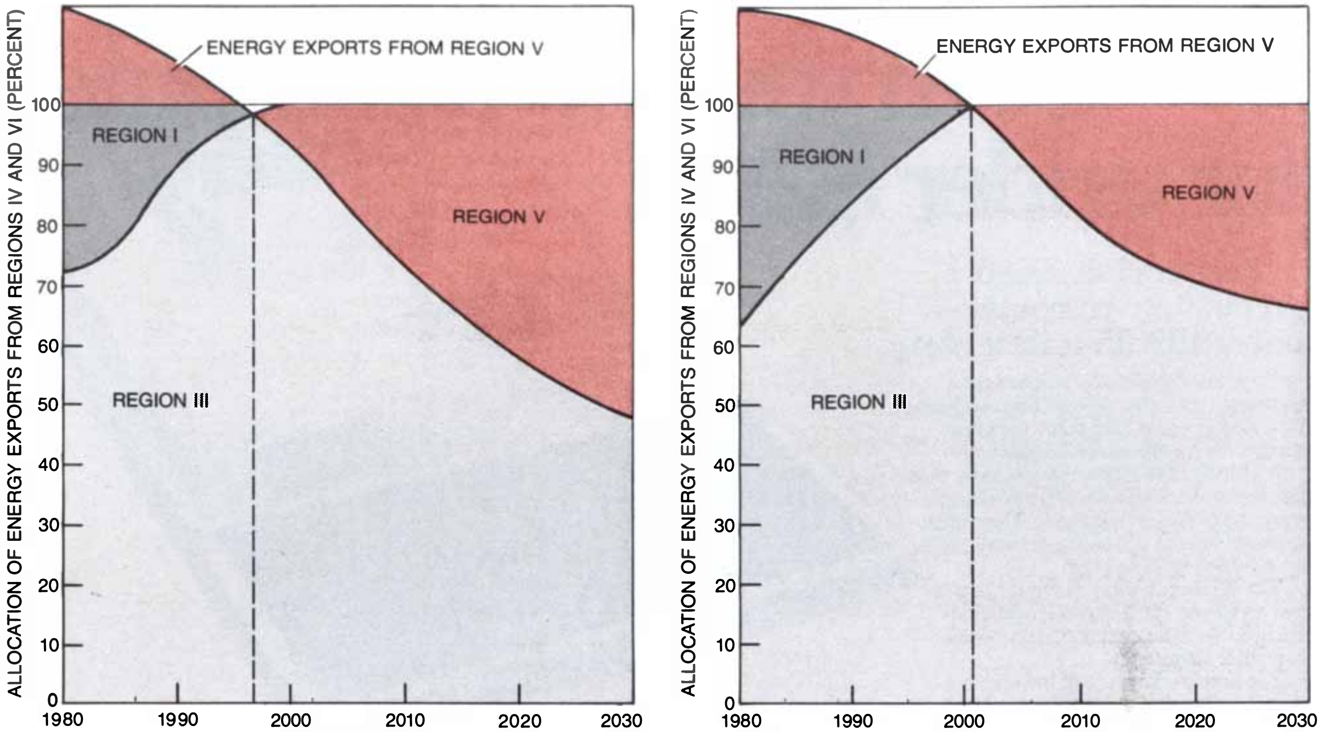
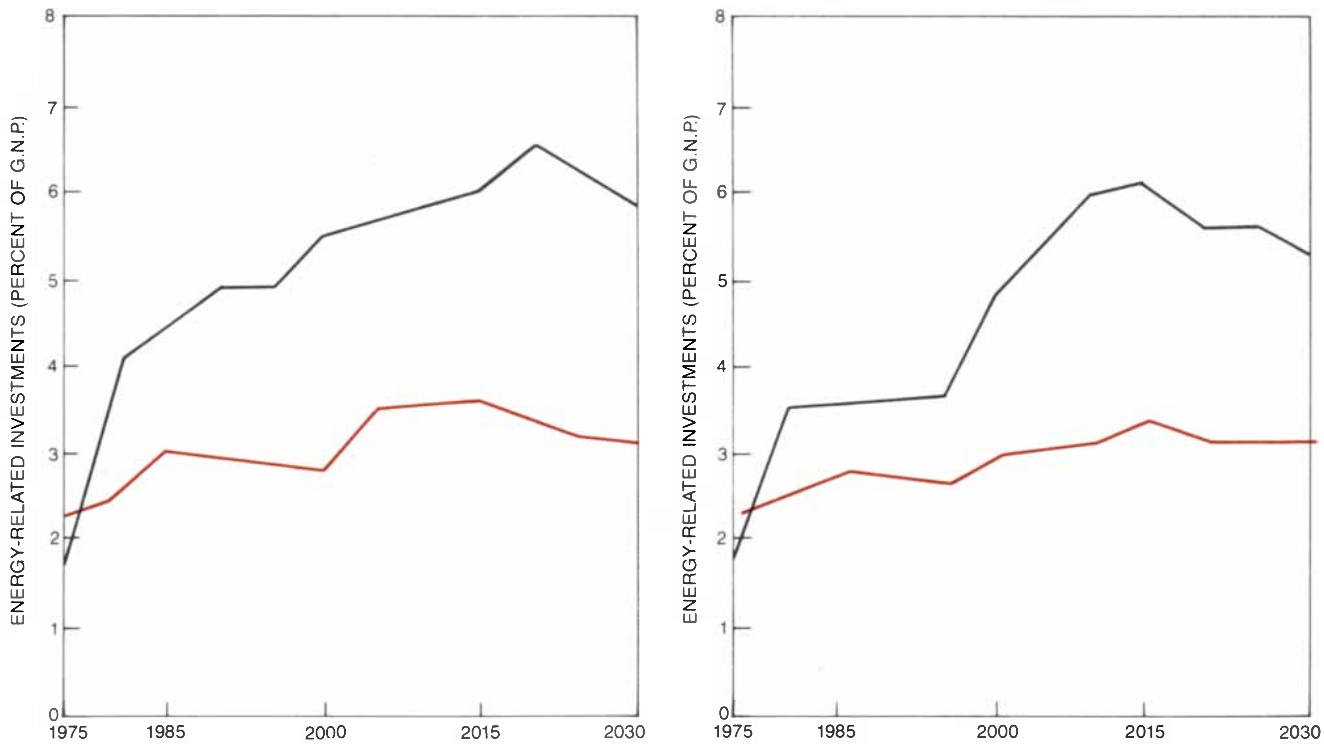


ABRUPT TRANSITION in the allocation of energy exports from the resource-rich developing countries of Region IV (Latin America) and Region VI (the Middle East and northern Africa) is forecast in both of the IIASA scenarios for about the turn of the century. At that time Region V (central Africa, southern Asia and parts of southeastern Asia) will switch from being a net exporter of energy (*colored area at top left in each graph*) to being a net energy importer (*colored area at upper right*). The present oil-buying competition between Region I (North America) and Region III (western Europe, Japan, Australia, New Zealand, South Africa and Israel) will presumably then be succeeded by a competition between Region III and Region V. If Region I does not succeed in reducing its oil imports essentially to zero by this point, the competition for imported oil between developed and developing countries could become sharper. The timing of the expected transition differs by only a few years between the high-growth scenario (*left graph*) and the low-growth one (*right graph*).



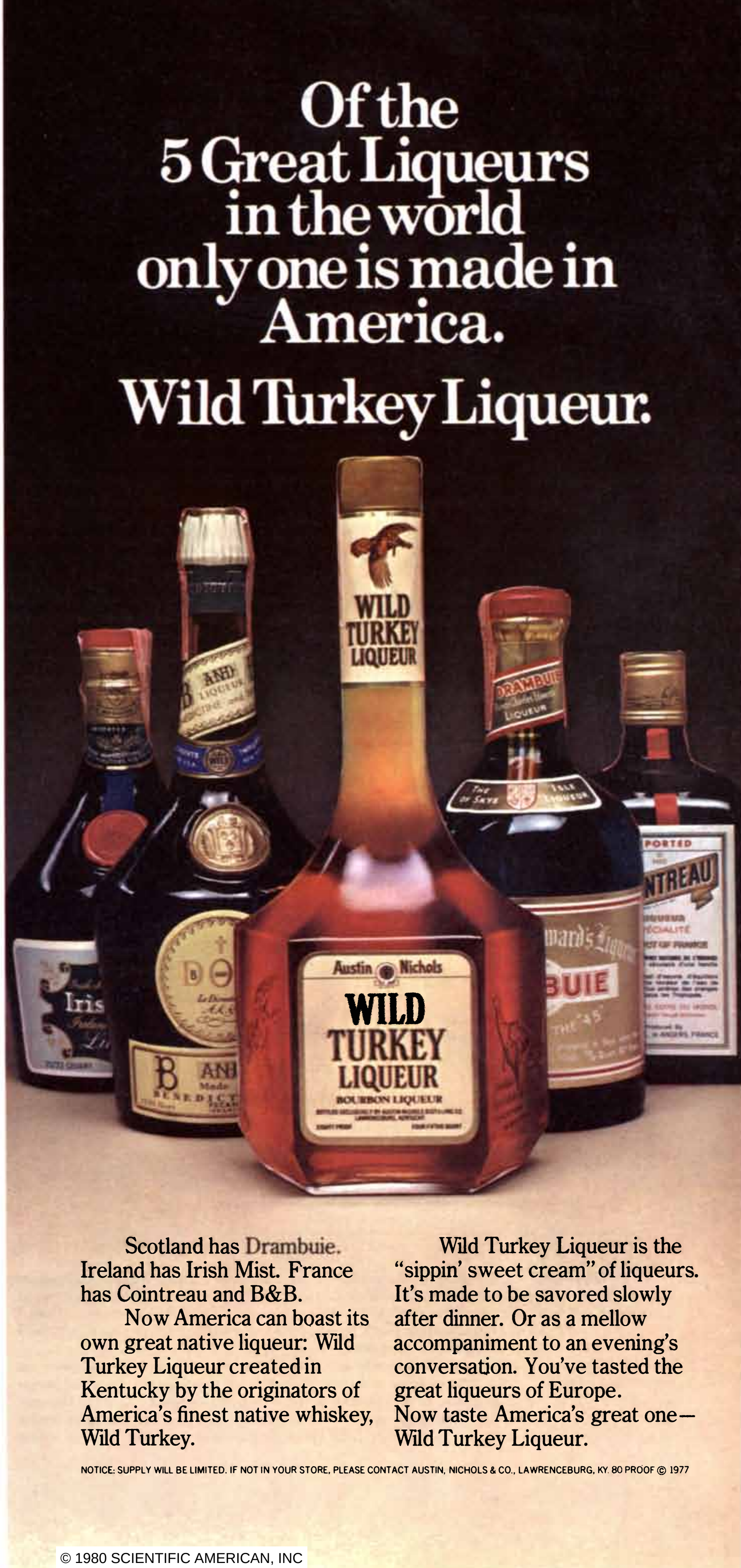
DIRECT AND INDIRECT INVESTMENTS required to build up the energy-supply systems of the developing regions (*black curves*) are bound to consume a larger share of those regions' aggregate G.N.P. than the corresponding investments required in the developed regions (*colored curves*). The investments called for in both the high-growth scenario (*left*) and the low-growth one (*right*) were averaged in the IIASA study over the two types of region, a procedure that tends to minimize the large amounts of capital that will have to be transferred across national boundaries to develop the great fossil-fuel resource basins on which much of the world's future energy supply will depend.

ties with the existing or expected density of human energy demand. The harvesting of certain fractions of natural energy flows in the environment results in specific energy-yield densities, which can be expressed in terms of the energy turnover per year per geographic area. Only in the most favorable cases could these supply densities exceed the demand densities identified for the IIASA regions in the two scenarios. They fall short of even the present demand densities of urban settlements.

The IIASA scenarios allocate all together almost 10 percent of the projected global energy supply to renewable energy sources. By 2030 this would amount to between two and four terawatt-years per year, a range close to the maximum energy-yield estimates from all resource-limited sources in most of the world's developing regions. Accordingly one has to expect a vigorous exploitation of all the biomass in Asia and Africa and much of it in Latin America. This prospect immediately raises questions of ecological stability, soil erosion, water requirements and global climatic effects. The cumulative impact of stretching agriculture, bioenergy production and hydroelectric power to their natural limits would transform the face of the earth in the decades to come. The responsible limits to such an ecological transformation are not known.

This projected view of how the world could balance energy supply and demand in the next two to five decades brings out issues at the interface of technology and politics. These issues emerge primarily from discrepancies among "what could be," "what should be" and "what will be."

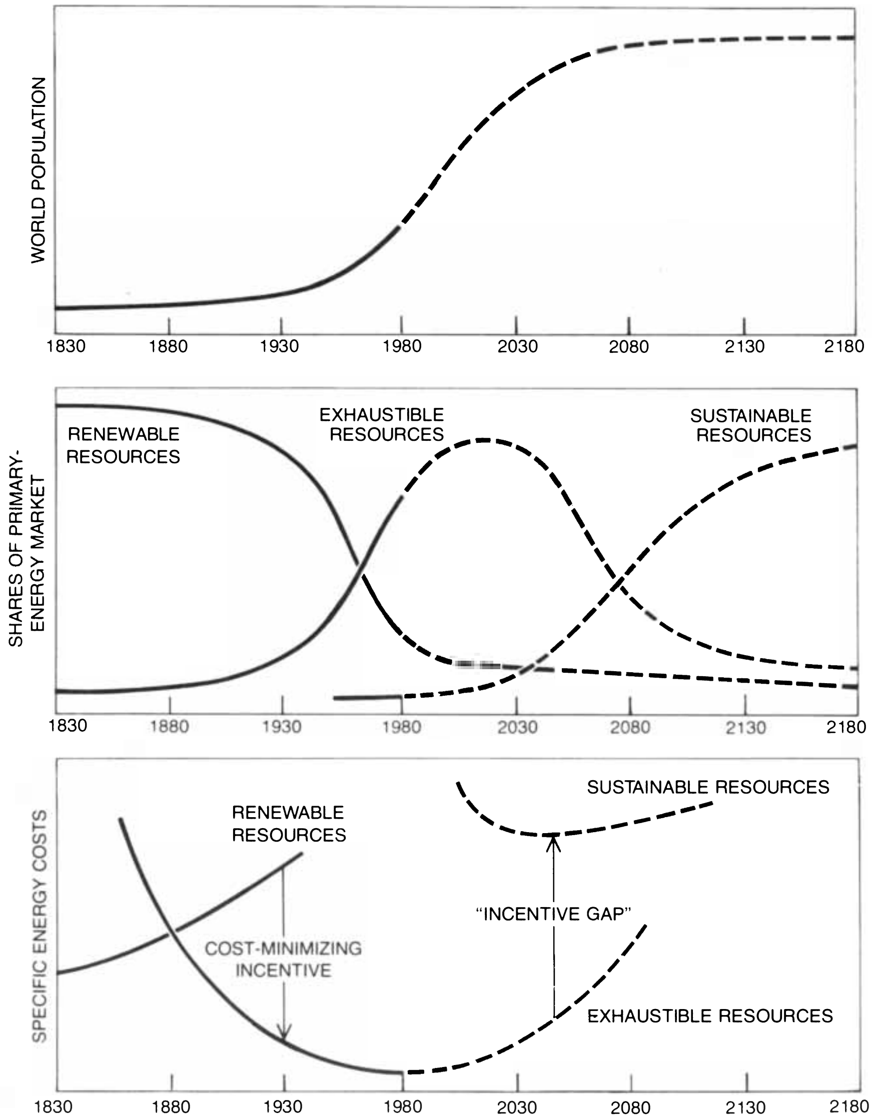
There is little doubt that the world will soon be inhabited by more people than the traditional renewable energy sources can sustain. This will be true even if the majority were to forgo achieving the material well-being the present-day developed countries enjoy. The developed countries were forced to give up renewable energy sources for fossil fuels on their way to industrialization as their energy demand began to exceed the local energy supply. The early transition from wood to coal in western Europe and the U.S. was largely driven by this requirement. The dependence of such countries on oil, natural gas and coal is now a worldwide phenomenon. Since the world's recoverable resources of fossil fuels appear to be quite large, the industrialized countries could in principle be supplied with enough energy to last for more than a century, even if the developing nations were to gradually build up a modern technological infrastructure and increasingly share in these supplies. Indeed, it was fashionable in the 1960's to conclude that there would be enough fossil fuel to allow for a timely buildup



of energy sources that are not resource-limited, such as nuclear power and direct solar power.

What seems to have turned the energy picture upside down in the 1970's was a small shift in trends that is not even now fully appreciated. For example, it appears that the transition from fossil-fuel energy to nuclear energy will probably be an uphill fight in terms of cost and effort. This trend is in striking contrast to the earlier experience of dropping energy costs, which accompanied the transition from renewable energy sources to fossil fuels. The ultimate consequences of such shifts are difficult to foresee, because they depend on the resolution of a conflict between hitherto sound economic principles: the minimizing of costs and the seizure of markets through technological innovation.

The recent history of the oil market provides an early warning of that dilemma. The drastic increase in all energy prices is starting to bring in more expensive energy supplies and conservation technologies that can be justified economically. Yet the actual production costs of energy remain rather low. The economic differential between energy prices and production costs, skimmed in the form of windfall profits by those in control of the prices, is definitely not being applied now to the buildup of new supply capacities at or near the new energy price levels. The OPEC countries are using their surplus oil income to develop their economies; the governments of the developed countries are financing public investments from energy royalties or energy taxes, trying to stimulate consumption and so further economic growth through social-transfer payments. In this situation high energy prices can be perceived primarily as a means for redistributing the benefits of high industrial productivity. As long as the actual costs of energy production remain low there is no reason for the global extension of an energy-intensive technological infrastructure to be seriously impeded.



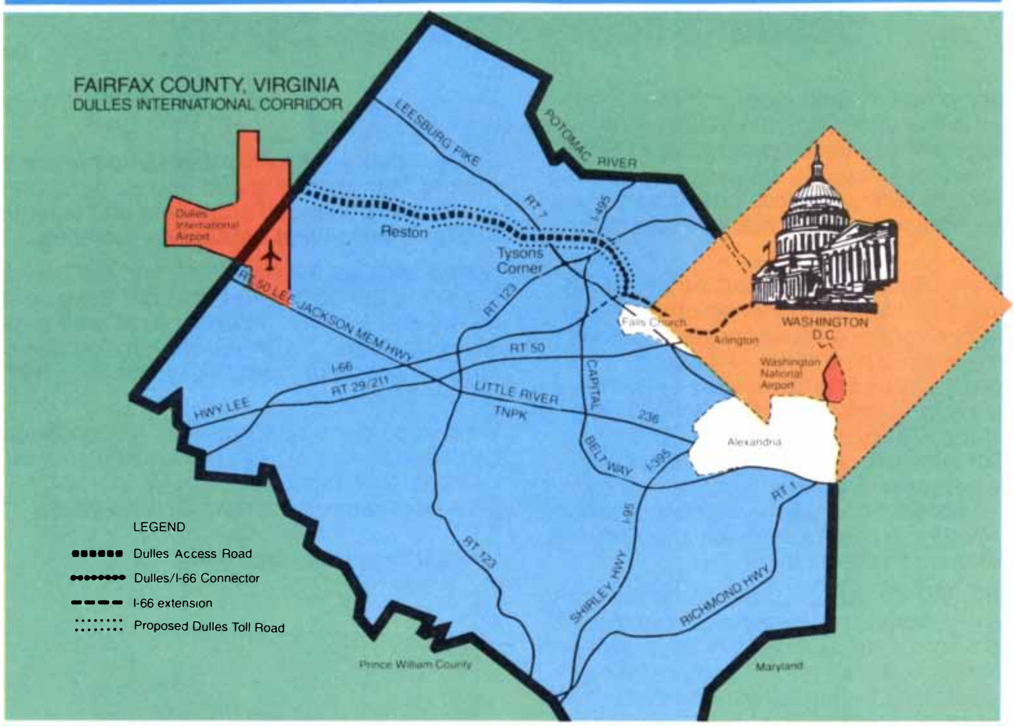
"INCENTIVE GAP" is foreseen by the author in the long-term transition from exhaustible energy resources (fossil fuels) to sustainable ones (such as breeder reactors, direct solar power and fusion reactors). The transition will be fundamentally different from the earlier changeover from renewable energy resources (such as wood) to exhaustible ones in that it will have to be made at a time of rising rather than falling energy costs. It follows that traditional cost-minimizing principles of economics cannot be relied on to stimulate the kinds of technological innovation needed to make the transition successfully. In this set of idealized graphs the incentive gap is placed chronologically in the context of the world-population trend (*top*), the substitution of primary-energy forms (*middle*) and the specific energy costs of the three major categories of primary-energy forms (*bottom*). All three graphs have arbitrary vertical scales.

In the years ahead energy investments will certainly be directed toward the deployment of second-best resources. The principle of the minimizing of costs will therefore first lead to the exhaustion of fossil-fuel resources that are easy to produce, convert, transport and burn. In spite of the fact that production costs for unconventional fossil fuels will in time reach a break-even point with the substitutes derived from nuclear power and solar power, reaching that point will not facilitate the quick buildup of the fixed capital stock representing these sustainable energy sources. The less rewarding the basis is on which an old infrastructure has to operate, the slower will be the pace at which one can afford to install an even less rewarding new infrastructure. In short, the transition to sustainable energy sources such as breeder reactors, direct solar power and fusion power might well become more difficult with time.

If this turns out to be the case, the entire global process of development must be seen as a race against time. It can only be won once the regions disposing of high industrial productivity and the regions disposing of limited cheap resources ally their different kinds of wealth in order to pay the price for building up a basis for sustainable energy sources. It will never be a minimum-cost operation. The transition from renewable energy sources to sustainable energy sources, the first steps of which have been conceptualized in the IIASA scenarios, appears to parallel a step mankind took in the Neolithic period, namely the transition of the food system from hunting and gathering to animal husbandry and farming. This time we have fossil fuels to ease the transition, but we have less time than our ancestors did. The transition to sustainable energy sources—breeder reactors, direct solar power and fusion power—cannot be put off to an era when the globe will have nearly exhausted its one-time energy endowment.

Advanced Technology Center Fairfax County

Northern Virginia



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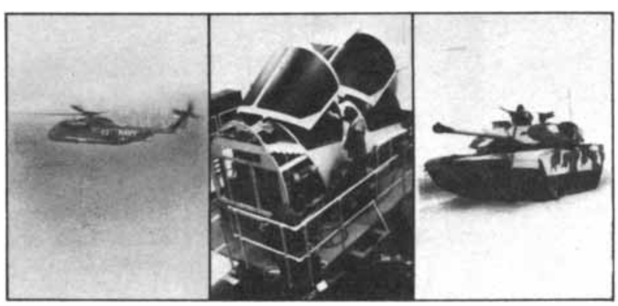

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Introduction to Fairfax County & Northern Virginia

George Washington, among other things an engineer and surveyor of some repute, lived there.

So did George Mason, whose insistence on a Bill of Rights as part of the U.S. Constitution made this country unique.

So did Robert E. Lee, whose genius spurred military technology by a generation or two.

Thomas Jefferson, an amateur scientist of much note, did not. He was, however, a frequent visitor and his home not far away with the university he founded are shrines to the questioning mind and technical excellence.

These men and many of their contemporaries who shaped the nation we are today lived just across the Potomac River from Maryland in Northern Virginia. The land it faces is now the District of Columbia, capital of the nation, seat of the Federal Government, the National Science Foundation, the Smithsonian Institution—"an Establishment for the increase & diffusion of knowledge among men"—and a host of colleges and universities. It is the source of much funding through many avenues for research, development and manufacturing at the very boundaries of existing knowledge.

The region has become a home for thousands of questioning minds and the benchmark of technical excellence.

Today, over 1,400 modern companies whose products test the extreme edge of many technologies sprinkle this attractive land between the wide and gentle Potomac and the quietly beautiful Blue Ridge Mountains of Virginia. Engineers, scientists and corporate managers have largely replaced landed gentry, freeholders and farmers. Spurred by the Fairfax County Economic Development Authority under the leadership of its recent Chairman, Earle Williams, President of The BDM Corporation, high technology, the fruit of the mind, has replaced the fruit of the land as the area's principal product.

But close to water and mountains, equally accessible to the peace of rolling rural farmlands and the stimulating atmosphere of one of the world's great capitals and educational centers, the area remains a uniquely pleasant and satisfying one in which to live and work.

A little light history

That part of Northern Virginia which now includes Fairfax County as well as neighboring Arlington, Loudoun and Prince William Counties and the city of Alexandria began as a land speculation.

King Charles II in 1649 granted to several noblemen all of Virginia that lay between the Rappahannock and Potomac Rivers. By 1719, Thomas, the sixth Lord Fairfax, Baron of Cameron, acquired all the shares, became the sole proprietor of the vast territory and actually travelled to Virginia personally to inspect and survey the property and eventually to live and die there. His cousin, William, built an estate at Belvoir where he became neighbors with people like George Washington at Mount Vernon and George Mason at Dunston Hall.

The County of Fairfax, named for Thomas, occupies only a small part of the original proprietorship. In 1742, the Virginia legislature carved the new Fairfax County out of Stafford County. The new jurisdiction, in its time, would also be pared away. Loudoun County to the northwest was formed in 1757 and a portion was given over to the new District of Columbia in 1798. Alexandria also became a separate entity in 1801 as part of the Federal District. Since the Federal Government at the time felt it had land enough on the Maryland side of the District, it returned these trans-Potomac sections to Virginia in 1846. They became Arlington County and the City of Alexandria, no longer part of Fairfax.

The Federal Government may have given up the Virginia part of the District of Columbia, but with the coming of World War II, they began to take it back, piece by piece. The need for vastly expanded office space to house all the new government agencies and the Defense establishment in particular soon had the Government bulging far beyond the D.C. line. The Pentagon, completed in 1943 in Arlington as the largest office building in the world, was only a taste of things to come. But it was also the catalyst that would cause extensive changes in the area and propel the government and the region into the forefront of new technology.

By 1980, David A. Edwards, Executive Director of the Fairfax County Economic Development Authority, could say: "We have the highest percentage of engineers and scientists in the workforce of any place in the nation. As a matter of fact on a per capita basis we have 2½ times as many such people as Los Angeles and three times as many as Boston."

Economic Background

The region's early economy was agricultural. Such industry as there was related to agriculture and shipping, grist mills, repair shops, carriage builders, wheelwrights, blacksmiths, shipwrights and the like. But it was hardly a center of burgeoning technology despite the scientific bent of many of its distinguished early inhabitants and institutions.

The business of Government and the servicing of it soon became the primary non-agricultural business of the region. And yet while government remained small and its support and use of technology in the pre-electronic age limited, the business of government support also remained small. From the nation's beginning until after World War II, technological innovation was the product of other areas, though the Washington area increasingly began to pay for much of it.

Population figures tell the story. From 1790 to 1930, Fairfax County grew from 12,000 to 25,000 people, a bare doubling in 140 years. In the 1930 decade, the population grew by 15,000 as a new philosophy of government took root. In another ten years, the population more than doubled. By 1975, it exceeded 530,000 and today is over 630,000. Many of these people live in Fairfax County and work in Washington across the river, in typical suburban commuter style. But increasingly and at an accelerating rate, many now both live and work in Northern Virginia.

The coming of technology

Today, Northern Virginia houses many Federal agencies besides the Department of Defense. Three major scientific/technical ones are the U.S. Geological Survey housed in a large complex near Reston, the Central Intelligence Agency at Langley and the National Technical Information Service (NTIS) at Springfield. The Agency for International Development Offices for Science and Technology and for Energy are also in the region.

The Government, of course, has always had a great need for people to staff its own departments and agencies. As elsewhere, these civil servants live near the job. Generations of them have been drawn from the Washington Metropolitan Area, including Northern Virginia. As the needs of an expanding wartime government brought tens of thousands of new people to the area, they found housing across the river in the congenial environs of Virginia. Many of their offices did so too. Companies doing business with the government were a bit slower. They at first moved into the city since that is where corporations had always done business.

"We had offices on Wisconsin Avenue in Washington," recalls Charles G. Gulledge, President of Dynalectron Corporation (and new Chairman of the Fairfax County Economic Development Authority.) "We were there 12 or 13 years and were running out of space. Further, we found it hard to recruit new people to work in the area. We had to move," says the CEO of the diversified high technology $350 million firm.

Others tell a similar story. "We opened an office with 40 people in downtown Washington in 1964 to be close to our major customer, the Navy," says Charles Briggs, Program Development Manager at TRW's Washington Operations office.

However, after the war as the influx of people and the growth of government programs continued at an ever higher technical level, the areas around Washington began to improve their infrastructures. More road systems and bridges were built, which improved access to the city but created traffic congestion. So companies began to short-circuit the situation by locating their operations outside the city.

Dynalectron moved to McLean, Va., a pleasant hamlet in Fairfax County. "We looked at lots of places, near some of which we have other operations. After a year of intensive evaluation, we settled in Fairfax County. The quality of life suits our employees, it's near our customers, it's convenient to domestic and international airports and it required minimum dislocation of our headquarter staffs." The company among other things provides facilities management including operation and maintenance of technical systems for the White Sands Missile Range in New Mexico and has just completed construction of the U.S.'s largest coal liquefaction plant at Catlettsburg, Kentucky. It employs nearly 800 people in the Fairfax County area—clerical, engineering, scientific and managerial—and, worldwide, about 8,000 U.S. citizens.

TRW, which in Washington does highly sophisticated computerized systems engineering and integration and software development for Government agencies, mostly the Navy, moved to Fairfax County in 1970 and now has some 650 people there. Many other firms followed a similar route.

Government itself began to decentralize operations, moving entire agencies some distance from the city center. In local communities, battles developed between growth and no-growth forces as the one sought new commercial and business activity to broaden the tax base and provide employment in the local economy while the other sought to go slowly and limit the rate of growth to that which the locality could absorb without major dislocation to people, institutions and environment.

Among the more forward areas was Fairfax County, which set up an Economic Development Authority in 1964 to "encourage desirable business and industrial development." At the time, the County was a second-ring bedroom community for the Metropolitan area with a very rapidly increasing population, most of whom worked elsewhere. There were relatively few industrial and business operations in the County. Those that did exist were there to service the population, not employ it. The infrastructure, however, the new roads, a new airport (Dulles International) and the land were there. The Development Authority's job was then to sell the County as a place to locate to the appropriate companies. In the main, these would be firms that supply services and products to one major customer, the U.S. Government, and to a number of second-level customers, one another.

To establish an Authority is one thing; to fund it another. The growth/no-growth factions in the County balanced one another and for many years the Development Authority had little authority. A blue-ribbon committee in 1975 appointed by the County Board of Supervisors, the County's elected governing body, strongly recommended that the Development Authority be adequately funded and staffed and that the County begin development in earnest. Says Earle Williams, who was a member of that committee, "We were becoming a bedroom community with an inadequate tax base to support the services our population needed and wanted. We had to promote development, not just let it happen, so that we could control the type of business that came into the area, broaden the tax base and provide employment within the community." Williams' company, The BDM Corp., is a $65-million diversified professional services firm that is testing the leading edges of energy, transportation, communications, defense and public policy theory and practice. The firm itself opened its local office in the District of Columbia in 1965 but moved early to Fairfax County, in 1966 and moved its headquarters there from El Paso, Texas, in 1970.

Charles Gulledge confirms the development philosophy. "We did not want to be the bedroom community for Washington," he says. "Our objectives were to control the quality of growth, to attract corporate headquarters and high technology organizations rather than heavy industry and also to attract all the supporting infrastructure—small businesses, shopping centers and the like. The committee report prevailed upon the Board of Supervisors to very substantially increase funding and objectives of the Development Authority. We have met or exceeded the objectives."

The goals have indeed been met. Since 1970, the number of firms has risen from 505 to 1,413. Employment has gained 131% from 24,662 in 1970 to 56,904 in 1979. More significant, however, are the types of firms and employees.

The number of companies, well-known and not-so-well known, engaged in research and technical manufacturing climbed from 135 to 342. Included in these are firms with names like Administrative Sciences Corporation, Advanced Technology, Axiom Systems Corp., BDM Corp., Sperry and Transcom Inc. that specialize in operations research, among other areas. In electronics, there are ACS International, AMF Electronics Research Laboratory, Atlantic Research Corp., Bendix Communications Division, Datatronix, Reston Consulting Group and Virginia Instruments.

Telecommunications, a particularly fast-moving area, has many companies represented, some of which do work in several related fields. Among these are GTETelenet, Source Telecomputing Corp., Northrop Page Communications Engineers, Inc., Digital Communications, Inc. and American Communications Corporation.

Computer programming, data processing and the like engage the staffs of perhaps more companies than any other activity, both as their primary business and in support. Again, the field is diverse and numbers among its members Advanced Technology Systems, Boeing Computer Services, Inc., The Bank of Virginia and the Virginia National Bank, Computer Sciences Corporation, Hazeltine Corporation, Litton Computer Services and Mailing List Systems.

Biological, chemical and environmental research is another large sector that includes firms such as Battelle-Columbus, BioTechnology, Inc., Clin Lab Medical Services, Environmental Technology Consultants, Inc., National Health Laboratories and Flow General Corp.

To support these and other organizations, there are several professional and technical training institutions, such as the Automation Training Center, the Computer Learning Center and the Performance Design Corporation.

Another category, corporate headquarters, administrative offices and manufacturers' representatives increased from 34 to 304. Many of these are also high technology, electronics and computer science oriented. Among them are Automation Industries, Dynalectron Corp., Documation, Honeywell, Inc., IBM Corporation, Memorex Corp. and Mobil Corp. The latter $48.2-billion company is moving all its U.S. marketing and refining headquarters to Falls Church in Fairfax County. The staff will include large numbers of the advanced technology people that are essential to the functioning of a modern petroleum corporation, including computer professionals, engineers, and communications specialists.

But most spectacular has been the increase in a related category, national and international trade and professional associations, which went from 2 to 100. Among these are such high-technology and science-oriented groups as the American Federation of Information Processing Societies (AFIPS), which moved to the region from New Jersey, the National Association of Biology and American Geological Institute. Others include the American Press Institute and the National Right-to-Work Committee.

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The need for people

Enterprises of this nature require large numbers of engineers, scientists, technicians and competent technical managers. Such people are not usually to be found in large numbers in rural counties, even those near large metropolitan areas. The employers and the area must attract the people from elsewhere. Money alone is not enough. Neither are pleasant living conditions. Competent, bright and curious people accustomed to working to a high level of technical excellence want assurances that their new work will be challenging, important, varied and of real value. They also want the company and professional regard of their peers and ready opportunities to advance in both their professions and careers through formal and informal continuing education and participation in professional societies.

In Northern Virginia, newcomers find no shortage of like-minded people. In Fairfax County, nearly 50% of people 25 and older have four or more years of college. More than 75% of the workforce in the County is white collar. Of those, over 60% are professional and managerial. To service the intellectual, professional and career needs of these people, there are eleven colleges and universities in the Metropolitan Area which offer on campus and extension courses particularly suited to the wide range of disciplines represented in the area. Two, George Mason University and Northern Virginia Community College, are within the County.

Challenging work there is enough, too. Since companies in the area exist largely to do for the Government what the Government cannot do for itself, the number and scope of projects are limited only by the Federal pursestrings and the imaginations of the strategists. Firms now are working on oceanography, air traffic control, computer sciences, rocket development, recombinant DNA, synthetic fuels, communications, electronics component R&D, electromagnetic management, protection, systems design and even manufacturing of advanced hardware from the design state to operation.

Much of the work, of course, is for the Department of Defense. However, there is truth to what Dr. Alvin E. Nashman, President of Computer Sciences Corporation's Systems Group and a Director of the Corporation, believes: "Often the forward cutting edge of technology is developed by the military, then diffused through other government programs to the civilian sector."

These firms employ professionals and technicians in many categories: engineers of all types; life scientists; physicists; computer scientists; chemists and biochemists; machinists. No two firms require the same mix of people, but few can find all the people they need. Many of these firms have been expanding so fast that the local supply of qualified technical and even non-technical people is constantly drained.

GTETelenet Communication Corporation, for example, which does research and technical manufacturing of communications and data transmission networks, set up shop in the County in 1978 with 125 people and now employs over 800. TRW expanded steadily from 40 to 600. Atlantic Research Corp. grew from 600 to 1,300 in four years. The Melpar Division of E Systems Incorporated has expanded its engineering group alone from 240 to 460 people in Fairfax County in the same span. More significantly, where Melpar had only 8 computer software people in 1976, the company now has more than 100.

And aside from expansion, normal turnover creates many openings. With a turnover of 10%, a 1,500 person firm will need 150 new hires a year even without expansion. Multiply that by some 30,000 technical and scientific positions in Fairfax County alone and the annual requirement is at least 3,000 new hires.

It's not just engineers and scientists. Some spots for skilled trades are equally hard to fill. "You used to be able to get skilled machinists who learned the trade at the Naval Gun factory across the river," observes Lambert Murphy of Atlantic Research Corp. "But that's gone. We need people who can work to tight tolerances and we can't find them. We have to go out and recruit them just as we do professionals. We have men in their seventies in our shop and no one to take their places."

Unemployment statistics reflect these figures. The entire Metropolitan region now averages 3.2% unemployment while in the District of Columbia itself it is 5%, in Northern Virginia 3.2% and in Fairfax County, a minuscule 2.8%. "Our rate normally runs from 40% to 50% of the national average," says Dave Edwards. So tight is the market, one manager complains that he cannot prune his staff. "I would like to cut the bottom 5% every year," says he, "but I can't afford to. I need the people who are, after all, qualified or we would not have hired them in the first place."

Which is not to say that there are never any layoffs in the region. There have been. However, when they do occur, they result from the specific difficulties of a particular company—a change in ownership or management, a mistake, a contract that failed to come through on time—and not from the general state of the local or even national economy. As Dr. E. Oran Brigham, Vice President and General Manager of Melpar puts it: "Defense employment in this area does not tend to follow the cyclical mode of other areas, like California." BDM's Earle Williams says the same thing differently: "We are more recession proof in Fairfax County than most other areas because the economy does not depend solely on the business cycle."

Nor is the expansion in people alone. Computer Sciences Corporation is a $450-million computer and communications company involved in the design, development and integration of complex state-of-the-art systems. CSC employs 15,000 people worldwide, has 4,000 in the Metropolitan area, 1,340 of them in Fairfax County alone. These computer scientists, mathematicians, electrical engineers, programmers, physicists and others are scattered in ten separate facilities in the County, a major one being at the western edge in Herndon, Va. Says Dr. Nashman: "We are at Herndon to give our people a more diverse geographic opportunity. They can live as far away as Middleburg (in the Blue Ridge foothills) or the District of Columbia and commute easily."

That Herndon facility is entirely concerned with a $220-million contract to design, develop and install a computerized communications and data system for Saudi Arabia. This is one example that not all the work done in the region is for the U.S. Government or even for domestic clients. Indeed, not all the companies are U.S. based.

The companies

Some seventeen firms in the County have headquarters abroad. These run as wide a range as the American firms, from sales and representative offices for supply and support organizations to manufacturing and R&D facilities for high-technology companies. Among these is NEC America, Inc., of Japan, which does research and manufacturing of digital communications radio and transmission equipment and Telecommunications Switching Systems, Inc., of France, which does R&D for telephone switching equipment. On a larger scale, the Belgian firm Gestinvest has bought land near Dulles airport on which to build a 146-acre industrial park on the desirable Dulles Corridor called the "Front Door to the Nation's Capital." The company plans 25 buildings to house 2,000 people concentrating on technology, research and development, organizations and companies not involved in heavy industry.

There may not be a typical Northern Virginia firm. But in the manner of their founding, growth and the nature of their customers, there appears a similar pattern. That of Atlantic Research Corporation is fairly representative of those that came later.

Founded in Alexandria in 1949 by two enterprising engineers on the strength of a $10,000 contract to develop a solid rocket propellant for the Navy, the company moved to Fairfax in 1958 to get more space. It was then basically a chemical company. But acquisitions added electronics capabilities, among others.

That same success also caused the company to be acquired by others, in 1967, after which it underwent a dissolution of sorts. In 1976, ten employees bought back the original Atlantic Research. Since then, though solid rocket motors are still 50% of the business and the Department of Defense accounts for 70% of its 1979 sales of $54 million, the company has expanded into other areas and other markets with such products as bottle cap liners, customized vans and buses, pollution control equipment and systems, coal-water slurries to replace fuel oil, electronic systems engineering and data communications.

Two programs illustrate the company's technical diversity. One is electromagnetic management—the management of the electromagnetic spectrum to reduce or eliminate interference. "Engineers and technicians with experience in this area are very hard to find," says Lambert Murphy, "we have to train them."

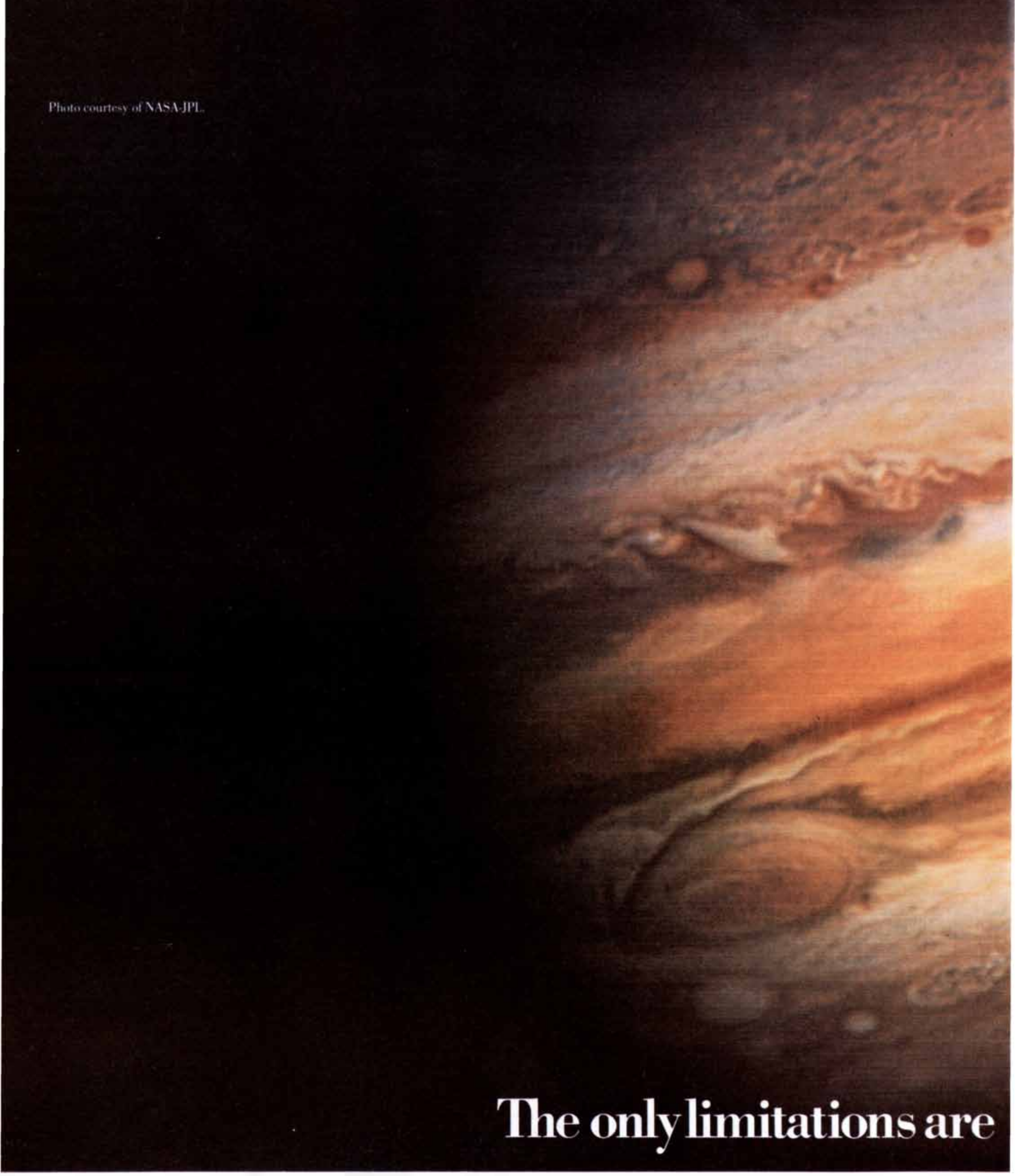
The other program is the Multiple Launch Rocket System (MLRS) a multiple-year, multiple-billion-dollar project in which ARC is teamed with Vought Aerospace to build a new generation of anti-tank weapons. "We will need 700 people in Camden, Arkansas, where the system will be built. But we need people here now to start up the program and get in on the ground floor of a ten-year project," says Murphy.

Dr. Oran Brigham at Melpar likes to say that his company is just about the only one in the area where an engineer or scientist can get hands-on experience with hardware. "In comparison to others in the region," says the General Manager of the facility where the work is so secret they may not even talk about the concepts or even with whom they have contracts, "where the emphasis is on studies, our emphasis is on technical applications. We don't just study it, we build it. And the same is true in our software area. Our people get hands-on technical applications experience. They conceive, design, develop, build and go into the field in operations."

While they can't talk about specific programs and contracts, Dr. Brigham could talk about disciplines and general applications. "We're in the intelligence business," he says, "in the sensitive business of electronic warfare, remote control reconaissance systems, airborne radio and the like." Among the products they can talk about are remote controlled flying drones, airplanes not much bigger than large models containing very sophisticated electronic surveillance gear.

While Melpar, which was originally started in the area by two engineers and then went a passage through a number of larger companies before settling down in 1970 as a division of E Systems, is a Research and Development firm. Its products are unique. "Of most of our products, we make only one or

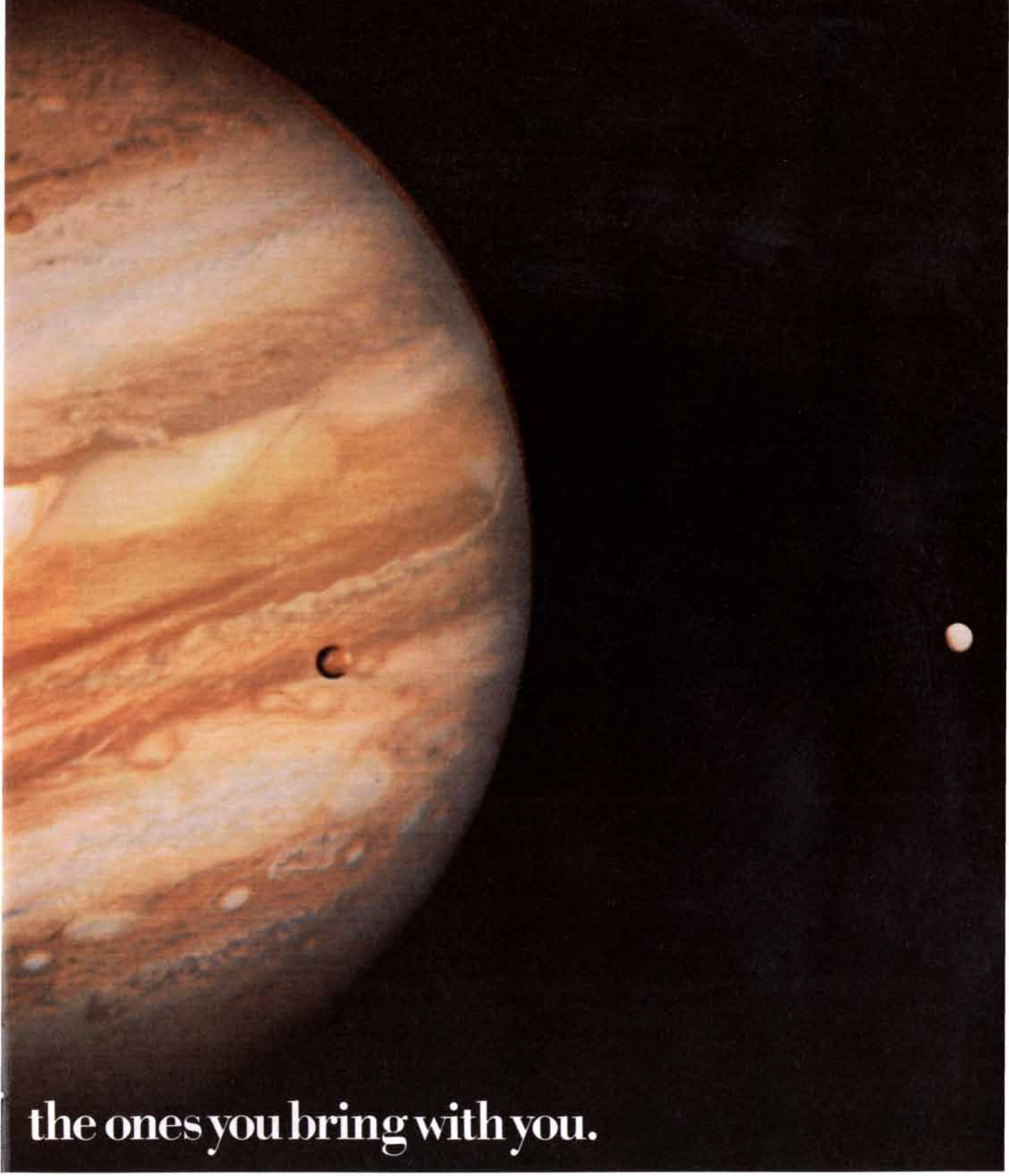
People in every type of technological endeavor are the underlying basis for Fairfax County's rapid development.



Computer Sciences Corporation believes that any problem humans can conceive of, they can eventually solve. The only limitation is the sophistication of their science. That belief has involved us in many of the world's most difficult problems and in some of its most astonishing accomplishments.

It has also made CSC the world's largest information services company. That may surprise you. Almost everyone knows what we've done, but hardly anyone knows that CSC has done it.

As NASA's computing partner, CSC has developed programs and systems and handled data processing for the missions that have orbited the earth and explored the solar system.


the ones you bring with you.

two," says Dr. Brigham. "There's always something new." The company has become increasingly engineering oriented, as indicated by the growth of the engineering department. Most of the engineers are electrical and electronic with a smattering of mechanicals, a couple of industrials and one chemical.

Loss of employees from one large company to another, however, is not a problem. People are of course free to do as they choose and the companies do not pirate one another. "If we have attrition," comments Dr. Brigham, speaking pretty much for all the companies in the region, "it is to the smaller electronic firms." As with any region filled with high technology people, universities and sources of funding for bright ideas, a major source of new industry and new firms is the existing base. Many companies spin off from the big ones as one or a few engineers get an idea they feel they can do better within a smaller environment. "Melpar has spun off a number of local companies," says Dr. Brigham with some pride.

Nowadays, these high-technology entrepreneurs are referred to both in derision and with affection, and perhaps some envy, as "Beltway Bandits." Bandits because the established companies feel there is competition enough without a couple of bright engineers setting up in a garage to write software for contracts the bigger companies might like to have. Yet these same Beltway Bandits provide the larger companies with a pool of talented people that are available to handle rush loads of highly sophisticated work. "It's a low risk, low capital business," says TRW's Chuck Briggs, "that encourages lots of people to leave the big companies and set up on their own." In time, of course, many a Beltway Bandit grows to join the Establishment.

One firm that did is ENSCO, Inc., of Springfield, Va., in Fairfax County. Four people from Teledyne in Alexandria, started the company eleven years ago. The firm founded by two engineers, a physicist and a secretary today does $15 million sales in a variety of high technology areas and employs some 300 people, 80% of them technical. The company specializes in research and development for government agencies and private industry in such areas as railroad and highway safety, energy, surveillance technology and anti-submarine warfare technology. For this, they hire electrical, electronic and

Tysons Corner attracts people and industry. Here is but a small section of the type of industries and architecture that dot this booming area.

mechanical engineers, physicists, mathematicians and computer experts. "We hire quality people," says Vice President Hal Demuth.

Demuth points to one specific. The company has developed an intriguing technique that uses radar underground to map coal seams. Technicians can take the special radar set into a mine and with it determine the extent of a coal seam as well as anomalies such as water or rocks that could pose problems.

It is this process of seeding and growth, reseeding and further growth locally stimulated and supported that is the mark of a successful economic development program.

Government contracts are the lifeblood of the Northern Virginia economy. And certainly during World War II and long after, the Department of Defense and its predecessors were the prime source of those contracts. Today, many of the companies in the area are still largely dependent on defense work, a growth industry. And the majority of firms are overwhelmingly dependent in their local operations at least on government work or on companies whose prime customer or client is the Government. But increasingly as more technology and more funds flow to the public civilian sector, these firms find themselves applying advanced technology to the solution of the problems of the public as well as those of the military. To paraphrase Dr. Nashman, quoted above, the technology the citizenry buys does soon benefit the people in more immediate ways than is manifest in space and weaponry.

Dr. Nashman's company, Computer Sciences Corporation, is a very good example of this flow-through. "Today, the basis of our business is one of high technological content exploiting the very, very radical developments in computers and communications, particularly in the past several years. These together permit a wide range of cost-effective solutions to problems," says Dr. Nashman. Much of this technology ranging from main-frame to mini- to micro-computers and concomittant communications technology was developed and refined for the military and space.

The Government is still the main consumer, accounting for 60% to 65% of CSC's total business. But in addition to the Department of Defense, "we work for the Department of Energy, Department of Labor, the Postal Service, the Environmental Protection Agency—we've worked for virtually all the departments in the Federal Government. The balance of our work is for multinational and national companies. Our work is quite variegated," says he in some understatement.

It is variegated intellectual rather than hands-on equipment work since the company manufactures no hardware at all. Scattered at several local CSC and customer sites in Northern Virginia, downtown Washington and nearby Maryland, the staff is involved in, among other things, designing a family of computer-based energy control and monitoring systems. These advanced systems are a long way from simple thermostats. They incorporate large main-frame computers with mini- and microcomputer systems linked through advanced communications equipment into distributed processing networks. Appropriate CSC software integrates the disparate elements into a functioning whole. These systems are intended to control and monitor energy use in large buildings and plants and at more dispersed sites such as Army camps. "We buy the hardware from various manufacturers and integrate it into systems which we design and for which we also design the software. The software is a very, very significant part of any systems operation," Dr. Nashman remarked. "It is what tailors a general purpose hardware suite into something designed to suit a specific application."

While CSC manufactures no hardware, which Dr. Nashman considers an advantage since it allows the company to give its best professional opinion unencumbered by any outside relationship, it can and will build one-of-a-kind items for some special purpose. "We are well versed in electronic componentry," laconically says the Group President.

Dr. Nashman and his company are firm believers in the computer and communications technology on which CSC has built its business and expects to continue to do so. "The world is going inevitably to solutions based on automation," says the scientist, with conviction. "The computer linked with suitable communications technology is a very energy efficient way to solve problems."

CSC's problem is people—not enough of them.

Says Dr. Nashman: "The work is demanding and requires high intellectual skills. Our performance depends on people. We emphasize the personnel aspects of our business." The company continually needs an ever growing roster of a full range of skills to meet its goals. The growth rate last year—3,000 people and $110-million more sales—indicates the magnitude of the problem. "We need mathematicians, physicists, programmers and computer science people particularly," says Dr. Nashman. These people need not necessarily have advanced degrees—only 5% to 10% of the present staff are Ph. D.s and 30% MS—though the company encourages and supports staff pursuit of higher degrees. "Because," says the Director, "the sophistication of the staff will have to increase within the next decade. Systems are becoming more complex. Reduced cost is making things possible and economic that we could not have contemplated before. And this will require the upgrading of staff capabilities."

Also hoeing the communications row, but with more emphasis on hardware, is Northrop Page Communications Engineers, Inc., a 30-year old wholly-owned subsidiary of Northrop Corp. The company, which employs about 1,000 people worldwide, has some 300 to 400 people in Vienna, whence it moved from the District of Columbia about seven years ago.

"We are a full-service organization," says William H. Bethel, Manager for Army Marketing and Business Development, "that does design, procurement, installation, testing and training for communications facilities. We furnish and install telecommunications systems on a turnkey basis. In support, we even do our own in-house research and development here in Vienna in two buildings of 235,000 square feet that house our engineering R&D lab, computer laboratory, and engineering test and calibration laboratory as well as administrative offices and engineering staff." A subsidiary, Page Technical Services, Inc. (PTSI), provides maintenance and services as well as training for customer personnel.

The company was once heavily defense oriented but in recent years has become less dependent on the Department of Defense as more and more of its customers have been foreign governments, as evidenced by the company's two subsidiaries in Rome, Italy, and Madrid, Spain. These work in the same areas as the domestic company. The type of work requires a varied and versatile staff that includes not only electrical and electronic engineers with subspecialties like UHF and VHF engineering, telephone and switching engineers but also civil engineers. "Our own government market is becoming important once again, though," says Mr. Bethel, "and our long-range planning is in that direction."

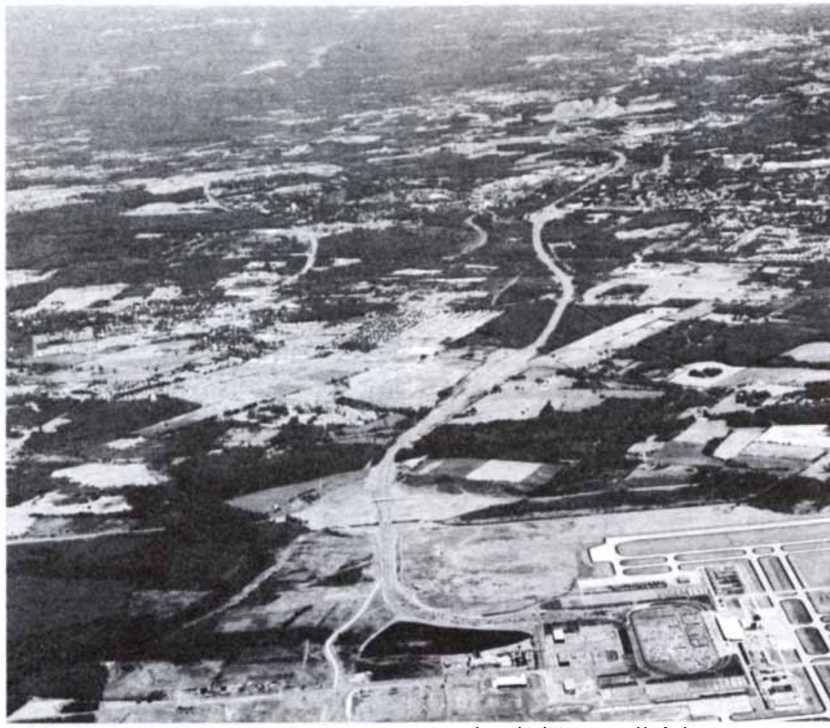
Nearly all the high-technology companies in the area are private companies, some publicly held, some not public, in business to make money for their stockholders and owners. One that is not is the MITRE Corp., a not-for-profit membership corporation that in both philosophy and mode of operation sits somewhere between the private sector and the government.

Quotes the 1978 Annual Report: 'In the beginning, MIT begat Whirlwind. Whirlwind begat SAGE. SAGE begat Lincoln Laboratory; Lincoln Laboratory begat MITRE." Whirlwind was a computer for continental air defense and MITRE's initial mission when established at Bedford, Mass., in 1958 was systems engineering and integration on SAGE, the continental air defense system. Set up by a university, MITRE was incorporated as a not-for-profit organization working in the public interest. In 1963, at the request of a couple of its "sponsors," the Defense Communication Agency and the Federal Aviation Agency (FAA), MITRE moved sixty people to Northern Virginia because "that's where the clients are. We set up next door," recalls Vice President Charles C. Grandy.

In time, these 60 people grew to become the Washington Center employing 1,600 people in five buildings in Fairfax County. "We are the second largest private employer in the County," says Grandy. The programs and sponsors have also diversified. While 90% to 95% of the contracts are still with the Federal Government, only 65% is now on national defense. Increasingly, sponsors are in the civil sector in such areas as transportation, energy, environment, justice, civil information systems, health care delivery, and the like.

MITRE differs from other organizations in the area in ambience as well as mission. It has an academic air, as perhaps befits an organization begat at one remove by an academic institution. "Our real role is to be a technical resource basically to help government clients get their jobs done well," says Mr. Grandy. "We are a bridge between manufacturers and the government agencies that buy their goods. We make nothing and do not take contracts from private companies. We can thus recommend and advise with complete impartiality." MITRE does some work for state and local governments and also for foreign governments but only under special circumstances.

Grandy cites as a typical problem that MITRE will study the application of technology to health care problems. It is a people-intensive business with rapid cost increases. "We felt that technology should be able to help improve productivity and began to investigate. Out of that have come some important government programs that show we can make tradeoffs that can help. Tele-



Dominating this photo is the Dulles Expressway/Corridor which is now called the "Front Door to the Nation's Capital." Dulles is in the foreground with the town of Herndon on the left followed by Reston, Tysons Corner and Washington in the background.

communications, for example, as a substitute for transportation. We did an experiment in New Mexico that showed the majority of medical cases in a remote area could be treated by paramedics who have various telecommunication capabilities with a distant hospital.

"We are looking for non-trivial problems in the public sector," says Grandy.

Flow General Inc., across the street from MITRE, has found a non-trivial problem in the public sector—cancer and virus infection control. A small group in the Flow Laboratories Division has a contract from the National Cancer Institute to develop a method to produce substantial amounts of interferon for clinical testing. Interferon is a natural substance that makes the body resistant to further virus attack. Produced by human cells in response to virus invasion, the substance is one of the most powerful biologic materials. "A dose is a few micrograms," says Dr. Victor Edy, director of the program. The material may be useful against a range of illnesses as diverse as the common cold and cancer. But the substance is so rare and so costly to produce, it isn't known for sure and can't be until there is enough for extensive clinical trials.

"We started working on it on our own a couple of years ago," says Vice President Dr. Harrison Hoppes. "Then when the National Cancer Institute sought bids for 50-billion units, we were able to respond and won the contract." The company is one of many pursuing this intellectually exciting goal which is also potentially life-giving and possibly very profitable. Flow General is taking the fermentation approach wherein human cells are induced to make interferon in large fermenters on the company's own Superbeads. "These are microscopic glass beads that give us tremendous surface area," says Dr. Edy. Absorption chromatography on glass beads then purifies the product. Purify is a relative word here. The 'purified' product is only 1.00% interferon.

The $60-million company, which employs 1,600 people worldwide and over 700 in the region, is not in the pharmaceutical business now but could be. Meanwhile, it does R&D and manufacturing on a range of biologicals, reagents and equipment for biomedical research, equipment and instruments for materials testing, and equipment for the communications industry. The company probably needs more people in the life sciences than most others in the area.

The Educational Milieu

As one would expect in so technically oriented a community, education is a major concern—the availability, quantity and quality of it both at the primary level and the continuing advanced level. The concern the local companies have for the topic is evident to any visitor. The first thing he is likely to see in many companies is a rack of brochures and leaflets by the entrance which detail the many courses and curricula available to employees at local campuses and by extension.

The many colleges and universities in the area, some of them of great renown, offer a virtually unlimited range of educational opportunities in any field from foreign affairs through law to physics, chemistry and engineering. Most of these institutions offer night and summer courses and have extension schools as well as full time day classes. All have close ties to the many government and quasi-government technical agencies in the areas such as the Geological Survey, Bureau of Standards, Smithsonian Institution, National Science Foundation and the like. The

An Information Resource

Should the scientist and engineers in the many high technology organizations in the area run short of information, they need go no further than Springfield, in Fairfax County. There they will find the National Technical Information Service (NTIS) of the U.S. Department of Commerce, a bureau on the same level as the probably better known and equally useful National Bureau of Standards.

NTIS collects, catalogs, indexes, abstracts and makes available all sorts of technical information that is produced by or for the U.S. Government. Much of the data, of course, come from within Government agencies developed in the course of their own work. But much more come from private companies engaged in research and development on Government contracts. Says Director Melvin Day, "We have 1.2 million documents averaging 25 pages each in our holdings and we add 70,000 new titles each year." That's a formidable amount of printed material for any researcher, even a dedicated documentalist, to plow through for something useful to his particular project. NTIS tries to make it easier.

"We have just come out with a new bulletin," says Mr. Day, "which we call 'Information for Innovators.' We go through all our material and select items that we think will be useful to industry in particular. Then we abstract these in a style suitable more to managers than to scientists so that businessmen can assess the business value of the item as well as its technical content." The first regular issue of this publication is available now.

For the more exacting researcher, the Service maintains at Springfield data banks for many government agencies, for which it is the clearing house. NTIS can also make Government computer software available to industrial users.

opportunities and the actuality of cross-fertilization between disciplines and sectors is immense and regularly carried on through the activities of the many technical and professional societies in the region. The local chapter of the Institute of Electrical and Electronic Engineers (IEEE), for example, has 3,000 active members and includes top management people, many of whom are Fellows.

Recognizing that it is easier for working people to keep up at work rather than miles away at the end of a day, many companies have entered extension agreements with the universities. Instructors will come from the schools to the firms and conduct formal classes there that carry credit and lead to degrees. A typical program is that of Melpar Division of E Systems which through the George Washington University Extension Service allows employees to obtain a masters degree on the premises. Other companies, like Atlantic Research, routinely compensate employees for courses successfully completed, whether or not they are related to the job. TRW has a fellowship program for full or part time study and currently awards about 100 fellowships a year. MITRE Corporation sends two employees to Carnegie-Mellon University each year to obtain doctoral degrees in a variation of the undergraduate cooperative program. The candidates work full time for some months, then attend the university full time for some months. A similar program allows many more employees to obtain masters degrees in three years of work and school.

One final indication of the level of the area's educational facilities: 80% of Fairfax County high school graduates go on to some form of post-secondary education and 60% to a four-year college or University.

Housing and life-style

Fairfax County today covers 410 square miles, all of it within minutes of downtown Washington, D.C. From its still rural western edge, one can in equal time and ease visit the museums, galleries, theaters and halls of government in Washington or seek the quieter pursuits of the Appalachian Trail and the Valley of the Shenandoah in the Blue Ridge Mountains. At Great Falls on the Potomac, white water canoists can run the rapids while further down where the Potomac becomes wide, placid and tidal affording a tranquil vista from Washington's beautifully preserved Mount Vernon, sailors of a more conventional stripe engage in weekend regattas, family outings and visits to the nation's most delightful waterland, Chesapeake Bay.

For travel further afield, the Northern Virginia resident has a wide choice. From convenient National Airport there are frequent flights to most domestic cities, large or small, and a direct connection by Washington's fabulous new Metro to downtown Washington and beyond and even into Fairfax County. From Dulles International Airport at the western edge, the local resident can reach any country in the world. First class superhighways traverse the area so that virtually no part of the region is more than an hour by road from any other part. Indeed, in few parts of the country can people live and play in such close proximity to their work and with so wide a range of life-style options available.

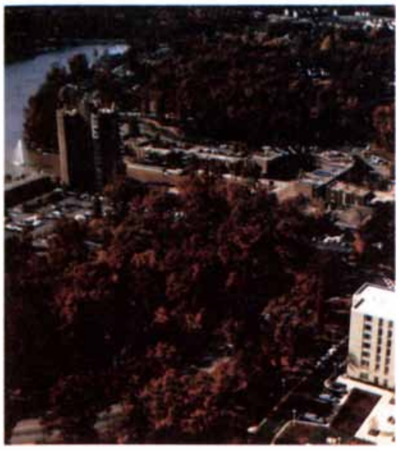
The County itself is something of an anomaly. Heavily populated, it is more like a sprawling city than the rural image the word "county" connotes. And its government and services—police, fire protection, schools, cultural activities—are decidedly urban-level rather than country like.

An elected Board of Supervisors governs the County. Eight of these are elected in regular and spirited campaigns from eight magisterial districts and a ninth, Chairman of the Board of Supervisors, from the County at large. The Board appoints all other bodies such as the School Board (which operates 167 schools) and the Economic Development Authority. Old-line established families have long since ceased to be the dominant influence in the County. It is now just too diverse. Any resident can become as politically involved as he or she wishes and line up behind one or another slate of Supervisors, who reflect local issues, i.e., growth or no-growth. Voters regularly turn out incumbents.

Within the County are a number of incorporated cities and towns that the County Government does not administer. These include Fairfax City, Vienna, Falls Church, Herndon and Clifton. These jurisdictions have their own services and taxes and, often, their own life styles.

The restored "Olde Towne" of Alexandria offers urban living on a human scale in town houses of distinctive, traditional regional architecture. The planned community of Reston provides self-contained suburban living in a uniquely communal concept. Between these, there are riverfront estates, condominium townhouses, apartments and single family homes for every taste and budget in both new developments and older communities such as Herndon, Vienna, McLean, Falls Church, the City of Fairfax and, more rural, beyond the county line toward Leesburg and Manassas.

In common with much of the rest of the country, the area has experienced housing price inflation and, particularly closer to Washington, prices are relatively high compared to many other areas. Indeed, some worry. "We're getting too expensive," worries Earle Williams, who would like to see a lot more moderate-priced housing being built.



Reston, industry and living at its finest. One of the world's most famous developments.

"If your service people—police, firemen, teachers—can't afford to live in the County, then you're in trouble." However, values are also correspondingly high—the buyer gets more for the money, especially when you add in taxes, utilities and environmental quality, the total "living package."

Rental apartments are in short supply throughout the region but rental houses, surprisingly, are not only abundant but available at lower rates than one would expect.

Culturally, the Region has much to offer. Aside from the attractions of downtown Washington—the Kennedy Center for the Performing Arts, theaters, museums—there is in Fairfax the world famous Wolf Trap cultural showplace and a symphony orchestra said by some to be better than the National Symphony Orchestra across the river.

Tomorrow

By 1995, planners expect the population of the Fairfax County area to be about a million. In the interim, the Government and its programs for defense and public welfare will continue to grow and to become increasingly dependent on high technology. The private sector, too, benefiting from the inevitable spinoff, will also become more technically oriented at every level from kitchen stove to personal communications. The companies and the people in good position to translate this huge outpouring of technology will be those physically located near its sources. And that source, for some time to come, will be at least as much if not far more the Federal Government as any private corporate program.

Northern Virginia, with the infrastructure already in place, with space for people and facilities still available and with the synergy already happening that comes when large numbers of interactive and like-minded people and projects come together, would seem to be already another major center of technical innovation. By 1995, it may be the major center.

Books for Readers of SCIENTIFIC AMERICAN

The Science of Human Behavior

The Social Animal
Third Edition

Elliot Aronson, University of California, Santa Cruz

Why is a compliment from a stranger probably more pleasing than one from your spouse?

Why can't candidates be sold like toothpaste, despite the claims of political cynics?

Why are you more apt to change your mind for fifty cents than for twenty dollars?

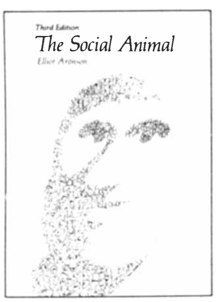
How did John Kennedy's bungling of the Bay of Pigs invasion increase his popularity?

Why are people living the closest to Three Mile Island also the most inclined to trust the Nuclear Regulatory Commission?

How do experimenters convince subjects that boring tasks are actually interesting?

Why is someone more apt to like you if he does you a favor than if you do one for him?

Why might a stern glance be more effective than a spanking in permanently quashing a five-year-old's desire to beat up his younger brother?



Drawing on a range of real-world examples, *The Social Animal* offers surprising and revealing answers to these and other questions about our beliefs, actions, and feelings. An acclaimed introduction to social psychology, *The Social Animal* draws you into the excitement of the subject through Aronson's colloquial style and array of concrete illustrations. Both the examples and the references in this new edition have been thoroughly updated, including, for instance, an expanded treatment of the mass media as well as material drawn from the tragedy at Jonestown and the nuclear accident at Three Mile Island.

The Social Animal is practical, amusing, and thought-provoking.

1980, 377 pages, 11 illustrations

Self-Perception
The Psychology of Personal Awareness

Chris L. Kleinke, Wellesley College

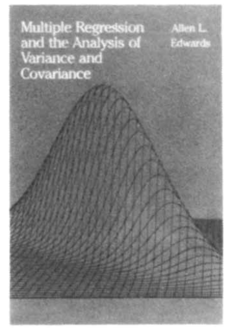
Chris Kleinke takes an experimental approach to self-perception, summarizing research and theory on how we perceive bodily states and behavior. Kleinke looks at pain and hunger, guilt and love, fear and prejudice, self-relaxation and fear of success. The reader gains not only interesting insights but practical strategies for change.

"You can come away knowing more about yourself than you might have known from a yardful of other books. . . . All in all, Kleinke has given us a psychological self-help book that works."
—*West Coast Review of Books*

1978, 265 pages

Multiple Regression and the Analysis of Variance and Covariance

Allen L. Edwards, University of Washington

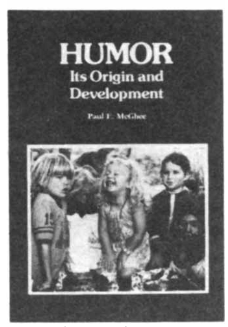


This book shows the correspondence between the analysis of variance and multiple regression analysis of experimental data. Stressing clarity and accessibility, the author has kept the examples and notations simple, so that readers can readily understand the methods of analysis rather than become involved in complex and time-consuming computations. Most of the calculations for the examples in the book can be made quickly and easily with just a hand calculator. Exercises at the end of each chapter provide additional insights into the material covered and test the reader's comprehension.

1979, 232 pages, 17 illustrations

Humor
Its Origin and Development

Paul E. McGhee, Texas Tech University



This book brings together current research on humor and offers new ideas on its evolutionary origins. Paul McGhee shows how children learn to create and appreciate humor and discusses humor as a useful clinical tool and a therapeutic way to cope with our problems. Tracing its development in the human species as well as in the individual, the book treats humor as a unique form of play with symbols, ideas, and images, perhaps not beyond the capacity of other animals. *Humor: Its Origin and Development* requires no specialized background or knowledge; anyone interested in humor will find it informative and intriguing.

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The Economic Development of China

In this fast-growing poor country a fourth of mankind appears to be secure against famine and epidemic disease. The decline in the birth rate promises a stable population by the year 2000

by 丁 忱 (Ding Chen)

Only three decades ago, on October 1, 1949, the People's Republic of China proclaimed its existence. In the brief time since then, this impoverished, backward, heavily populated nation of ours has carried out a socialist revolution, has undertaken socialist construction and, in spite of twists and turns in the road on the way, has won historic objectives. Today 977 million Chinese people, nearly a fourth of the world population, are secure against famine, flood and epidemic disease.

This is a great event in history. Socialism has demonstrated its vitality as a system for the promotion of economic development.

Hundreds of millions of Chinese alive today remember the feudal order that is recalled only in the history books of Western nations. In the typical Chinese village the landlords and the rich peasants, less than 10 percent of the population, owned 70 to 80 percent of the land. In rent and crop shares, in taxes and graft on taxes and in usury they appropriated as much as they pleased of the product of the land and work of the middle and poor peasants and the landless laborers. Even the children of a poor family could be seized in payment of a debt, although a teenage girl in a poor crop year would not fetch 50 kilograms of grain. In a bad winter a village would find its poorest peasants dead of starvation in their hovels. The peasant masses of China had neither the means nor the incentive to improve their productivity.

Foreign capitalism played an important part in the disintegration of China's feudal economy. In their invasion of China, however, imperialist interests sought not to develop Chinese capitalism but to transform China into their own colony or semicolony. Imported rice and flour fed the people, imported oil lighted the cities and imported cotton supplied the looms. The collusion of the agents of imperialism with Chinese feudal forces and the comprador bourgeoisie arrested the development of Chinese capitalism. In preliberation years the steel output of China never reached a million tons.

Chiang Kai-shek rose to power in 1927. Over the next 22 years, his Kuomintang regime brought China into desperate straits. From the outbreak of the Sino-Japanese war in 1937 inflation raged out of control. By the time the Japanese had gone the old economic order was in ruins.

On their liberation in 1949 under the leadership of the Chinese Communist Party the people turned to the work of healing the wounds of war and the building of the socialist economy based on public ownership. The feudal land-tenure system was abolished, and 50 million hectares of land were distributed to the poorest peasants. Major bureaucratic capitalist enterprises were confiscated. For the middle- and small-size businesses owned by the national bourgeoisie a policy of restricting, utilizing and transforming private capitalism was adopted. Inflation was curbed and prices were stabilized. As early as 1952, with the resulting release of productive forces, the output of nearly all the major agricultural and industrial products surpassed the highest levels ever achieved in preliberation times.

The year 1953 ushered in the First Five-Year Plan. Since then economic development has gone forward hand in hand with the socialist transformation of agriculture, handicrafts, industry and commerce. The Chinese peasants, in possession for the first time of their own plots of land, could see that neither socialism nor increase in productivity could be based on a small-peasant economy. They took the first steps toward socialism with the organization of mutual-aid teams. Under the tutelage of Chinese Communist Party cadres they have gone on to learn that full collectivization places larger resources—electric power, machines, fertilizer, pesticides, improved strains of plants and animals, reclaimed land and irrigation works—in their hands to improve output per hectare and per man-hour.

In the industrial and commercial sectors an entire set of measures was devised for transforming capitalist enterprises into socialist ones. In 1956 the middle- and small-size businesses were reconstituted as joint state-private enterprises, and their owners were paid an annual interest of 5 percent on the value of their assets. By then there was little difference between these enterprises and those that were owned by the whole people. Capitalists who had managed the business became administrative personnel, their skills still engaged at times in its management. In 1967 the state

SILT-LADEN WATERS of the Chang Jiang (Yangtze River) empty into the East China Sea in the digitally enhanced Landsat image on the opposite page, acquired on August 4, 1979. The flat alluvial lowland that fills the scene has been formed over thousands of years by the deposition of sediments from the river. Canals, some utilized for the transportation of harvested crops but most dug to promote drainage, crisscross the lowland. The area is intensively cultivated. The principal rural crops are rice and mulberry (for silkworm fodder); close to the more built-up areas truck farming and animal husbandry (pigs and fowl) predominate. The meandering stream entering the Chang from the south (*bottom center*) is the Huangpu Jiang (Whangpoo River). The urban complex on its left bank is Shanghai, China's largest city and most important seaport. Most of the territory surrounding the city, including the islands in the mouth of the Chang (but not the land north of its left bank), comprises one of the three *zhixia shi*, or federal districts, of the People's Republic. (*Zhixia shi* is translated literally as "city directly under the central authority.") This district is of course Shanghai Shi. The other two districts are Beijing Shi (Peking and its surround) and Tianjin Shi (Tientsin and its surround).

stopped paying interest to former owners. The joint public-private enterprises then came completely within the system of ownership by the whole people.

After 30 years the Chinese economy has an entirely new presence in the world. The country's great rivers, subject to disastrous flooding, have been tamed. Some 45 million hectares are now under irrigation. Two-thirds of the waterlogged fields have been drained and a fifth of the cultivated slopes terraced. The gross value of agricultural production in 1978 was 3.4 times that of 1949, reflecting an average annual increase of more than 4 percent. Foodgrain output had increased at an average annual rate of 3.5 percent, to nearly 200 million tons.

Industry has made corresponding strides. Steel production exceeds 30 million tons. Electric power, petroleum, coal, chemicals, machine building, textiles and light industry have all vastly expanded. Many new industrial cities have been built. Today there are 350,000 industrial enterprises in the country. The fixed capital under ownership by the whole people amounts to more than $200 billion, which is 25 times the total capital accumulated in the century before liberation. Industrial development has had its bad years, but even so the annual growth rate has averaged more than 10 percent.

Comprehensive transportation and communication networks now knit together the diverse regions of the country. Since liberation 30,000 kilometers of railroad have been built, reaching into the formerly isolated southwest and northwest provinces. Nearly 800,000 kilometers of new highway have made more than 90 percent of the nation's communes accessible by road vehicles.

In a nation where 80 percent of all the people and 95 percent of the rural people were illiterate more than 200 million children are now in school, more than 60 million of them in secondary schools. Higher education, just recovering from the excesses of the misconceived "egalitarianism" of the Gang of Four period, enrolls fewer than a million students. Nevertheless, the nation's progress in

MAP OF CHINA locates the 21 mainland provinces (the island of Taiwan, which ranks as a province of China, is excluded from this count), the five autonomous regions, the 13 cities with a population in excess of a million, the 16 other major urban-suburban population centers and the principal rivers. The total land area of China, roughly 1.04 billion hectares, is greater than that of the 48 contiguous states of the U.S.; only 106 million hectares are considered arable. Most of this land lies within the zone outlined in green. The dotted part of the rail net (*red*) is being electrified and the dashed part is being double-tracked. The blue rectangle indicates the area seen in the Landsat image on the preceding page.


HEILONG
HEILONGJIANG
QIQIHAR
HARBIN
JILIN
CHANGCHUN
NEI
MONGOL
ZIZHIQU
LIAO
SHENYANG
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ANSHAN
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HUIZU
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GANSU
BEIJING
TANGSHAN
HEBEI
TIANJIN
LUDA
TAIYUAN
SHANXI
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YELLOW
ZIBO
SHANDONG
YELLOW SEA
ZAOZHUANG
LANZHOU
ZHENGZHOU
JIANGSU
WEI
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SHAANXI
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ANHUI
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KUNMING
YUNNAN
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ZIZHIQU
GUANGDONG
GUANGZHOU
XI
PINGXIANG

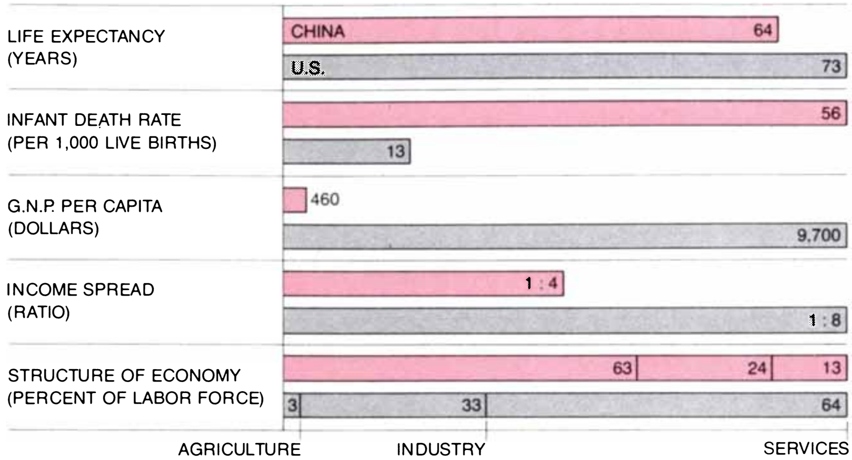
Painting by Richard Hess

science and high technology is evident in its possession of nuclear weapons and capacity to launch and recover earth satellites. In medicine progress in research has been crowned by the synthesis of insulin, but the great achievement has been the extension of health care to substantially all the people. Several million paramedical personnel administer primary care and send patients on to the care of physicians in the hospitals and medical centers.

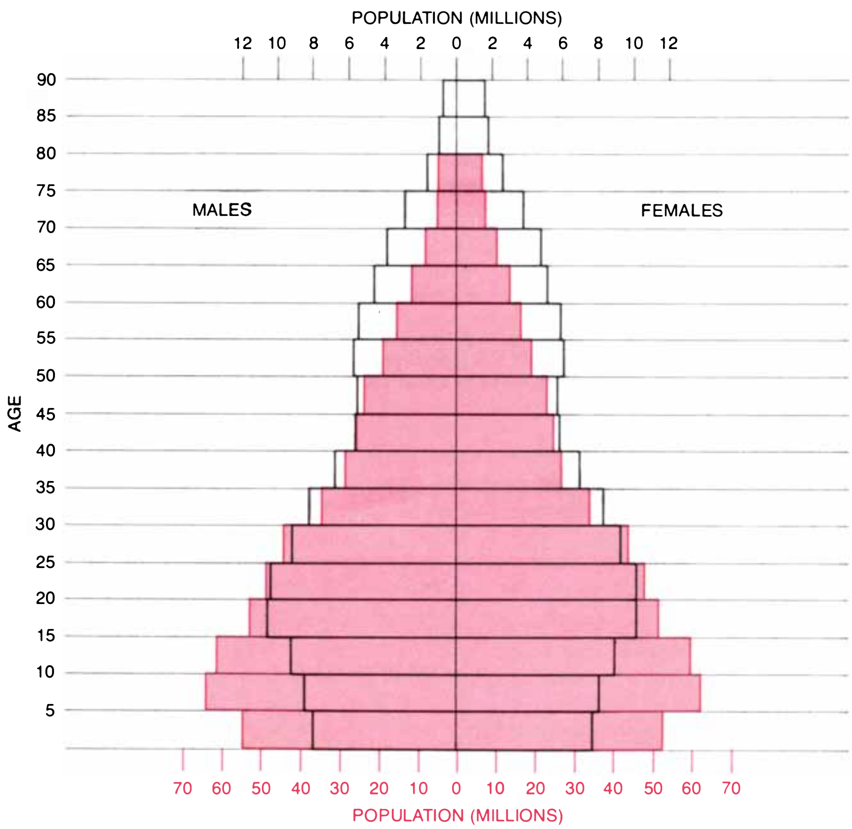
The explosive growth of the Chinese population by more than 400 million since liberation provides the most convincing evidence of the improvement of the people's well-being. Prior to liberation China's population statistics exhibited the classical combination of a high death rate, a high birth rate, a low rate of natural increase and a short life expectancy that described the human condition throughout history down to the present. The sharp decline in the death rate soon after 1949 brought the natural rate of increase up to 20 per 1,000 and for a few years to more than 30 per 1,000. Decline in the birth rate has now reduced the net annual increase to 12 per 1,000, signifying the entry of the Chinese people into the second stage of the demographic transition.

The progress in our socialist construction has been remarkable, but we have paid a high price for the twists and turns along the way. The First Five-Year Plan brought real progress in the "three transformations": of industry, agriculture and commerce. Then in 1958 came the call to accelerate the Second Five-Year Plan into "the great leap forward." The rate of accumulation of investment capital was pushed from 24 percent to a backbreaking 44 percent, with overemphasis on heavy industry and an attempt to complete the collectivization of agriculture, tantamount to effecting the transition to communism almost overnight. Under the banner of "egalitarianism"—particularly in the distribution of resources as between advanced and backward production brigades and teams of the new communes—agricultural production actually fell in this period. Only after three years of readjustment, with the rate of accumulation throttled back to 26 percent, could the Third Five-Year Plan be launched in 1965. The Fourth Five-Year Plan foundered in the excesses of the Gang of Four. The country is now undergoing another period of readjustment, the first battle for the "four modernizations": of industry, agriculture, science and technology, and national defense. The rate of accumulation, 36 percent in 1978, was much too high and is being resolutely reduced, step by step, to reach the optimum rate of 25 percent in a few years' time.

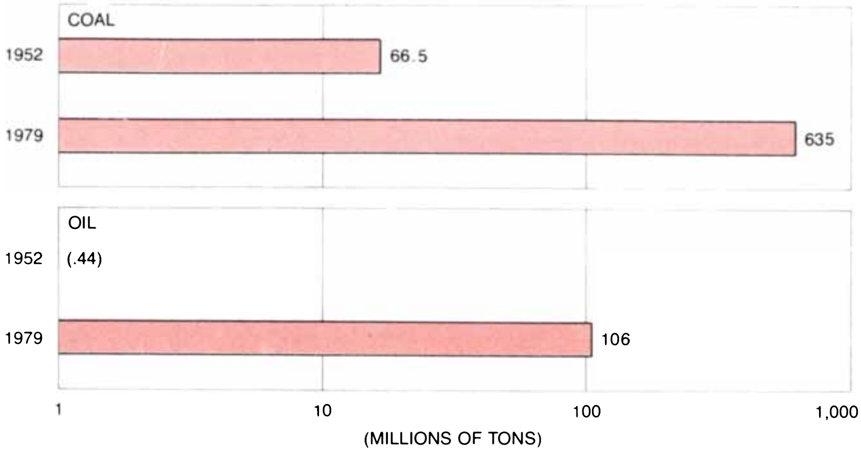
In retrospect it can be seen that to a



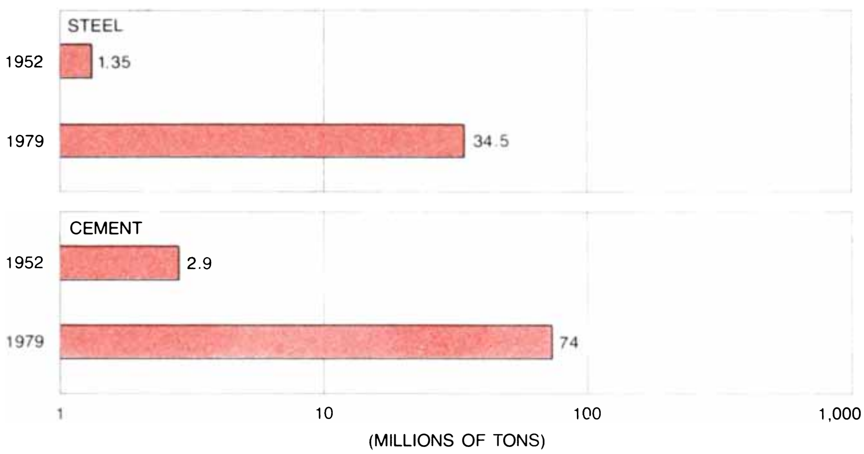
FIVE INDICATORS of development appear as contrasting pairs of bars in this chart. In the first four pairs, whichever is the maximum value is taken to be 100 percent and the lesser value is presented as a percent of the maximum. In all five pairs the standard for comparison is the U.S. statistic. For example, in 1977 U.S. life expectancy at birth was 73 years (*dark bar*). In China in 1979 life expectancy was 64, or 88 percent of the U.S. value. Next, U.S. infant mortality (13.6 per 1,000 in 1978) is less than a fourth of that in China. U.S. per capita income in 1978 was $9,700; the equivalent dollar figure for China is less than 5 percent as high. Next, the richest fifth of all U.S. households have some eight times the income of the poorest fifth, whereas in China the richest fifth have only four times the income of the poorest. Finally, the U.S. labor force is only 3 percent agricultural, 33 percent industrial and 64 percent service, whereas the Chinese labor force is 63 percent agricultural, 24 percent industrial and 13 percent service.



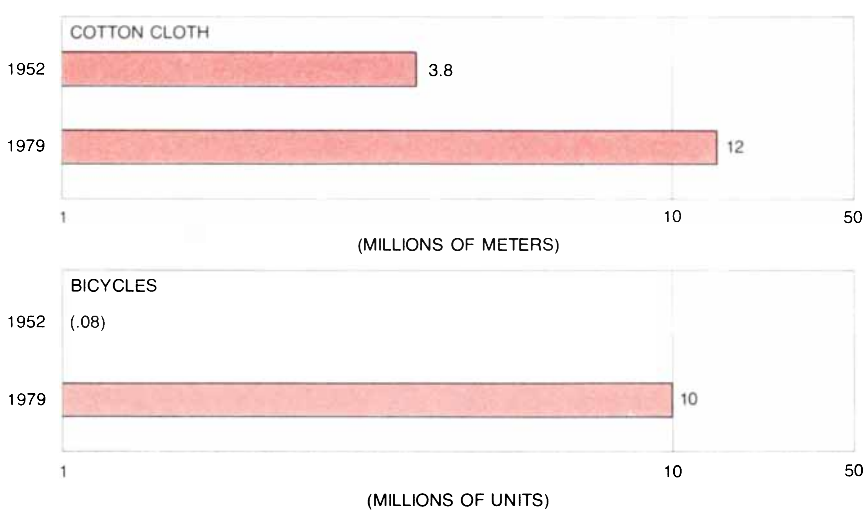
POPULATION PYRAMIDS compare the percent of the total population of China (*color*) and the U.S. (*black*) in each of 16 age brackets. Males are at the left and females at the right. Actual numbers in each cohort are indicated by the scale at the top for the U.S. and the scale at the bottom for China. The Chinese population, as projected here for July, 1980, totals 977,-320,000, of which 499,457,000 are male and 477,863,000 are female. The U.S. population, as estimated for July, 1979, totals 220,585,000, of which 107,457,000 are male and 113,128,-000 are female. The Chinese pyramid shows the broad base typical of less developed nations; more than 60 percent of the population are under 30. The base might be even broader except that the size of the youngest cohort has been diminished by population-control techniques.



FUEL PRODUCTION between 1952, the year preceding the First Five-Year Plan in China, and 1979 has shown a phenomenal increase. The annual amount of coal mined, 66.5 million tons in 1952, was 635 million tons in 1979. The amount of petroleum produced in 1952, too little (.44 million tons) to appear on this logarithmic graph, reached 106 million tons in 1979.



INDUSTRIAL MATERIALS were also produced in increasing quantities. In 1952, 1.35 million tons of steel were produced; by 1979 annual production reached 34.5 million tons. Under three million tons of cement were made in 1952; 1979 production exceeded 70 million tons.



CONSUMER ITEMS showed a more modest increase during the same period. For example, some four million meters of cotton cloth were produced in 1952 compared with 12 million meters in 1979. The number of bicycles manufactured in 1952 (some 80,000) was too small to appear on this logarithmic graph. In 1979 the annual production attained a level of 10 million.

certain extent the setbacks we encountered in this period could not have been avoided; after all, there had been no experience in the building of socialism in such a large and backward nation. The various precedents we had, for example in the building of the U.S.S.R., proved not to be applicable to China. We had to start from the actual situation in our country and, following the principles of Marxism-Leninism, to find original solutions for the problems of economic development.

How in the first place were we to establish a new socialist countryside? In the guerrilla Base Areas of the North, in the provinces of Shanxi and Shaanxi, whence the Red Army went on the offensive in 1947 to its victories over the Kuomintang, Mao Zedong and his colleagues had gained deep experience in rural work. They heralded their military offensive with a decisive political stroke: the proclamation on October 10, 1947, of the Draft Agrarian Law. That law abolished feudal ownership and canceled all debts incurred under it. Article VI turned the land over to village peasant associations for distribution in accordance with the stipulation that "surplus shall be taken to relieve dearth and, with regard to the quality of land, fertile shall be taken to supplement infertile, so that all the people of the village shall obtain land equally, and it shall be the individual property of each person." This sweeping promise rallied the peasantry behind the Red Army as it rolled forward and soon isolated the Kuomintang forces in a last few city refuges.

The distribution of the land gave the villagers their first taste of self-government and started them on the way to socialism. Typical was the experience of the 60 households of the village of Dazhai, later to be held up to the entire country as a model production brigade. In this ordinary little village in the arid, heavily eroded loess landscape of Shanxi the people found themselves in possession of some 60 hectares of cultivated land scattered in a crazy quilt of 4,700 fragments over eight ridges and seven gullies. They could see the advantage of organizing for mutual aid once the land was their own.

An enormous population, insufficient cultivated land, frequent natural calamities and backward farming methods had made the life of the peasant masses difficult even after agrarian reform. They could escape poverty only by taking the road to socialism. All over the country, as at Dazhai, the people took the first step toward socialism by organizing themselves in producers' cooperatives in which they pooled their still privately held land. Thereafter they progressed to fully socialist cooperatives in which the land, animals, machines and

tools became the property of the village. The profound social change did not sap individual initiative or undermine social productive forces. On the contrary, it motivated more ambitious enterprise in the development of agriculture. At this stage the village would be ready to join others in the organization of a commune. It is a three-tier institution: a commune consists of a number of brigades; each brigade is made up of production teams, and the team is the basic accounting unit. Although the commune merges the interests of a few hundred villages and their several thousand households to secure the advantages of large-scale development and cultivation, sharing in the product of a team strongly sustains the producer's incentive. The advantages won at each stage of the transformation showed the people the way to the next.

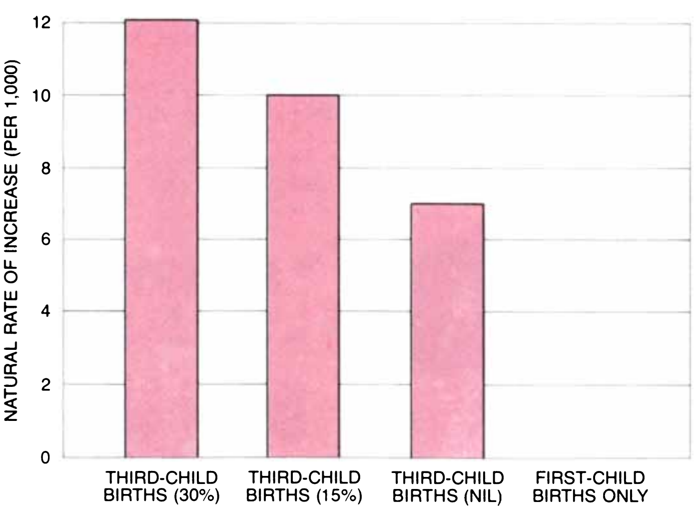
Thus the villagers of Dazhai went on to accomplish feats—literally "moving mountains"—they would not have dreamed of had they remained tillers of their own little patches of soil. They leveled and terraced the former hillside fields, buttressing them with embankments and dams of stone and earth; they filled in four of the seven gullies, adding to their cultivable land; they dug a seven-kilometer canal and built a pumping station to irrigate their lands, formerly drought-stricken nine years out of 10. On the uplands they afforested 27 hectares with pines and planted 40,000 fruit trees. In 1975 their land yielded a harvest of 8.4 metric tons of grain per hectare, more than 10 times the preliberation record. This once barely surviving, subsistence-farming village now delivers an average annual two tons of grain per household to the state distribution system.

In support of such self-reliant communal enterprise the agencies of the government at the county, provincial and national level undertook infrastructure investments scaled to the resources at their command. For such investment the Yellow River presented an urgent challenge to all levels of government and to the 100 million inhabitants of its 750,000-square-kilometer watershed. On its 5,500-kilometer course to the sea this great river traverses the Loess Plateau of the northwestern provinces, stripped of vegetation generations ago and only now coming under afforestation and restorative cultivation. To its lower reaches on the meander plain and to its delta on the Bo Sea the river carries annually a burden of 1,600 million tons of silt. Settling on the bottom as the current slackens, the silt has built up the bed of the river from three to five meters above the surrounding plain and in some places 10 meters above it. This "elevated river" actually serves as a watershed, the rivers south of it flowing to the Huai River and those north of it to the Hai River. When the Yellow River, in periodic heavy flood, overran its dikes in the past, it would inundate thousands of square kilometers all the way to Tianjin, 200 kilometers to the north, and to the valley of the Huai, 250 kilometers to the south.

The lower stretch of the Yellow River is now confined by a second Great Wall: by massive dikes built on the foundations of the old, each dike wide enough to carry a highway on top and rising six or seven meters and in places 10 meters above the ground. A system of diversion channels and reservoirs is in place to reduce the peak flow. At Sanmen Gorge, where the river issues from the mountains, a large electric-power and irrigation dam holds back the flow in a vast new reservoir. Similar multipurpose dams upstream in the river and its tributaries deliver irrigation water to former dry-land farming country and have brought the annual two-peak flood under secure regulation. The domestication of the Yellow River and its tributaries has greatly lessened the dependence of the north of China on the granaries of the south.

Taking account of China's growing population and limited land, it is apparent that the modernization and mechanization of agriculture must be sustained at all levels of initiative and available resources. Currently identified needs call for an investment of more than a trillion yuan, the equivalent of $700 billion. The state is committed to continuing its investment in agriculture in proportion to the expansion of the economy as a whole. The major fraction of the capital for agriculture will be accumulated by the communes themselves, much of it by the "accumulation of labor." That means the same kind of volunteer unpaid or low-paid labor that filled the gullies at Dazhai and moved 400 million cubic yards of earth by the basketful onto the Yellow River dikes.

With progress in the mechanization of agriculture, where can the displaced workers go? China cannot follow the example of the capitalist nations and allow displaced people to move to the cities. It is anticipated that continued expansion of agriculture and the labor-intensive investment in infrastructure this requires will keep the rural work force to a large extent employed. In the meantime there is need for the development of commune- and brigade-run manufacturing and handicraft enterprises and associated economic activity, based on local materials and encouraged by local initiative. With two or three decades of hard



POPULATION FORECASTS indicate the scale of the Chinese increase. At present (*left*) 30 percent of all births are third children, and the natural rate of population increase is approximately 12 per 1,000. If third-child births were reduced to 15 percent of all births, the rate of population increase would fall below 10 per 1,000, and if no third children were born, the rate of increase would fall below seven per 1,000. If one-child families become standard, the goal of "zero population growth" will be achieved. Between 1950 and 1980 (*right*) China's total population nearly doubled. If zero population growth can be reached in 20 years, the population will then total 1.2 billion.

work the relatively poor and backward villages of China will be transformed into new socialist villages in the first stages of modernization.

The vital question for national economic management, we have learned, is how to maintain the optimum proportional relations among the various sectors. This is crucially related to the speed of economic development. It is also related to the style of management. For many years, on the model of the U.S.S.R., China has placed a one-sided emphasis on heavy industry. With the consequent slighting of agriculture and light industry the people's standard of living has actually been lowered in some years. This strategy and its price were certainly necessary for the U.S.S.R. in the two decades preceding World War II. There were those, however, who propagandized this emergency measure as if it were the only correct approach to socialist industrialization. Although the excessive emphasis on heavy industry in the five-year plans of China leaves problems still to be cured, the 1979 policy of "readjusting, restructuring, consolidating and improving" has already begun to moderate the pace of capital accumulation. For example, increase in the price of agricultural products (offset by wage increases to consumers) has encouraged that sector, and similar measures have quickened the development of light industry.

TERRACED FIELDS of Dazhai, once a small village in the barren hills of Shanxi Province, are one of China's showplaces. In the 1940's the 60 hectares of arid farmland here were split into nearly 5,000 separate parcels occupying eight ridges and seven gullies. Villagers have now terraced the hillside fields, filled in four of the gullies and constructed an irrigation system.

Another decisive proportional relation that demands careful consideration is the one between investment for physical production and investment in "human capital": in science, culture and education and in housing and urban amenities. This relation has a quite apparent long-range bearing on the tempo of national development. The First Five-Year Plan put 28 percent of the total investment in infrastructure into the building of schools and hospitals, into scientific research and into housing and municipal services. That figure was reduced to 15 percent in the 1966–78 period. Today as a result only .5 percent of China's people have a college-level education and only 20 percent have been to high school. Inevitably that mistaken policy must seriously limit the pace of modernization. Investment in China's intellectual capital is now recognized as of utmost importance to the acceleration of development.

Although 30 years of heroic investment effort have given China a considerable industrial base and a substantial agricultural infrastructure, the output of the country's factories and farms remains rather low. The situation betrays serious defects in the management system. In the early 1950's, again on the model of the U.S.S.R., the state executive organs attempted to manage the economy from the center, formulating a unified national economic plan and directing the enterprises by administrative order. This system did play a significant early role in mobilizing national resources for development, centered in 156 major undertakings.

With further development of the economy the weaknesses in centralized management became clear. Managing the economy by the apparatus of government, making the enterprises its mere appendages, blocked horizontal relations between enterprise and enterprise, between trade and trade and even between region and region. Administrative orders deprived enterprises of the right to make their own adjustments to changing conditions. The suppression of cues from the market led to dislocation of supply, production and distribution. Since enterprises were not responsible for profit and loss and did no independent accounting, good performance and poor performance were rewarded equally. The result was low labor productivity and waste of other precious resources.

Attempts at reform, beginning in 1958, have oscillated between the centralization of power and the distribution of it to localities. The central link in the reform that began in 1979 is to increase the autonomy of the management of enterprises, enabling them to work out their own production plans under the guidance of the national plan and in response to market demands. Although enterprises are still held to the fulfillment of state-stipulated production objectives, they may now market their own products and do their own purchasing. Except in the case of certain price-fixed commodities, a degree of flexibility is allowed in pricing; this encourages competition among enterprises, not only in pricing but also in the upgrading of their technology and management. Enterprises engage in independent accounting, are held responsible for their own profit and loss and are allowed to keep a percentage of their profit. They may use the retained profit for innovation, restructuring or expansion, and for bonuses and cash incentives for the managerial staff and workers. The interest of the staff and workers is thus enlisted in the success or failure of the enterprise.

Within the framework of policy and regulation, enterprises will have the right to hire and fire personnel. Under the previous "iron rice bowl" policy workers had been guaranteed their jobs regardless of performance. Enterprises may also compensate workers and staff on the socialist principle of "To each according to his work," linking the individual's reward to the size of the contribution.

The removal of the artificial barriers set up by government organs allows enterprises to go into cooperative ventures with one another and even to form joint companies where it is fruitful. In keeping with their increasing autonomy, enterprises are encouraged to democratize their management, enabling the staff and the workers to become the real masters. Managerial autonomy is being encouraged in rural communes too. The state does not attempt to impose production plans; it depends rather on its purchases and its pricing policy to ensure fulfillment of its plans. Each commune is free to examine state plans and decide what it wants to produce, how much it wants to produce and how it will go about it, provided that it fulfills its undertakings to the government purchase plan.

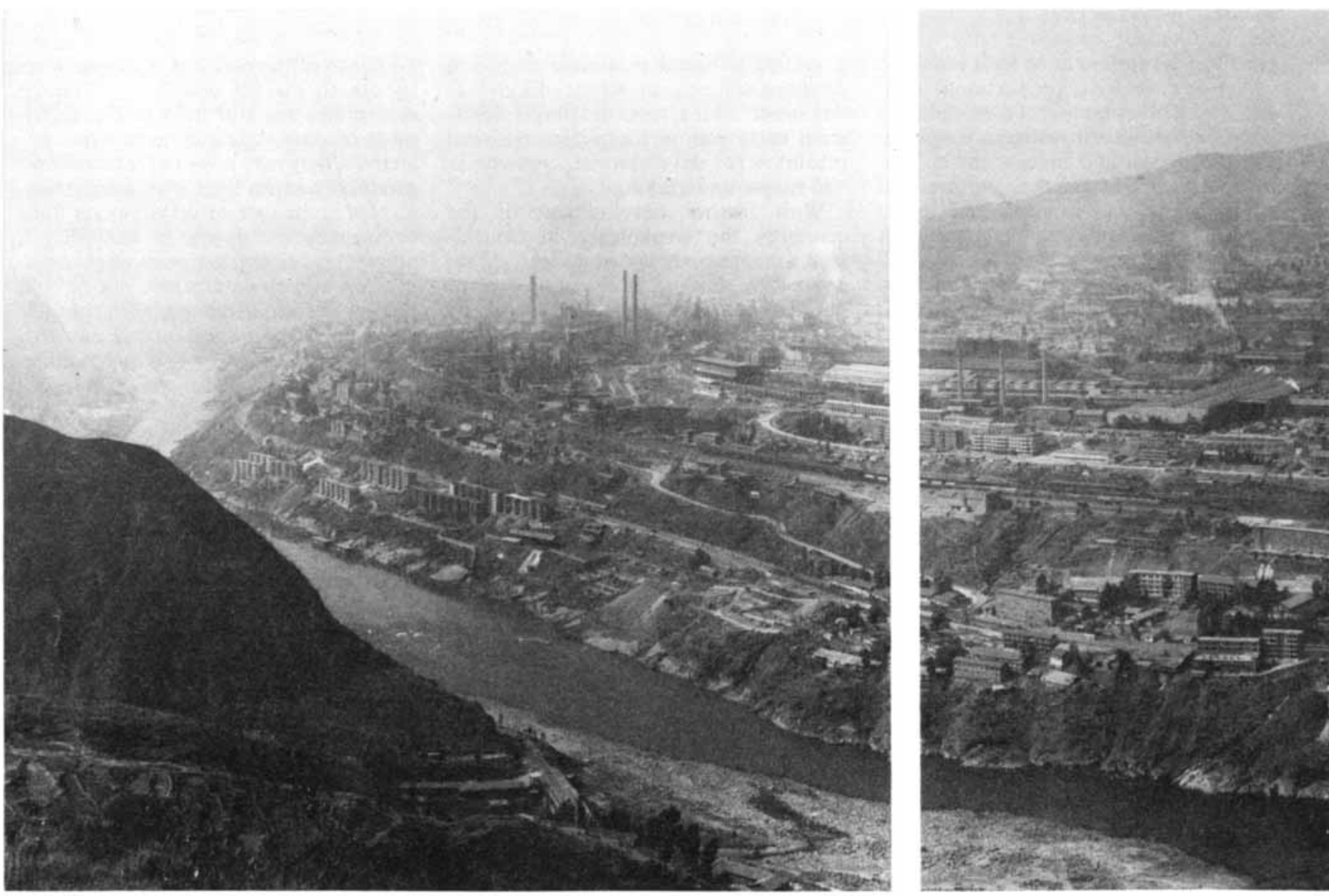
Hence the emerging new style of national economic management combines regulation by planning and regulation by the market, with the former dominant. Initiative in the management of enterprises and national economic planning are linked. The system is unified but not rigid, flexible but not chaotic. Inevitably some industrial enterprises and some communes, brigades and teams will pull ahead and prosper. These leading people and units will become models, providing incentives for other units and members to move together on the road to common affluence.

A significant aspect of the new turn in the country's economic-development strategy is the determination to utilize capital and advanced technology from abroad. In its first years the People's Republic of China encountered blockade and embargo from the Western nations. Foreign trade for a long time remained at a low level. In 1978 it had grown only to 35.5 billion yuan, no more than 6 percent of the gross value of the country's industrial and agricultural output. The purchase of technology from the Western nations began in the early 1960's but on a limited scale. Not until the 1970's did the volume expand. Last year, at the second session of the Fifth National People's Congress, Chairman Hua Guofeng called for new emphasis on the introduction of foreign technology, the utilization of foreign capital and the expansion of exports.

China, being such a large country and being committed to rapid development, will continue to depend mainly on its own efforts in independence and self-reliance. It will also endeavor to learn and selectively introduce from abroad urgently needed advanced technology and equipment. In this respect China will follow historical precedent, which shows that economic and technological development in all nations of the world has gone down the path of economic exchange with foreigners and the mutual transfer of technologies. From a grasp of China's real needs the country's scientists and engineers alike will study, digest and comprehend advanced foreign technology in order to develop their own creative potential, the faster to attain and surpass advanced international levels.

Along with its welcome to foreign technology the Chinese government has invited foreign capital to play a role in the country's development. It is expected that by this means the country's foreign-trade income can be expanded more rapidly to pay the costs of imported technology. The law of joint ventures published last year gives legal status to such enterprises in our country and provides protection for the legitimate interests of foreign investors.

The most serious problem confronting the economic development of China is also, as has been mentioned above, a measure of the country's progress in development. It is the population problem. Rapid increase of population, as we have learned, can create great difficul-



PANORAMIC VIEW of a major iron and steel plant in southern Yunnan shows both the production area and blocks of workers' housing constructed along the steep riverbank. This is the Pan Zhihua plant, near Wenshan in the Miao Autonomous Area of Yunnan. The

ties for the expansion of production, the improvement of the people's livelihood, the assurance of employment and the expansion and upgrading of culture and education. For a long time we failed to realize fully the seriousness of the problem. There was no clear population policy other than "hands off." At one time the advocacy of population control was criticized as Malthusian, and it was even said that the more people we had the better.

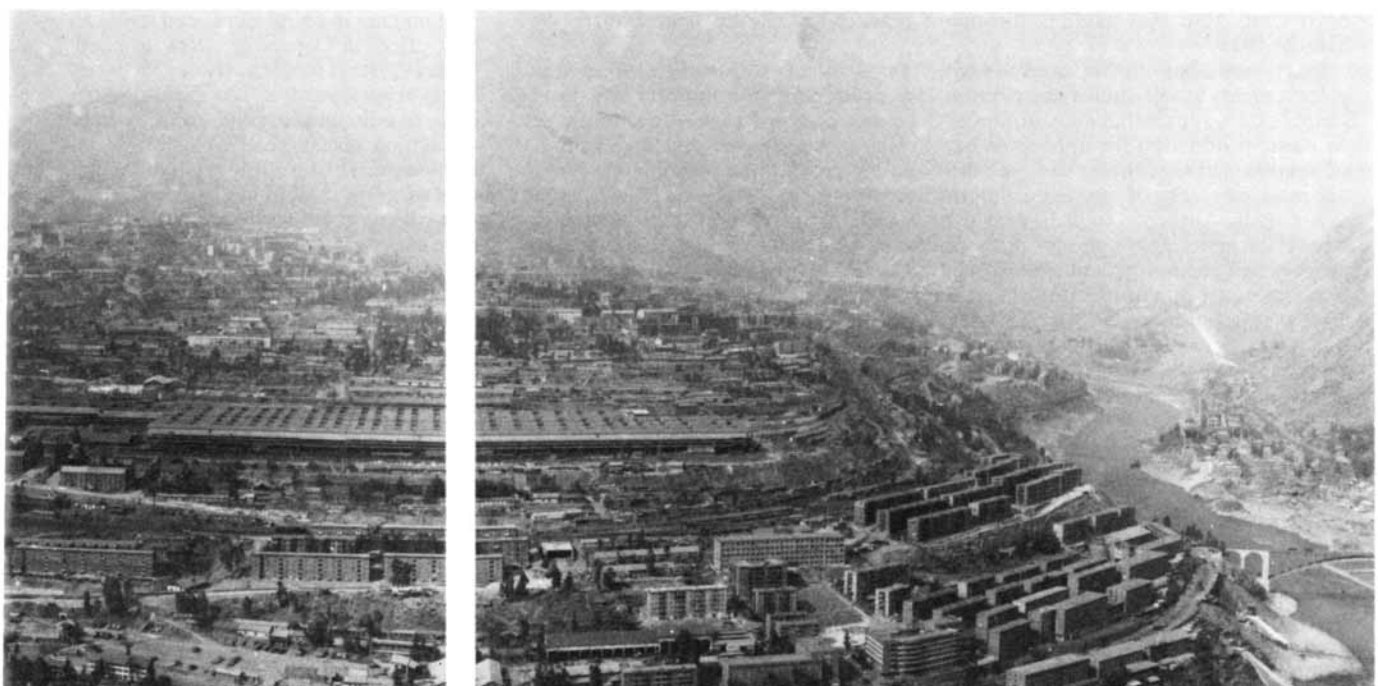
The tremendous increase of population, year in and year out, has imposed a heavy burden on the national economy and has sharpened the competitive claims of consumption and of capital accumulation for investment. From 1953 to 1978 the total consumption expenditure for the nation's entire population increased 2.8 times; in the same period, however, the population increased by two-thirds. Of the yearly increase in consumption expenditures, 58 percent went to support the newly added population and only 42 percent went to improve the consumption level of the original population. Since 1949, 600 million infants have been born. The expense of raising these millions has claimed more than a trillion yuan, approximately 30 percent of the cumulative national income of all these postliberation years.

Such arithmetic explains the attention now being given to population control in China. Owing to efforts over the past 10 years the rate of population growth has already dropped to 12 per 1,000. Policy now calls for arrival at "zero population growth" in two stages: reduction of the rate of growth to five per 1,000 by 1985 and to zero by the year 2000.

The program for population control combines population education in family planning with such economic measures as material rewards for those who adhere to family-planning regulations and penalties for those who do not. Couples are urged to have only one child. Of the newborn infants every year 30 percent are the third child or a later one. If the number of third children could be reduced by half, population growth would decrease to fewer than 10 per 1,000; if the number could be reduced to zero, population growth would come down to fewer than seven per 1,000. If the entire nation could observe the one-child norm (if there were basically no three-infant families), the rate of population growth would be zero by the year 2000. The total population would then be close to 1.2 billion. Considering the success of population-control measures in some provinces and in cities such as Beijing and Shanghai, this goal appears attainable.

Out of 30 years of experience the most important lesson for our nation is that action must be based on objective economic laws. As Deputy Chairman Deng Xiaoping recently stated: "We have paid our tuition and have suffered a little, but what counts is that we are accumulating know-how and beginning to obtain results."

The four modernizations define the program for establishing China as a socialist power within the next two decades. Our nation, with its long history, its continental domain and its large population, is already a world power. In terms of our people's living standards, however, we are still only starting on the road to affluence and are some way behind the economically developed nations. Internally we now have a stable, unified political situation; internationally conditions have never been so favorable. By the end of the century the economic development of China will quantitatively, qualitatively and powerfully prove the superiority of the socialist way of ordering human affairs.



river is the Panlung, a tributary of the Red River of northern Vietnam. Nationwide production of pig iron and steel in 1979 was 36.7 million tons and 34.5 million tons respectively, which represented a percentage increase over 1978 of 5.6 for pig iron and 8.5 for steel.

The Economic Development of India

Although it has the largest mass of poverty, India has made gains in industrialization and the modernization of agriculture. Inequity in distribution and uncertainty in management leave the issue in doubt

by Raj Krishna

For nearly three decades an independent India has been struggling with the development of a partially planned economy. Throughout these years there has existed a national consensus on four objectives: a high growth rate, national self-reliance, full employment and the reduction of economic inequities. The consensus has been affirmed most concretely in a series of five national plans that spanned the years from fiscal 1951 through 1977 and a draft sixth plan that extends through March, 1983.

India now has to its credit such achievements as self-sufficiency in grain supply and a substantial substitution of domestic production for imports in basic sectors. On the whole, however, India remains a case of stunted, suboptimal growth, burdened as it is with the world's largest single national mass of poverty and unemployment. The World Bank estimates that in 1975 the poverty-level population in India was 277 million, or 43 percent of the total poverty-level population in a group of 36 poverty-stricken countries. In this article I shall review the performance of India's economy with regard to the four objectives of Indian economic policy. Then I shall consider the inevitable question: Where does India go from here?

Over the five National Plan periods spanning the fiscal years 1951 through 1977 the Indian economy recorded an average annual growth rate of 3.65 percent. A rate of growth of 5 percent or more was targeted repeatedly, and growth rates higher than the long-run average were in fact achieved for short periods, including the four years of the Fifth Plan, from fiscal 1974 through 1977. In other plan periods, however, the economy grew at the long-run rate or a lower one. The low rate of long-run growth has allowed only a very slow growth of per capita income: less than 1.5 percent per year.

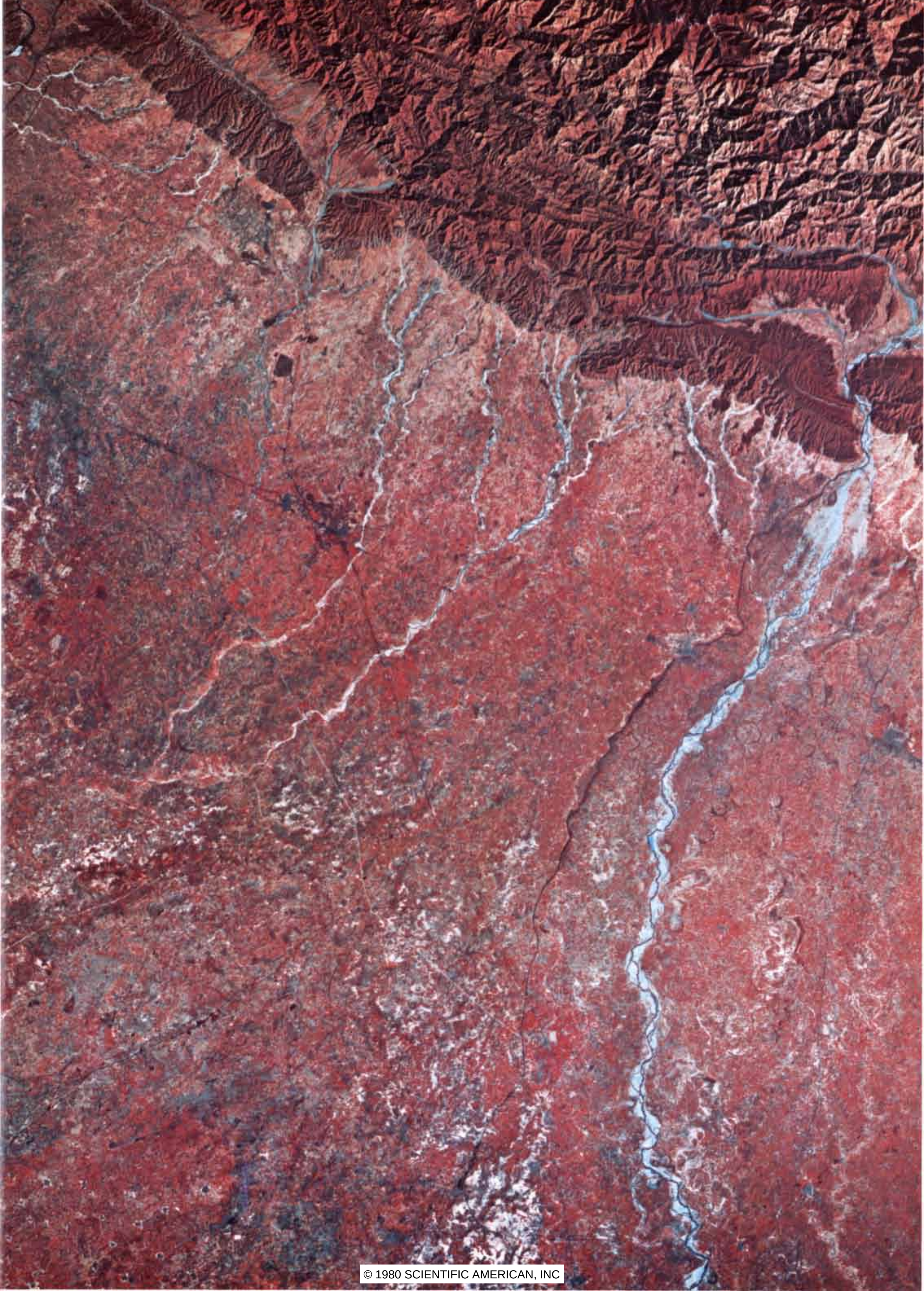
The Indian growth rate has been low in comparison not only with the targeted growth rates but also with the rates achieved in most other countries. In as many as 90 nations out of 121 the rate of growth of the gross national product (G.N.P.) per capita exceeded that of India for the period from 1960 through 1977. All that can be said about the growth rate achieved in India is that it is more than twice the growth rate the Indian economy recorded in the final 47 years of British rule, from 1900 to 1947.

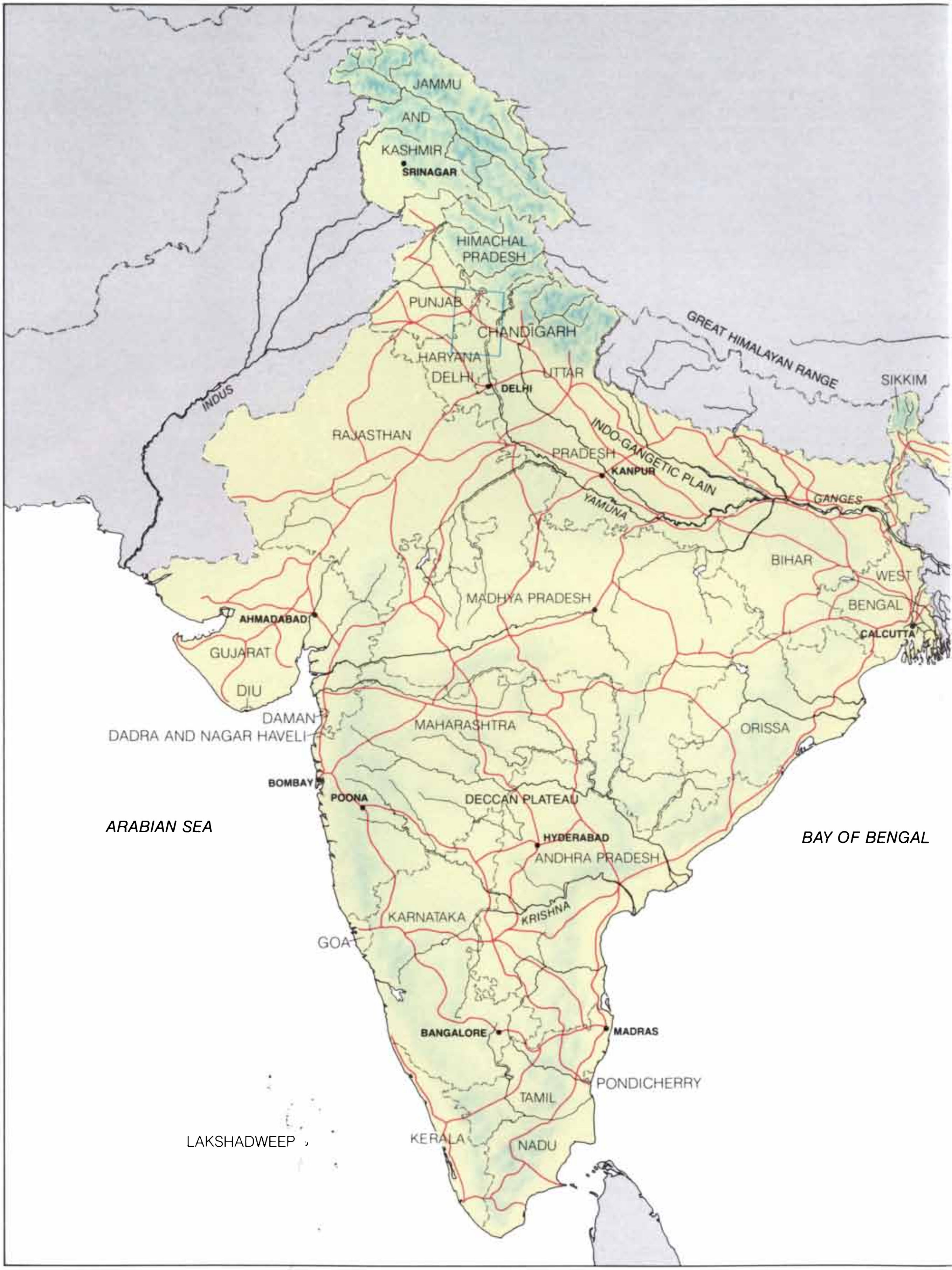
It is in the substitution of domestic production for imports and the resulting progress toward economic self-reliance, the second objective of Indian policy, that Indian planning has had the most success. Over the 23-year period ending in March, 1978 (the Indian fiscal year runs from April 1 through March 31), imports fell to a level of between 2 and 21 percent of total supply in 21 industrial sectors, including petroleum products, basic chemicals and fertilizer and many categories of machinery. They exceeded 25 percent of the total supply in only six industrial sectors. Examples are oil and gas, organic heavy chemicals and some categories of machinery. This development is the outcome of an explicit long-term policy to establish an adequate indigenous capacity in all the basic sectors, particularly metals and machinery, heavy chemicals, energy and transport and communications. The policy has been criticized both in India and abroad because of its alleged association with the neglect of rural development and the production of consumer goods. It has also been attacked for having created a sheltered, high-cost industrial sector.

On balance, however, the policy has been beneficial. For one thing it has made many of the goods produced by India cheaper in the long run than their imported counterparts. Steel is an important case in point. European steel export prices in December, 1978, implied Indian prices ranging from 2,850 to 3,050 rupees per ton, but the domestic price of comparable product categories (excluding taxes) were lower by 44 to 61 percent. The resulting relative cheapness of many Indian engineering products (the term embraces machinery and even entire plants), along with the emergence of new markets in Asia and Africa, has made it possible for Indian exports of such products to record an impressive growth in recent years. In fiscal 1978 they amounted to 6.85 billion rupees and had become the single largest group in the Indian export bill, accounting for more than 12 percent of total exports. In fiscal 1956 engineering products were less than 1 percent of the exports. The largest exports were farm products, including tea, jute manufactures and cotton textiles.

The policy of import substitution also generates the basic industrial capacities

HIMALAYAN FOOTHILLS AND INDO-GANGETIC PLAIN are seen in the Landsat false-color image of part of northern India on the opposite page. The broad river at the right is the Yamuna, whose course leads it south to Delhi, then east to a confluence with the Ganges. As the Yamuna passes through the foothills at the top right an irrigation canal shares its bed. The canal gives off branches toward the southwest. They irrigate land on which the main crop is wheat. The line cutting diagonally upward from right to left across the middle of the image is a railroad. It passes through the city of Saharanpur at the right and Ambala left of center. The compact city (*grayish area*) three inches (30 miles) north of Ambala and just south of the foothills is Chandigarh, created to be capital of the state of Punjab (and later Haryana too) after much of Punjab, including its ancient capital Lahore, became part of Pakistan in 1947.




JAMMU
AND
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BANGALORE
MADRAS
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TAMIL
NADU
KERALA
LAKSHADWEEP

that are the prerequisites of growth in all other sectors. The ratio between the growth rates in the consumer-goods and other sectors of an economy is determined by the overall pattern of transactions between the sectors, which are reflected in the input-output coefficient matrix for that economy [see "The World Economy of the Year 2000," by Wassily W. Leontief, page 206]. A significantly higher growth rate in the consumer-goods sector and a lower growth rate in non-consumer goods therefore can be projected only if it is assumed that consumer goods can be produced without non-consumer goods or that all the required non-consumer goods can or should be imported or that there is an Indian input-output matrix radically different from the one Indian planners use. None of these assumptions can be sustained.

The contention that there has been excessive investment in capital goods and infrastructure is belied by the simple fact that shortages of coal, cement, steel, nonferrous metals, fertilizer, power and transport persist in spite of substantial growth in the basic industrial sectors. On the other hand, the lack of purchasing power by the poor has already generated a grain surplus, and whenever drought reduces the income of even the farm households with middle and large holdings, many consumer-goods industries suffer a recession.

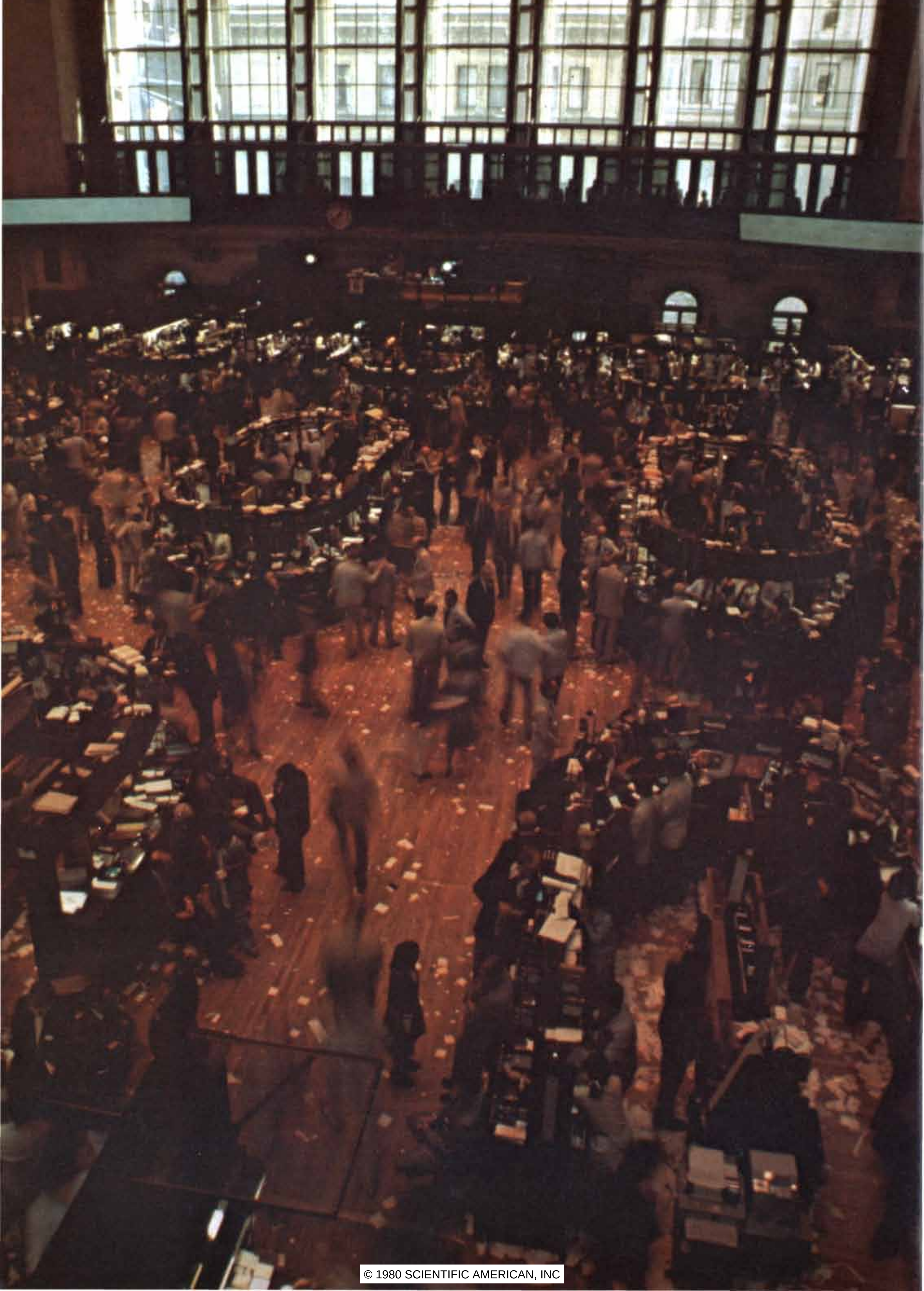
It was inevitable in any case that India, as a large subcontinental economy with vast natural resources, manpower and market potential, should strive for independence in basic economic sectors. Other subcontinental economies, including those of the U.S. and the U.S.S.R., did the same in the crucial phase of their own economic growth. The critics of the strategy of self-reliance forget that a significant fraction of industrial growth in all developed economies has been due to the substitution of domestic production for imports. Even in export-oriented Japan 38 percent of the net output of industry from 1914 through 1954 (over and above industry's proportion of all output in 1914) was due to import substitution. Only 6 percent was due to increased exports.

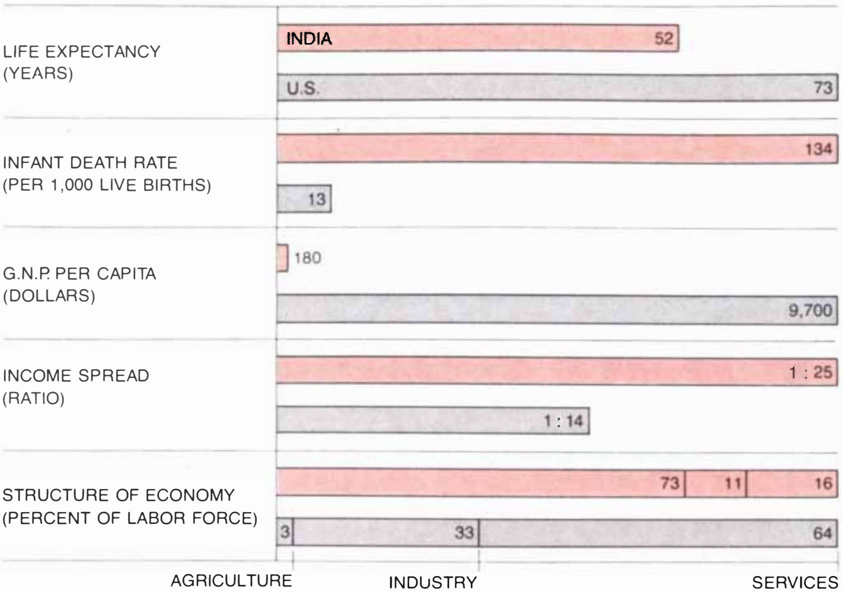
One of the most disturbing aspects of economic development in India is that the volume of unemployment keeps growing, contrary to the third objective of Indian policy. In 1978, the most recent year for which the information is available, it stood at 16.85 million man-years for people between 15 and 59 years old. Moreover, the modern industrial sector, with 25 years of planned growth behind it, still employs only 26.5 million workers, or 9.7 percent of the work force. During the decade ending in 1978 it provided jobs on the average for only .75 million new workers per year, or 11.5 percent of those who entered the work force. Even if this yearly absorption is doubled to 1.5 million, which is clearly impossible in the near future, policymakers will still have to find ways to give employment to five million other young people who reach working age every year. At present India's young are drifting into unemployment or underemployment at low incomes. The other side of limited absorption in the modern sector is the remarkable phenomenon, unique in the history of development, that for the past seven decades in India the share of agriculture in the work force has not declined. It was 72 percent in the census of 1911 and 74 percent in the census of 1971. Survey data suggest that it is not much lower now.

As for the equitable distribution of income and assets, the fourth of India's objectives, again the picture is gloomier than it is almost anywhere else. The present poverty population of India is estimated to be 309 million, or nearly half of the total population. Poor households are counted as those having a per capita monthly consumption of less than 65 rupees (about $8) in rural areas or 75 rupees (about $9) in urban areas. Montek Ahluwalia of the World Bank has estimated that the number of rural poor decreased from 53 percent of the rural population to 42 percent in the early 1960's, rebounded to 58 percent in the late 1960's and declined again to 48 percent by 1974. The ratio has thus shown no significant trend. The total number of rural poor continues to grow by about five million per year, however, because of the overall growth of the population.

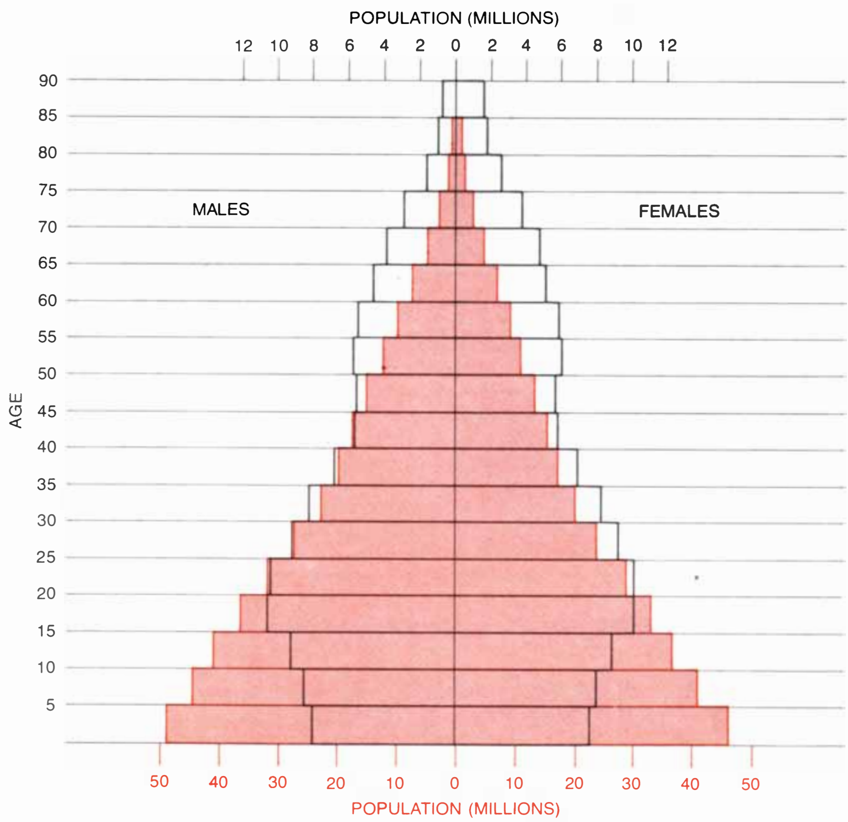
The distribution of rural assets actually worsened somewhat between fiscal 1961 and 1971. The share of the poorest 10 percent of Indian households in the assets of India fell from a mere 2.5 percent to 2 percent while the top 10 percent continued to account for 51 percent. And in spite of massive legislation the redistribution of land has been negli-

MAP OF INDIA shows the country's three geographic regions: a zone of Himalayan peaks and foothills to the north; then the Indo-Gangetic plain, formed by three rivers, the Indus, the Ganges and the Brahmaputra; then a plateau that tapers to the south. Politically the country is divided into 22 states and in addition nine territories administered in part by the government in Delhi. In 1971, the year of the most recent census, nine cities had a population of more than a million each. They are Calcutta, Bombay, Delhi, Madras, Hyderabad, Ahmadabad, Bangalore, Kanpur and Poona. Four-fifths of the population was rural. Blue rectangle on border between Punjab and Haryana in north India marks location of the Landsat image on page 167.





FIVE INDICATORS of Indian development are displayed here in a format also used in other articles in this issue: the indicators appear as proportions of their value in the U.S. One striking fact embodied by the indicators for India is that in spite of three decades of industrialization three-fourths of the Indian work force find employment (or underemployment) in agriculture. Figures shown in the "income spread" bars reflect the following data: in 1971 the richest tenth of Indian households had 51 percent of India's assets whereas the poorest tenth had 2 percent.



POPULATION PYRAMIDS for India (*color*) and the U.S. (*black*) show the differing patterns due to greater fertility and greater mortality in the underdeveloped nation. The data were calculated by the U.S. Bureau of the Census. For India they are extrapolations from the census of 1971 and apply for the middle of 1978, a time when the total population was estimated to be 656 million. Of each 1,000 people in India 15 died that year and 34 to 36 gave birth. In the U.S. 8.8 died of each 1,000 and 15.3 gave birth. U.S. population is charted for middle of 1979.

gible. Only 1.5 million acres have been redistributed to date, out of a potential, legally distributable surplus of at least 5.5 million acres and possibly 20 million. In the urban corporate sector the concentration of capital has been proceeding apace. Between 1969 and 1976 the assets controlled by the top 20 business houses increased from 24.3 to 54 billion rupees. The latter figure implies that these houses controlled 64 percent of the total productive capital in the private corporate sector.

The mobilization of resources that has contributed to India's industrialization is impressive by any standard. From the First Plan to the Fifth, India managed to step up its gross investment rate from 10.8 percent of the gross domestic product (G.D.P.) to 20.9 percent. Meanwhile the gross domestic saving rate was doubled from 10.4 to 21.3 percent. Rates on this order are typically achieved only by nations with a per capita income of $400 to $500 in 1964 U.S. prices. In India the rate was attained although the per capita income in the mid-1970's was less than $100 in 1964 U.S. prices. As a result of this achievement the net inflow of resources from abroad declined from its peak of 3 percent of G.D.P. in the Second Plan to barely .8 percent in the Fourth. And in the years of the Fifth Plan several factors—the accelerated growth of exports, a domestic recession and the receipt of large remittances from Indians living abroad—combined to produce a negative resource inflow: a rise in foreign-exchange reserves to the all-time peak of 73.57 billion rupees at the end of March, 1979. This amount was 8 percent more than the cost of the imports for all of the preceding fiscal year.

The rate of investment has been raised in India by the tapping of many sources. One of them is taxation. The ratio of government tax revenue to the G.N.P. has been raised from a mere 5 percent in fiscal 1950 to 18.7 percent in fiscal 1978. The latter is high for a low-income nation. About 38 percent of what the central government spends now goes into capital formation, and total capital formation by the government (central and state) has recently averaged 41 percent of all capital formation. This can hardly be regarded as excessive for a poor, developing country, although the private sector understandably criticizes it as a drain on private investment.

Another source of public investment is the nationalized financial system. (Almost all the financial institutions have in fact been nationalized.) The system is compelled by a set of laws and guidelines to lend a high proportion of its funds to the government. From the First Plan to the Fourth as much as 60 percent of the total transfer of resources from nongovernment sectors to the government came from the financial institutions.

The two other sources of finance for government investment, namely deficit financing and foreign aid, have been tapering off. Deficit financing, which accounted for 20 percent of public expenditure in the Second Plan, accounted for only 13 percent in the Fifth and is projected to be only 4 percent in the Sixth (although it may turn out to be much higher). Foreign aid, which in some years had accounted for as much as 84 percent of public expenditure, accounted in the Fifth Plan for only 14 percent.

When India looks ahead on the basis of trends already established, it is in agriculture that the outlook is most promising. During the 1960's the population grew at an average annual rate of 2.24 percent. The rate for the 1970's will be known only when the results of the census of 1981 are available. Interim data suggest, however, that the growth rate may have decelerated to 2.00 percent by 1974 and then to 1.97 percent by 1976. The growth rate now being used even for "pessimistic" official projections for the years from 1981 through 1991 is 1.7 percent. Meanwhile the growth rate in grain production from fiscal 1949 through 1977, excluding two years of extreme drought in the mid-1960's, has been 2.57 percent. The rate for agricultural production overall has been 2.60 percent. If these rates or even slightly lower ones are maintained, agricultural production per capita should continue to rise.

On the other hand, grain consumption per capita has been falling. It fell by 9 percent during the period from fiscal 1961 through 1973. The reasons for the decline are of course different for those who are poor and for those who are not. For the nonpoor it is the normal result of an increase in income per capita. For the poor it reflects a persistent lack of purchasing power. The rectification of this lack would not, however, cause a shortage. Even if the per capita grain consumption of the bottom 25 percent of the population, who are known to be suffering from severe malnutrition, were raised to the level of the top 25 percent, the current grain reserve and the prospective production of grain would easily meet the additional demand.

There are many reasons to think the agricultural growth rate can be kept at 2.5 to 2.6 percent per year over the next two decades. First, the amount of land in India that can be brought under irrigation can still be doubled, from 52 million hectares to 112 million, or almost two-thirds of India's present cropped land surface. And for the 30 percent of

India's agricultural land that lies in a high-rainfall zone the problem is the inefficient use of water, not an overall deficiency. In the remaining semiarid zones hope lies in drought-resistant crops, ridge cultivation, land sloping, the recycling of scarce water and animal husbandry.

Second, the yields that have been realized on farmers' fields under a National Demonstration Program are many times the actual average yields. Even in Punjab, the Indian state where agriculture is most advanced, the yield of wheat can be doubled. In other states it can be raised three to seven times. Rice yields in the monsoon season can be raised two to 13 times, rice yields in the dry season two to three and a half times, jowar (Indian millet) yields two to 11 times, maize yields two to 10 times, groundnut yields three and a half to five and a half times and potato yields one and a half to five and a half times.

Other agricultural frontiers lie in many directions: high-yield seed for noncereal crops, two- and three-crop systems, the recovery of damaged soil, the recycling of organic waste, biological fixation of nitrogen, genetic and chemical control of weeds and pests and the exploitation of cheaper and renewable sources of energy such as biogas and sunlight. In most parts of the country the productivity of animal husbandry, fisheries, forestry and horticulture can also be raised many times. India now has an autonomous and well-organized agricultural research and extension system that can be trusted to deliver the means to exploit the various possibilities.

For India the gloomy prediction of a growing gap between food demand and food supply, a prediction that some international agencies publicize regularly, seems in fact to have no basis. Only in the event of two or three successive droughts that exhaust the nation's grain reserve would India have to draw on world reserves, and then only to a small extent.

In industry the outlook seems much bleaker in the light of four economic indicators. They are the rising ratio of investment to output, the low rate of return on investment in the public sector, the low rates of capacity utilization in key sectors and the long gestation periods for new capacity. All four, of course, are highly interrelated.

In the Indian economy as a whole the ratio of added investment to increases in output has risen steadily from 3.6 in the First Plan to 6.2 in the first three years of the Fifth Plan. Surely some of the increase is due to the changing mix of output and techniques and some is due to droughts and to industrial recessions. A significant part, however, can be attributed to sheer inefficiency. The increase explains why the ratio of investment to G.N.P. rose from 11 to 21 percent from the First Plan to the Fifth whereas the growth rate increased only marginally, from 3.6 to 4.8 percent. If the ratio of capital to output had remained at the First Plan level, the current rate of investment would be generating a growth rate close to 6 percent.

The low rate of return on investment in the public sector is demonstrated by the analysis of balance-sheet data by the Reserve Bank of India, which shows that in recent years (fiscal 1970 through 1975) the private corporate sector has been averaging a profit rate of about 11 percent of net assets. In contrast, central-government companies have averaged 4.4 percent and state-government companies have averaged 2.2 percent. There are some valid reasons why the return on public-sector investment should be somewhat lower than the return on private investment. Administered prices for certain commodities and services have often been held below costs as a matter of policy, to keep inputs cheap for other industries. This has been the case for irrigation water, electricity, coal, steel, fertilizer and even petroleum products. Again, however, the main reason for low returns on public investment seems to be inefficiency. Instead of generating large surpluses the public sector has become a drag on resources. People have to be taxed at higher rates year after year to finance the mounting losses and new public investment in public enterprises.

The rate of capacity utilization in India has recorded a zigzag course. From 1970 through 1978 it averaged 78 percent in all industries. In three key sectors, however (basic metals including steel, nonelectrical machinery and transport equipment, which are dominated by public enterprises), it was 65 to 68 percent. And in electricity generation, which is almost entirely in the public sector, it was only 44 percent. Figures for the single fiscal year 1977 show the same pattern. In 17 sectors where public and private ownership coexist capacity utilization was 80 percent in private units and 65 percent in public units. And in 18 sectors where the government operates the entire capacity the utilization was only 64 percent.

Finally, the long lag in the construction of new industrial capacity in important sectors causes the escalation of capital costs. In the steel sector, for example, two major projects originally scheduled for completion in December, 1976, are now expected to be completed four to six years late. The cost is expected to rise from 7.46 billion rupees to 23 billion. In the railway sector the completion of two important gauge-conversion projects has been delayed by

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three to four years and four electrification projects by four to five years. Two major port projects have been completed six years late. The construction of a number of power-generation and -transmission projects is currently running six to 20 months late. The total cost of 28 major irrigation projects has gone up more than three times, from 15 billion rupees to 49 billion, because of lags in construction.

These facts suggest a severe manmade managerial crisis that is keeping down India's overall industrial growth. For example, in fiscal 1979 industrial growth could have been 7 to 8 percent if the supplies of fuel, power and transport had been sufficient to allow fuller utilization of capacity. That is in fact the industrial growth rate recorded by India in the Second Plan and Third Plan periods. It is the minimum the nation needs for the balanced development of all sectors. It is also the rate the nation could maintain over the next few decades under better management.

The stagnation due to bottlenecks in the supply of fuel, power and transport is compounded by a growing crisis in industrial relations. More than 20 million man-days of work have been lost each year for the past three years owing to industrial disputes. (The record, however, was 40 million days in 1974.) And incidents of industrial violence and sabotage have continued to increase.

For some of these problems there are obvious answers. In the coal and power sectors competitive dualism can be tried: a part of the capacity in these sectors can be operated privately under management contract.

To promote industrial peace national guidelines for wage contracts must be established. They should link increases in wages to increases in objective indexes of performance in every industry and to increases in cost-of-living indexes as determined by expert bodies. Whenever collective bargaining fails, arbitration must then be compulsory. The arbitration judgments should conform to the national guidelines, and they should be quickly delivered and rigorously enforced.

The greatest single constraint on industrial growth in India is bureaucratic overcontrol. Critical materials are rationed, credit is rationed, foreign exchange is rationed, all large investments are licensed after prolonged processing, labor laws are overprotective, taxes are numerous and complex and tax rates are high, all key prices are centrally administered, capacity expansion (and even full capacity use) is restricted, hundreds of items are reserved for small units or fixed allocations of capacity are made between large and small units, investments by large business houses are severely limited, foreign collaborations are licensed and there are restrictions on the siting of industries. Corps of generalist civil servants, still trained in the British literary-historical-gentlemanly tradition, administer these supposedly socialist controls, and armies of inspectors collect kickbacks to allow the producers to produce. That Indian entrepreneurs manage to run their part of the industrial production system at all under these circumstances is truly wondrous.

Some of the regulations are of course socially necessary, but many are utterly dysfunctional and should be dismantled or simplified on the basis of the recommendations made by a commission appointed for that purpose. Indian policymakers must realize sooner or later that the 30-year-old control system has delivered neither high growth nor reduction in poverty or in distributive inequity. A more relaxed system should therefore be given a trial. At the same time public-sector management can be improved simply by transferring it from the generalist civil servants to autonomous corporations run by professional managers and technocrats. At least 15 of the 142 central-government corporations have managed to remain autonomous and professional, and they have a good record of performance. They operate in the fields of international aviation, heavy electrical machinery, oil and gas, fertilizer, state trading and agricultural finance.

To be sure, supply bottlenecks, labor problems and poor management are not the entire story. The deficiency of purchasing power has also limited the economic growth of the country. Recent consumer-survey data show that the poor half of the Indian population accounts for only 19 percent of aggregate consumer expenditure. The nonpoor half controls the remaining 81 percent. The contrast is even more striking in food and clothing. The poor half spends more than two-thirds of its budget on food, yet its share in the total expenditure on food is only one-third of the total. In the case of clothing its share in the total expenditure is as low as 9 percent. With such a skewed distribution of purchasing power the emergence of food surpluses in the midst of mass malnutrition and of slow growth in the textile and certain other consumer industries is not surprising. The simple truth is that the poor half of the Indian population has enormous unsatisfied needs but is hardly in the market.

This leads to the subject of direct antipoverty policies. After a long period of trial and error India today has the knowledge and the field experience acquired in about half a dozen successful approaches to the reduction of rural

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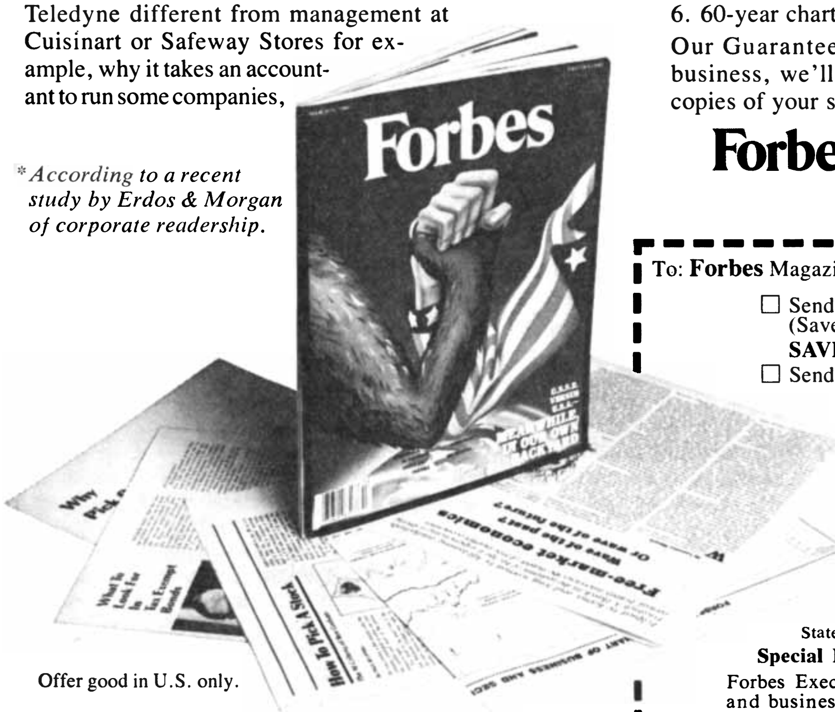

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poverty and unemployment on a substantial scale. The foremost of these is the recent program of accelerated irrigation (2.5 million hectares per year) and the promotion of the use of fertilizer. The program directly absorbs at least .44 million man-years of rural labor per year. (An irrigated and fertilized hectare requires an average of 122 man-days of labor per year, or 48 days more than a dry hectare.) It will be necessary, however, to ensure that small and economically marginal farms get their due share of new canal water, pump sets and fertilizer.

The second promising program is the Employment Guarantee Scheme (E.G.S.) of the state of Maharashtra, which is generating 160 to 180 million man-days of employment (or 533,000 to 600,000 man-years of 300 days each) for the poorest rural people at a minimum wage. More than four-fifths of the E.G.S. budget is now spent on irrigation, conservation and afforestation. The E.G.S. approach should be extended to all parts of the country, and particularly to the high-poverty belts, as soon as possible. The high-poverty belts occupy the central states, the western arid lands and the Himalayan periphery in the north. Only under the philosophy of E.G.S. does the state accept the moral, legal, technical, financial and organizational responsibility to provide guaranteed employment at poverty-line income to the poor within a definite period of time. The current unemployment in India could all be absorbed at a direct cost of 30 billion rupees per year, which is less than a fourth of the present annual plan outlay.

For promoting self-employment the *Antyodaya* (Redemption of the Last and the Lowest) approach of the state of Rajasthan is the most promising. Within two years under this scheme 160,000 of the poorest families have acquired income-yielding assets such as pumps, dairy animals, sheep, bullock carts, camel carts, looms and sewing machines.

A fourth approach with promise is the scheme of the Small Farmer Development Agency, under which six million farmers with holdings of less than two hectares have received loans preferentially. In many districts where the scheme is well administered hundreds of thousands of farmers have risen to the poverty line. If the scheme were expanded to cover four million additional farmers every year, the entire marginal farm sector would be covered in only a decade.

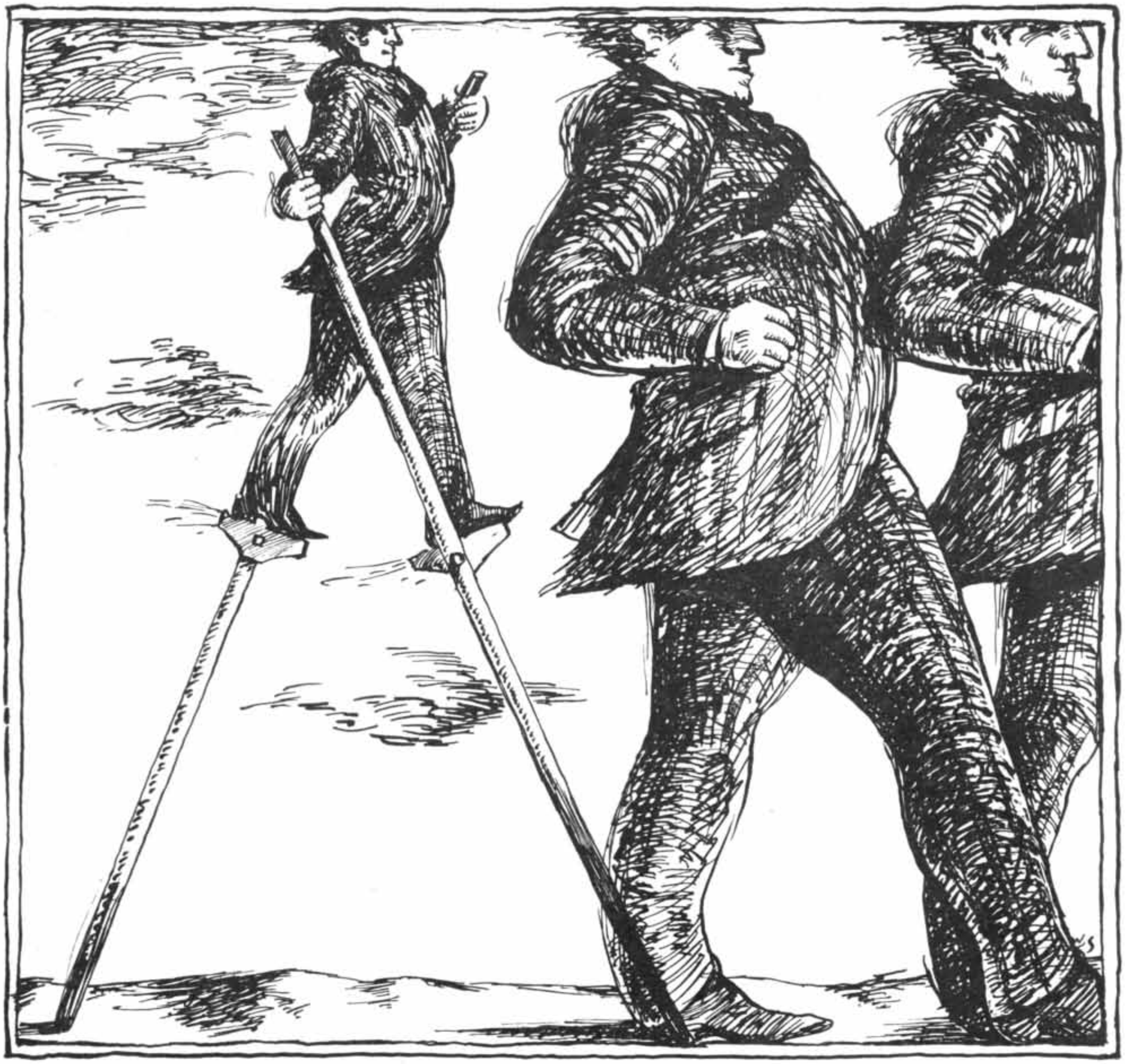
A fifth approach is the Food-for-Work Program (F.W.P.), which generates employment by paying for it partly or even entirely in grain. A conservative norm for the program would be one man-year of labor for each ton of grain paid out, and in a year of normal climate four million tons could be disbursed (twice the level of disbursement in fiscal 1979), creating employment for four million people. In drought years the disbursements could be increased further. The Food-for-Work Program is the best way to absorb the rural labor surplus, create or restore rural assets and improve the food intake of the poorest. Indirectly it sets an effective floor to the rural wage rate.

A sixth approach is Operation Flood. The flood is a flood of milk. Cattle are artificially inseminated to produce better breeds. Their milk is bought by the government at an established price. The milk is chilled, bottled and sold in the cities. The dairy scheme Flood II, a proved success in the states of Gujarat and Rajasthan, is now programmed to have covered four million milk-producing families by fiscal 1978 and 10 million by fiscal 1985. The covered families, with a minimal land base, have been able to rise to the poverty line within three years.

These six schemes together have the potential to generate about five million man-years of new employment every year, in addition to the employment that other labor-intensive programs may create. Employment on that order could absorb almost the entire annual addition to the rural labor force. Eventually the programs could cover the bulk of the poor. Whether the programs will in fact be properly extended depends on the degree to which the poor are effectively politicized and unionized.

The overall prospects for India's economic development remain unknown. The resources and the knowledge to eradicate deprivation exist. The failure to use them is purely managerial. The Indian political system has simply not produced a leadership that is knowledgeable and sincere enough to break the syndrome of slow growth and growing poverty. A revolution is unlikely in India, and if one does come about, it will probably bring to power a feudal, noncommunist dictatorial junta even more ignorant and insincere than the elected representatives. Like many African, Asian and Latin-American dictatorships, an Indian dictatorship might perhaps jack up the growth rate, but poverty will keep growing too. The Indian problem of poverty is just too vast to be solved by the average dim-lit dictator.

Economics—"the dismal science"—can project for India either the established trend of slow growth and growing poverty or the many possible scenarios of rapid growth and the eradication of poverty. Which scenario in fact materializes will depend on the shifts in leadership that may occur. These are in the lap of the gods.



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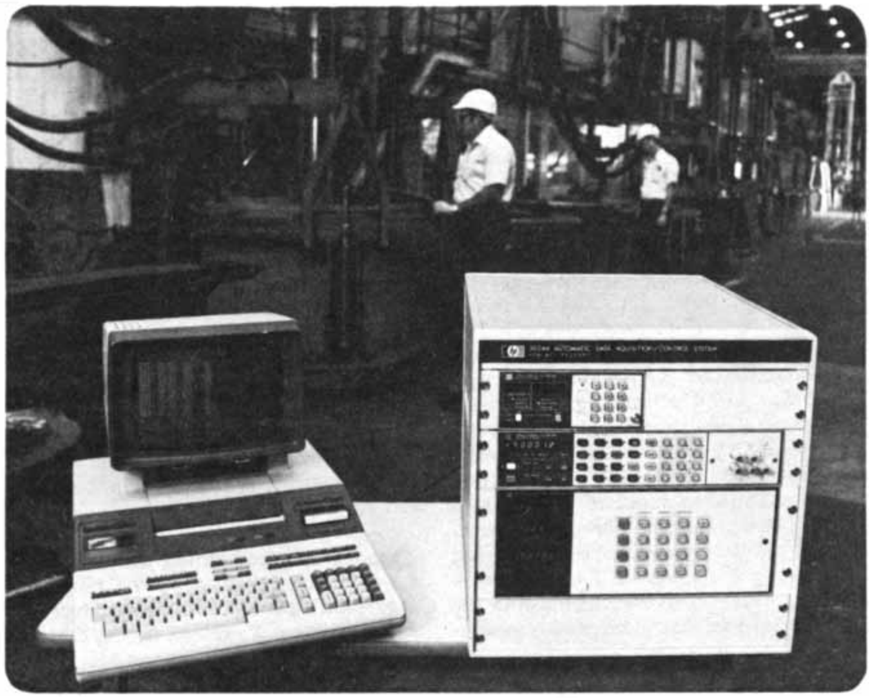

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The Economic Development of Tanzania

One of the poorest countries in the world, this African nation has set out to become a modern industrial state that preserves the traditional values of "ujamaa": society as extended family

by Robert B. Mabele, William M. Lyakurwa, Beno J. Ndulu and Samuel M. Wangwe

In the new nation of Tanzania on the east coast of equatorial Africa some 18 million of the world's poorest people have set out to compress 10,000 years of history into a lifetime. From the social order of the extended-kinship clan and a precarious subsistence by pastoral and hand-tool agricultural technology they are on their way to full self-governing citizenship in a nation state and to command of the tools of industrial technology. There is no precedent or model for their enterprise. What is more, the people of Tanzania look beyond easily measured increase in the productivity of their labor and improvement in their standard of living. As their goal is articulated by their leadership they seek to realize, in the full physical well-being ensured by industrial technology, the values inculcated by their traditional way of life. These are the values of mutual respect and loyalty and of "cooperation in production and sharing in distribution." In the vocabulary of political science this means no exploitation of man by man, public ownership of the major means of production and distribution and the equalizing of economic rewards. American and European observers have called this "socialism." Tanzanians call it by the Swahili word *ujamaa:* society as the extended family, the ideal of "familyhood."

The conventional indicators show that in the two decades since its founding in 1961 Tanzania has made progress. Increase in the output of agriculture and industry has kept ahead of the increase in population, bringing an increase in consumption per capita. These indicators show their significance in the decline of infant mortality, the lengthening of life expectancy and the rise in literacy. Continuation of these trends seems to be ensured by the stability of the country's government under the presidency of Julius K. Nyerere, one of the most respected leaders of the new Africa. A well-structured hierarchy of state banks and state development and operating companies, together with foreign-owned and domestic private enterprises, carries forward the work of technology transfer. In the not distant future Tanzania proposes to arrive at self-sustained economic growth and realization of the second value asserted by the national watchwords *ujamaa na kujitegemea:* self-reliance.

Readers who remember the classroom wall map displaying the pink-colored lands on which the sun never set will recognize Tanzania as the former British territory of Tanganyika, united today with the large offshore island of Zanzibar. The country embraces some of the fairest landscapes of Africa, between the Great Lakes—Victoria, Tanganyika and Nyasa—of the Great Rift Valley and the Indian Ocean. The diversity of terrain from the palm-shaded beaches to the Serengeti Plain at 5,000-foot altitude, habitat of the greatest concentration of wildlife on the earth, allows both temperate-zone and tropical agriculture within 10 degrees north and south of the Equator. Rainfall and accessibility to water has determined in the main the distribution of population. The people inhabit the periphery of the country, the seacoast and the lakeshores and the rainy highlands in the south and in the north around glacier-capped Kilimanjaro, the highest mountain in Africa. More than 70 percent of the people live on their tribal lands in thatched houses they build for themselves following diverse designs from region to region in order to take advantage of local materials and to achieve maximum comfort in the local climate. The durability of the tribal institution is apparent in the rich differentiation in culture, social organization and language that distinguishes the tribal communities. Most of the languages are based on the great Bantu language of East Africa, however, and most of the people today are literate in Swahili, the country's lingua franca and official language.

Swahili, an expressive language fully responsive to the experience of life in this century, is itself Bantu enriched with grafts from Arabic and European languages that evoke a long past. To this part of the world travelers have been coming since earliest times, brought by

STRING OF VOLCANOES along one of the major branches of the Great Rift Valley in northern Tanzania, seen in the computer-enhanced false-color Landsat image on the opposite page, has had a profound influence on the ecology of the surrounding countryside, which supports an extraordinary abundance of large wild animals. The three biggest lakes in this image are Lake Natron to the north (*top*), Lake Manyara to the south and Lake Eyasi to the southwest. The bright red region at the lower center encompasses the vegetation-covered Ngorongoro Crater Highlands, the site of several extinct volcanoes, some of which have collapsed to form calderas. The largest caldera of the group, Ngorongoro Crater, is the one with a lake in it near the southern end; it is about 16 kilometers across and some 700 meters deep. Elephants, lions, rhinoceroses, wildebeests and zebras live on the floor of the caldera. The dark peak at the northern end of the highlands, just south of Lake Natron, is Oldoinyo Lengai, the only recently active volcano in the region. On the left is the Serengeti Plain, an expanse of rolling grasslands famous for its vast herds of migratory wildlife. The exceptional fertility of the soil in the Serengeti is renewed by occasional ash falls from volcanic eruptions in the highlands. Olduvai Gorge, one of several sites in the area where the fossilized remains of early hominids have been discovered, is on the western flank of the Ngorongoro Crater Highlands, just south of the center of this satellite image. The region as a whole is the center of the Tanzanian tourist industry.

the consistent monsoons, which blow southward in the season from December to February and northward from April to September. The Phoenicians, the ancient Greeks and the Chinese, it is said, paid visits here. Archaeological digs show that as long ago as the first century immigrants from Arabia and Persia began to establish settlements on the coast all the way from the Horn of Africa to the Limpopo River, which today marks the boundary between majority-ruled Africa and minority-dominated South Africa. The immigrants freely intermingled and intermarried with the indigenous African peoples. The jealously independent Afro-Arab settlements, as they became, engaged in trade with one another and with tribes in the interior and with the outside world to the north, trade in such indigenous

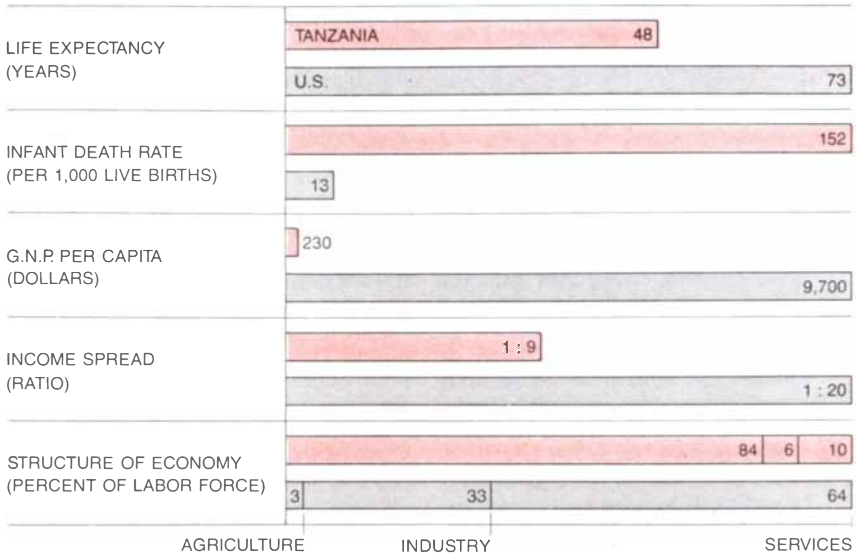
MAP OF TANZANIA shows the 17 mainland administrative regions, the islands of Pemba, Zanzibar and Mafia, the major rivers, the Great Lakes (Victoria, Tanganyika and Nyasa), the ports of Tanga, Dar es Salaam and Mtwara and the principal inland cities. Dar es Salaam, whose population was 851,522 in 1979, is the country's capital and chief industrial and financial center. By 1990 the capital will have been shifted to Dodoma. The blue rectangle on the map marks the area shown in the satellite image on the preceding page.

commodities as ivory, gold, spices and slaves. For a brief period in the 17th century the Portuguese controlled the settlements from what is now Tanzania southward. They were displaced by forces from the Arab state of Oman. The Omani dominated the coast for nearly two centuries.

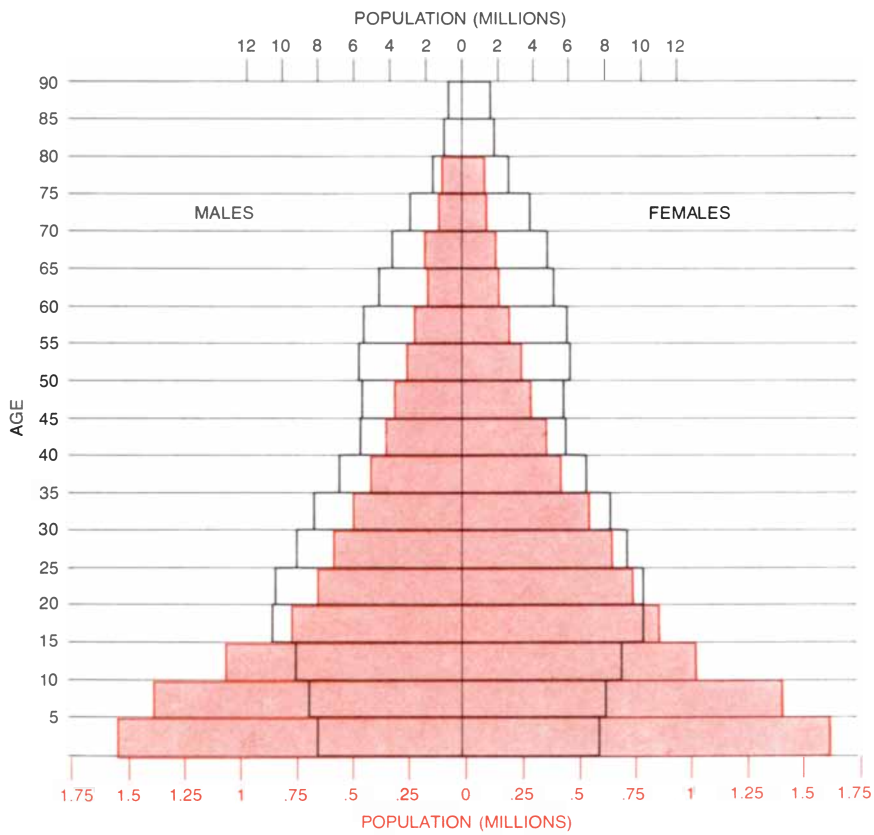
The first challenge to Arab domination came from European missionaries in the 1870's, who ventured into the interior to establish mission posts and schools. (Their success is reflected in the prevalence of Christian first names among families in the interior, in contrast with the Islamic first names and sometimes family names from the seacoast and lakeshore areas of Tanzania.) In the scramble of imperialism that closed the 19th century Kaiser Wilhelm II assembled Tanganyika, Burundi and Rwanda into German East Africa. The Germans worked hard to make their empire a success; they built the first railroads in the country and succeeded in getting the first produce from European-style plantations into the world market. They started with cotton and tobacco and later introduced the cultivation of rubber, coffee and sisal. Initially by force and then by taxation they coerced the people into seeking employment on their plantations. By the same methods the Germans induced the cultivation of *Volkskulturs,* lesser "people's crops," by the people on their own land.

Taking over from the Germans after World War I, the British brought Tanganyika (minus Burundi and Rwanda, which were tied into the Belgian Congo on the west) together with their Kenya and Uganda territories under a Joint East African High Commission. In such development as was encouraged by this setup—further road and railroad building, research services in agriculture and veterinary sciences, a joint airline and so on—Tanganyika was the Cinderella. Kenya, with a greater settler population, drew the significantly larger share of benefits, with Uganda coming in second. After the three countries got independence they tried to maintain their economic association, but the East African Community proved short-lived.

Tanzania owes little, except in the negative sense, to its legacy from imperialism. The plantations never engaged more than a tiny percentage of the potential labor force; most of the people continued untouched in subsistence agriculture. Although the cash crops still provided the new nation's principal foreign-exchange earnings, they did so by dint of increased production and shipment against a constant decline in world agricultural-commodity prices and a constant increase in the price of manufactured goods from the developed countries. At independence the indus-



FIVE INDICATORS of development in Tanzania are contrasted with the U.S. statistic. The life expectancy in Tanzania was 48 years in 1977; it was 37 years in 1960. The infant-mortality rate was 152 per 1,000 in 1977; it was 190 per 1,000 in 1960. The G.N.P. per capita was estimated to be $230 in 1977, which is less than 3 percent of the U.S. figure. The richest twentieth of all Tanzanian households have nine times the post-tax income of the poorest twentieth. In the U.S. the richest twentieth have 20 times the pretax income of the poorest twentieth. The Tanzanian labor force is 84 percent agricultural, 10 percent service and 6 percent industrial.



POPULATION PYRAMID of Tanzania (*color*) breaks down the population of 1978 by age and sex. The comparable population pyramid for the U.S. is shown in black. The total population of Tanzania was 17,528,000 (8,596,000 men and 8,932,000 women), which is an increase of 42 percent over the population in 1967 of 12,313,000. The geographical distribution of Tanzanians is uneven: two-thirds of the people inhabit a tenth of the land. Most people live in Zanzibar and in the districts of Kilimanjaro and Mwanza. The regions of Tabora and Ruvuma and the district of Nachingwea are virtually uninhabited. The population density varies from 134.2 people per square kilometer in Zanzibar to 4.6 people per square kilometer in Tabora.

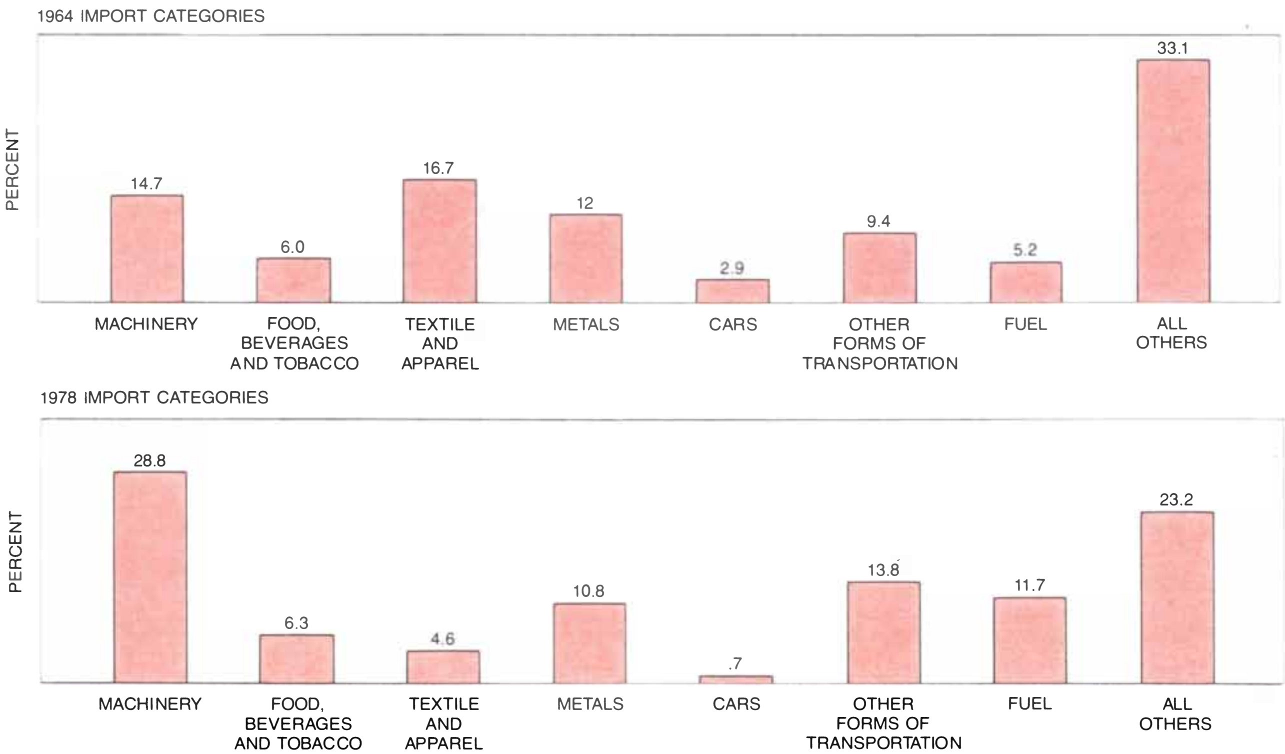
trial sector had a still smaller role in the economy. It consisted of no more than 220 establishments employing 10 or more people and having as much as $40,000 in capital. They processed commodities for export (sisal decorticating and cotton ginning) or manufactured minor consumer goods for the town-dwelling elite in Dar es Salaam, Tanga, Arusha and Mwanza. Less than 4 percent of the gross national product was generated by these enterprises, and they employed a correspondingly small number of people. The towns, as enclaves of colonial power, imported most of the goods they required, including even their food. Only a few of the indigenous people were literate (in English) and trained up to even the secondary skills that were of service to the colonials.

The policy of *ujamaa na kujitegemea* did not spring full-blown as a program on December 9, 1961, when the country achieved independence under the Tanganyika African National Union (TANU) party and its leader Nyerere. That policy evolved by induction from experience in the first years of independence. It received its first concrete statement in the Arusha Declaration at the party conference held in that town in 1967. First and foremost the policy is directed to rural development and gives agriculture a prior claim on the human and material resources available for development. In agriculture as in the industrial sector, however, the tempo of development has to be measured by output. The record is by no means phenomenal. It nonetheless highlights the experience in which policy evolved.

Any consideration of the recorded output of the country's agriculture must be qualified beforehand by recognition that much of it goes unrecorded because it is consumed by the producers and never reaches the market. For nonedible cash crops such as cotton the marketed output comes close to indicating total production. For food crops the marketed output can be used only as an indicator by proxy of the total. It is to be expected that in response to price incentives peasants will seek to increase the marketable surplus and therefore the total output of a given commodity. Because the surpluses go to market through their appropriate crop authorities, however, the records in Tanzania can be depended on.

The cash crops for export show the most consistently disappointing trend. Sisal, once the country's principal export crop, declined by half over the decade of the 1970's. Competition from fibers made of polypropylene brought world prices for sisal down to a small fraction of the high in the early 1950's. Fluctuations in the output of tea and coffee similarly reflect oscillations in world prices. One factor that helps to explain the sluggish growth in the overall tonnage of the marketable surplus is to be found, however, in the country's drive for self-sufficiency in food production and the effort to bridge the income gap between the cash-crop regions and the food-growing ones. In recent years the government has repeatedly raised the prices of food crops paid to their producers. Peasants, responding to the incentives, have been switching from cash crops to food crops. The loss of foreign exchange, which has been in part illusory considering the depression of world commodity prices, has been offset in some measure by an improvement in peasant nutrition, if an increase in the marketable surplus of the food crops can indeed be taken as indicating an increase in total output.

Although the policy of seeking self-sufficiency in food production can thus be credited with some success, the extreme swings recorded from year to year in such essential crops as maize, rice and wheat call out for something more than economic incentive. Agriculture in Tanzania depends still on the hoe. Increase in productivity per hectare and per man-hour of course requires in-



BAR GRAPHS OF IMPORTS to Tanzania from all countries except those in East Africa are shown for 1964 (*top*) and 1978 (*bottom*). The graphs indicate the success of the Tanzanian government's import-substitution campaign, which sought the importation of less consumer goods and more machinery. Textile and apparel imports, which constituted 16.7 percent of all imports in 1964, decreased to 4.6 percent in 1978. Although food, beverage and tobacco imports went from 6 percent to 6.3, the demand for these commodities rose much more than that over the 14-year period as the population and standard of living increased. Machinery imports went from 14.7 percent to 28.8.

puts from modern agricultural technology. It was soon recognized, however, that to make those inputs available on the land would require basic changes in the way the people of Tanzania arrange their lives.

The siting of a house in a Tanzanian peasant community is not constrained by the availability of water or energy or sanitary services. Members of a clan will build their houses pretty much as they please over the territory staked out by the clan. Although the land is held in common, the product of each household is its own, subject to the claims of mutual help and identity with the extended-kinship family.

In Europe and America, under socialism as well as capitalism, the changes in folkways occasioned by the technological revolution in agriculture have been accomplished by phasing out the peasant and turning the farm into a factory or a business. This is inconsistent with the path Tanzania has chosen—as the government was to learn from its own experience. Immediately after independence it was thought agriculture could be modernized by creating capital-intensive new rural settlements. These settlements failed not only because they called for considerable investment but also because the new "settlers" never considered the settlement theirs.

With the Arusha Declaration a new approach was undertaken. The peasants were to be encouraged, on their own initiative, to live and work together in *ujamaa* villages. A considerable number of these villages (1,100 by 1972) did get organized, with workers of the TANU party on hand to motivate and guide the effort. Some villages committed themselves wholeheartedly to communal production; in others, particularly those organized in response to pressure from the party and the government, the communal effort was minimal. The distribution of the yield also differed from place to place; some villages followed the principle of "To each according to his ability," others the principle of "To each according to his needs." Those that put the greater effort into communal production got results that encouraged them to continue and in some instances to expand their production. On the other hand, many villages died.

By 1972 it was apparent that the village movement was proceeding at much too slow a pace to bring about the transformation of rural Tanzania. Although the leadership was persuaded that the commitment to communal production had to remain voluntary, it determined that something more radical should be done to get people to at least live together. To the suggested minimum village of 250 families it would be economically feasible to provide not only the capital inputs and extension services to agriculture but also such essential human services as medical dispensaries and schools.

A campaign of "villagization" was begun, and over the next several years a massive transfer of rural population was accomplished. (The World Bank, in its effort to do something about the world's 400 million poorest people, has recently been urging such action on other countries.) Local leaders were of course urged to consult with the peasants about where and when they would move. Yet some overzealous leaders, wanting to complete the exercise in record time, made mistakes: moving people when they were busy with their farm work and disrupting production. Some villages, it is now realized, are too big and are threatened by such problems as overgrazing of their lands. Mistakes of this kind are being rectified. With more than two million peasants settled in 5,000 villages as early as 1974, however, the effort must be reckoned as a successful first step toward the modernization of Tanzanian agriculture.

Longer strides remain to be taken. Out of five million hectares of cultivated land only 126,000 are irrigated. The rapid expansion of this form of agriculture—to exchange the present one-crop gamble with rainfall for the ensured and expanded yield of year-round cropping on irrigated land—has been set as a major goal of the 1980's. The ground-water resources for the purpose have already been surveyed and earmarked. Beyond lies the development of the country's river basins. They are sparsely inhabited today owing to infestation by insects and other vectors of sleeping sickness, malaria, onchocerciasis ("river blindness") and schistosomiasis. Pending measures to control these scourges, river-valley development has begun with the building of dams for the generation of hydroelectric power on the Pangani and Great Ruaha rivers and the planning of installations on the Rufiji and Kagera rivers. Ultimately the waters impounded by these dams can be distributed to greatly extend the cultivated and irrigated lands of the country.

Fisheries on the Indian Ocean and the Great Lakes already contribute significant quantities of protein to the people's nutrition. Here again output can be increased by improvement in the technology of fishing, accompanied by the provision of preservation and processing facilities to bring the expanded output to the table.

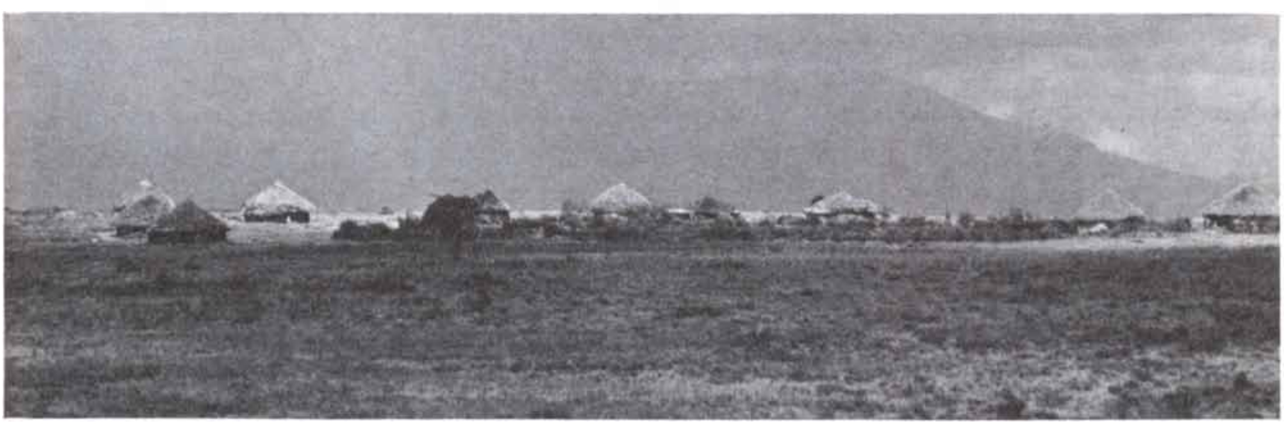
The industrial development of Tanzania, no less than the agricultural, looks to the Arusha Declaration of 1967 as its benchmark. The new nation had framed a three-year plan (1962–64) and then a five-year plan (1965–69) to hasten its development, but these plans looked to inflows of investment capital and economic assistance from abroad that did not materialize. The Arusha Declaration embraced the need for self-reliance and aggressive, centralized direction of the development effort, based on public investment in all major industries and public ownership of them. By 1974 the predominantly private (more than 90 percent of value added in 1967) manufacturing sector had become predominantly public (more than 50 percent of a larger value added). Assets of the private enterprises were taken over not by confiscation but by compensation of the owners. More than 90 percent of the investment in new industrial enterprise has since been public.

The industrial-development plan has sought (1) the substitution of domestically produced consumer goods for imported ones, (2) the support of these industries by the building of primary tool- and machine-manufacturing industries and (3) the development of the country's own mineral resources as the foundation of its industrial system. Progress is reflected in the increasing share of the G.N.P. credited to industry, from 4 percent in 1962 to 10 percent in 1977. The footwear, textile, food-processing, beverage, tobacco and furniture industries are now satisfying increasing or at least constant percentages of increasing domestic demand. It has become possible to turn to the establishment of engineering and metalworking industries and workshops for the manufacture of spare parts, farm implements, railroad freight cars and motor vehicles and the still more basic rolling of steel sheet and shapes for the metalworking industries and construction.

This strategy has been pursued under the direction of the National Development Corporation, which acts as the general supervisory holding company of operating subsidiaries. Its success has been marked by the spinout of a new holding company, the National Chemical Industries Corporation, charged to develop plastics, fuel alcohol, fertilizer and pesticides and intermediate industrial chemicals such as soda ash.

Over the longer term the country counts on the development of its mineral resources. Tanzania is a big country, and it is endowed with a diversity of mineral wealth. In colonial days the mining of gold and diamonds yielded substantial returns to the colonial powers. As late as 1966 the mining industry earned significant foreign exchange, generating 2.9 percent of the G.N.P. Exhaustion of the gold and diamond deposits brought that figure down to .6 percent in 1978. The mining industry in the future will come squarely into the center of the domestic economy, contributing iron ore, coal, nickel and phosphates. Promising finds of natural gas will supply some of the required energy.

The ultimate control of investment



VILLAGE in the Monduli district of the Arusha region of northern Tanzania was settled in the mid-1970's as part of the government's program of "villagization." The walls of the houses consist of poles covered with clay and dirt. The roof is thatch. The floor and the foundation are clay and mud covered with a thin layer of cow dung, which makes the surface smooth and hard. The Monduli village is inhabited by traditionally nomadic people. Today only the young men in the village move from place to place as they guide the livestock to the seasonal grazing lands. The photograph was made in late 1979 by Alan G. Johnston of the University of North Carolina at Chapel Hill.

strategy lies with the nationalized banking system and the central bank of Tanzania. Once the government has determined the lines of development and the rate, this bank sees to it that the necessary domestic credit and foreign exchange are made available. In the Third Five-Year Plan (1976–81) more than a fourth of the investment capital mobilized has been going into the manufacturing industries.

The foreign exchange required to purchase the technical inputs to the country's ambitious development plans must be secured on disadvantageous trading terms with the industrial countries. In 1978 exports principally of coffee and cotton into their soft world markets equaled 12 percent of the G.N.P., whereas imports principally of producers' and capital goods at their inflexibly administered prices came to 27 percent of the G.N.P. The foreign-exchange deficit of $243 million was the first incurred in some years of frugal management.

The real goal of development, of course, is the well-being and fulfillment of people. To this end Tanzania has been devoting a substantial percentage of public expenditure to education and health services. Starting again from the Arusha Declaration, the program of "education for self-reliance" had reversed the elitist imbalance in the schools that had emphasized secondary education for the few. By 1977, 91 percent of the children of school age were in school. A mass campaign had meanwhile increased effective literacy in the adult population from 33 percent in 1967 to 73 percent in 1978. It has now become possible to restore secondary education with an expanded and diversified curriculum in vocational subjects. Students who prove academically eligible for admission to a university must spend two years in a job following graduation from secondary school.

In the same egalitarian spirit the country's system of medical care has been transformed into a true health-care system. From preoccupation with the curing of the ills of the few who could pay for its services in the cities it has been turned to the provision of preventive services for the entire population. The training of paramedical personnel and the building of rural dispensaries and health centers have taken up the major share of medical expenditures since the Arusha Declaration. Mass campaigns of instruction in hygiene and nutrition have been launched, and wells are being drilled to provide safe drinking water within a kilometer of every dwelling place in the country. As the first hopeful return from these efforts infant mortality has been reduced from 190 per 1,000 live births in 1960 to 152 in 1977, and life expectancy has been increased from 37 years to 48.

For all its hope and progress Tanzania remains a poor country. The government has sought to secure for everyone a share in the hard-won gains of development by promoting equity in the distribution of incomes. At the time of political independence, as in other former colonial countries, the disparity between the richest and the poorest was extreme: between the top and the bottom 5 percent income groups the differential was 50 to one. By 1975 that gap had been reduced to nine to one. This has been accomplished with a number of measures: by setting ceilings on top salaries, by forbidding government officials to accept income from any other source, by progressive taxation, by leveling up the lower minimum-wage levels, and so on.

Nevertheless, a potentially divisive disparity in incomes persists between the urban and the rural population. A farm household has a standard of living just over half that of an average wage earner's household. While the percentage gap has remained constant the disparity in absolute income has been widening. It has resisted change even by the other powerful income-redistribution measures the government has brought into play, such as price controls that differentiate between luxuries and necessities in the market basket. The divergence between town and country is moderated for the present, however, by the strengths of kinship. Most of those who work in the towns are the sons and daughters of peasant families living in the countryside. Their families expect them, with their better education, to earn more in cash terms although not necessarily in real terms as values are reckoned by the people. What is more, the sons and daughters contribute to a considerable redistribution of cash income from town to country.

Tanzania will celebrate 20 years as an independent nation in December, 1981—a short span in the time frame of the development of nations. Although it remains a poor country, faced with enormous problems in expanding its productive base, it has gone a long way toward curing the defects left by imperialism in the structure of its economy and toward securing its political sovereignty in economic independence. In this brief period, furthermore, the country has made a significant break with conventional doctrines of development; it has resolutely undertaken to design and implement change by building on values and institutions familiar to its people. The economic development of Tanzania raises new issues in political economy. The textbooks of economics have little to say about distribution. Equity is a central principle, however, in the transformation of Tanzania into a self-sustaining industrial economy because this nation cherishes its traditional values in the spirit of *ujamaa na kujitegemea.*

DAR ES SALAAM (the name means "haven of peace" in Arabic) is the commercial and financial center of Tanzania and one of the largest ports on the east coast of Africa. In 1976 about 4.4 million tons of cargo moved through the port. The harbor is congested because it handles goods not only for Tanzania but also for other countries such as Zambia, which is connected to Dar es Salaam by the modern Tazara railway, built by the Chinese. The railroad terminal is on the far side of the harbor. The photograph was also made by Johnston.

The Economic Development of Mexico

A number of indicators make it easy to mistake Mexico for a developed country. Actually its development is highly unbalanced, with most of its population impoverished, poorly educated and underemployed

by Pablo Gonzalez Casanova

World statistics place Mexico in the van of the nations entrained in the worldwide revolution from the age-old agricultural way of life to modern industrial civilization. Starting from the nationalization of its petroleum resources and industry in 1938—a political overturn that has proved correspondingly important for the nations of the Middle East during the past decade—Mexico has seen an inflation-discounted economic growth rate of never less than 5 percent per year. The cumulative growth of its production in this period has generated a nearly hundredfold increase in industrial output per capita, in spite of a more than 100 percent increase in population. With an income per capita of $2,100, Mexico might be mistaken for a developed nation. Yet because the benefits of economic growth have been so inequitably distributed, Mexico exhibits some of the sharpest indexes of underdevelopment. Nearly half of the population subsists at the margin of nutrition or below it; nearly half of its children have no schooling; the disparity in income between the richest and the poorest approaches 40 times.

Mexico is accordingly stretched by social tensions that seriously stress the unique mechanism of revolutionary mythology, political pragmatism and economic oligopoly that has maintained the nation's stability from its anticolonial revolution of 1910–17 down to the present. The recent recognition of hitherto unsuspected petroleum reserves has temporarily slackened those tensions. The contest between forces of the left and forces of the right over the direction the development of Mexico should take remains nonetheless still to be resolved.

The government of Mexico has been controlled by a single party (the Party of Institutionalized Revolution, or P.R.I.) for 52 years. This state party's candidates for the presidency and the governorships of the federal entities of the United States of Mexico (31 states and the Federal District, which is the site of the nation's capital) always triumph.

P.R.I. is not the only party participating in the government. The opposition, however, occupies only secondary positions and is unable to assume the leadership of a majority of the electorate. Its efforts are limited to leveling criticism at and bringing pressure on the government. Still, these efforts often play a part in the reformulation of government policies. The mechanism resembles a relief valve benefiting the state, although it is more than that.

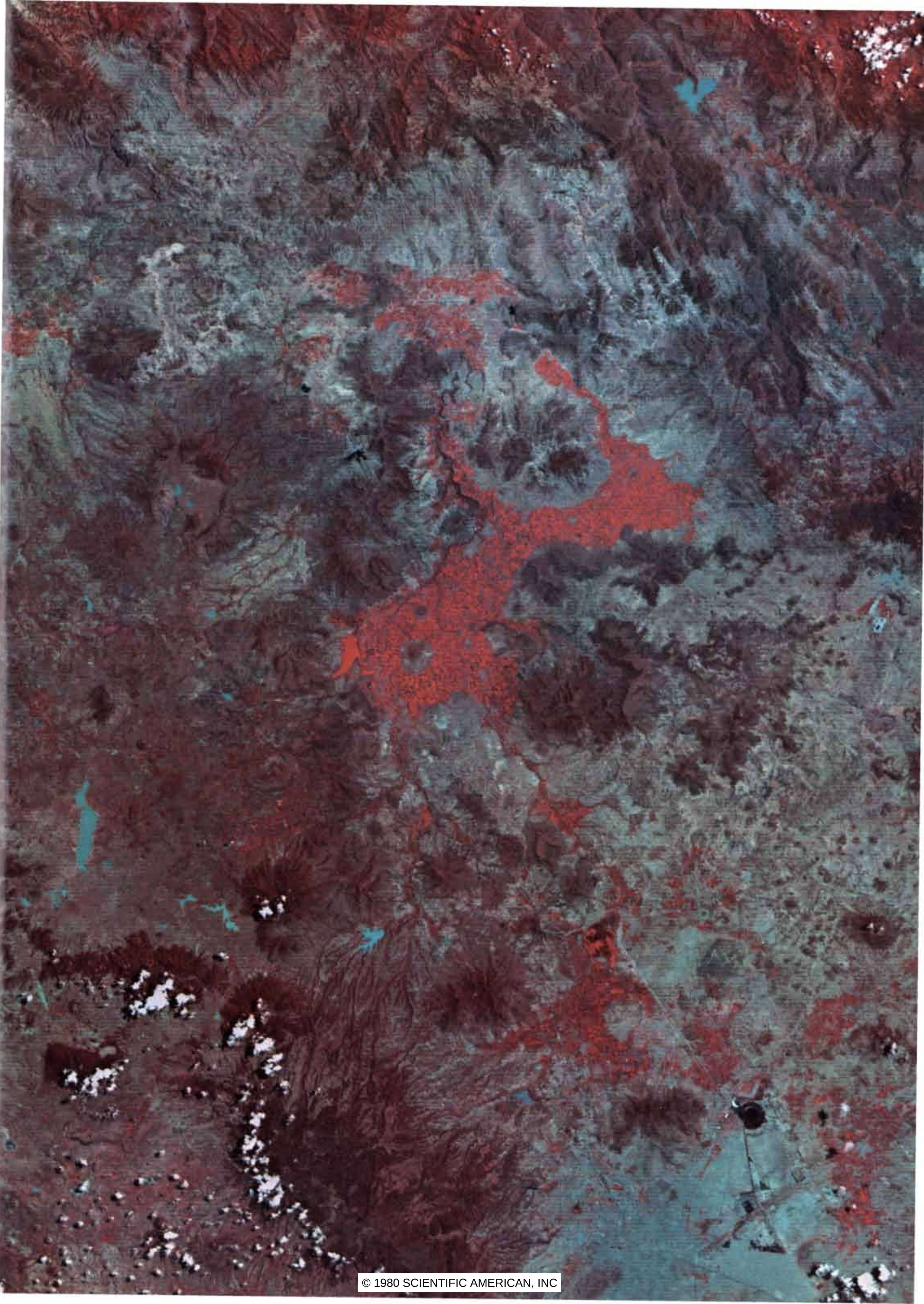
The fact that the system works is part of its originality. The system operates within a society where regions and social strata are notably out of balance. A complementary feature of the system is the existence of a pervasive political culture. Society speaks the official language and participates in the national myths fostered by the state. A sort of logic of power, combining myth and reality, is constantly renewed by community and state leaders, whose concern is to go beyond political form and myth and to serve national unity or survival as fundamental premises.

The state dominates this logic of power, and the opposition is forced to accept it in view of the populace's conditioned interpretation of reality. It is also significant that the state has been able to eliminate the old alternatives of church and oligarchy that persist in other parts of Latin America. The state has been able to establish a system of government in which the military lacks the political power that the military has in many other Latin-American nations.

In dealing with a series of crises such as labor unrest in 1958 and student unrest in 1968 the state has created a mechanism with which it can maintain control by a coordinated use of symbols, repressive action and concessions to opposing groups, which include labor, the middle and intellectual strata of society and the minority parties. All of this has been controlled by a strong executive branch whose power is concentrated in the presidency. In addition the state owns the country's energy resources and participates in a high proportion of domestic investments. In such a country it is difficult to consider economic development independently from the state.

One other important consideration is Mexico's relations with the U.S., with which it shares a boundary of almost 1,300 miles. Mexico both quarrels with and accommodates to the inhabitants and leaders of the U.S. Lying behind this process is the fact that Mexico lost more than half of its territory to the U.S. more than a century ago, the view in Mexico that the U.S. has made other interventionist or threatening moves, and a sense of national pride. As a result both the people and the government of Mexico have kept the problem of national survival foremost in their memory and concerns. National survival, the magnitude of Mexico's popular move-

CENTRAL HIGHLANDS, which constitute only about 15 percent of the total area of Mexico, contain approximately half of the country's total cropland and more than half of the total population. In the enhanced false-color Landsat image on the opposite page crops can be seen under cultivation in the central-highland valleys northwest of Mexico City. The principal crop here is corn, grown mainly under rain-fed conditions during the rainy season, which lasts roughly from July through October; other crops such as wheat, vegetables, strawberries and potatoes are grown during the winter months when irrigation is available. Mexico City itself is the bluish area at the bottom right. It is the only large city in the world without either direct access to the sea or an important river passing through it. It is also the fastest-growing metropolis in the world; by the year 2000, according to United Nations projections, it will be the world's largest metropolis, with a population of almost 32 million, or nearly a fourth of the national total.



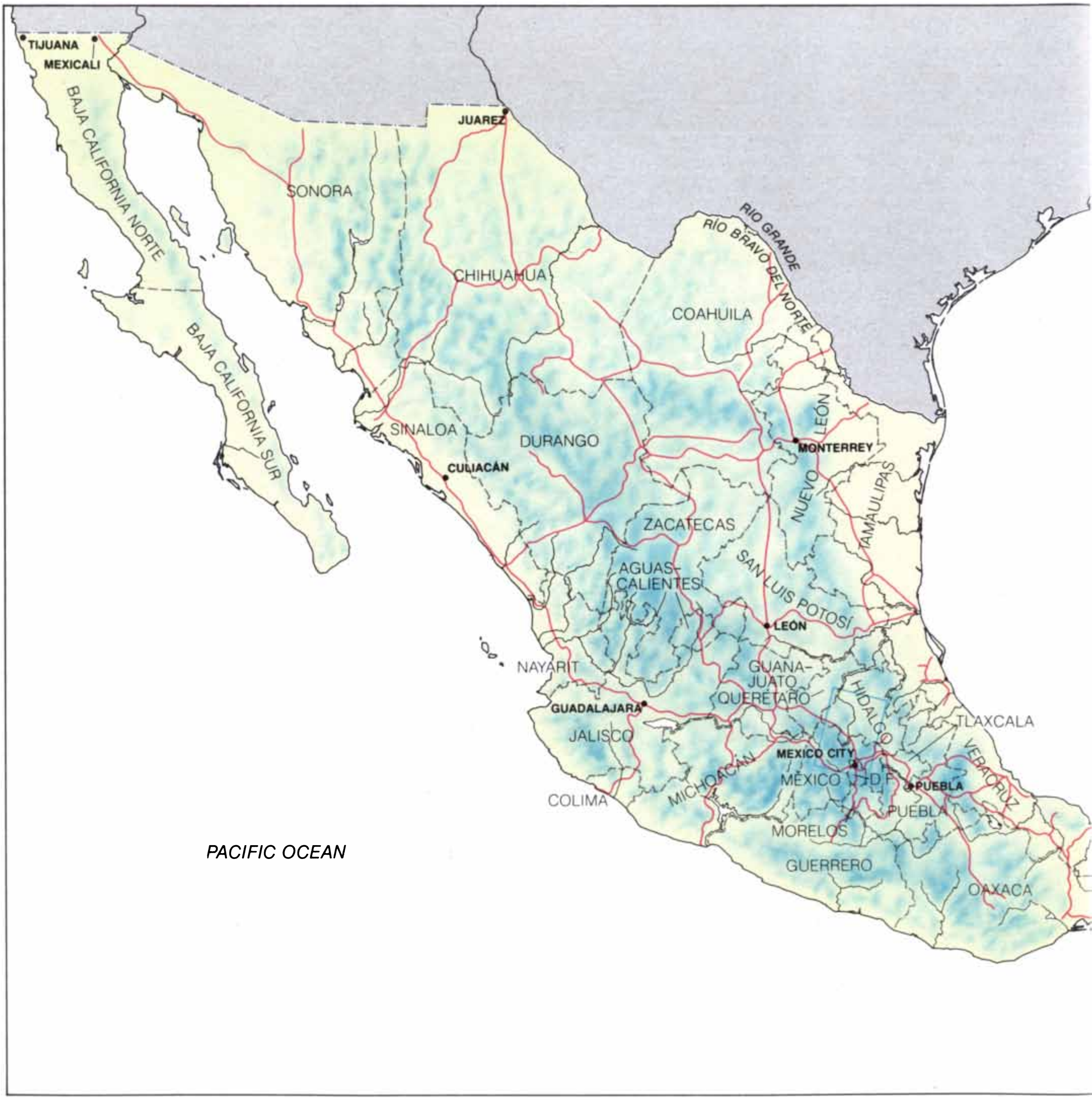
ments and the nature of the involvement in those movements of a middle class that sprang from the wealthiest Spanish colony in the New World contribute to the explanation of a complex historical process.

Mexico's area of 1,972,544 square kilometers (761,600 square miles) has a population of 70 million. The country ranks 13th in the world in territory and 11th in population. Its population is the second largest in Latin America (after Brazil's) and the first among the Spanish-speaking countries of the world.

Between 1900 and 1950 the population of Mexico almost doubled. It almost doubled again between 1950 and 1970. If the historical trend continues, Mexico will have more than 132 million inhabitants in the year 2000. Mexico City, the capital, which today has a population of about 14 million, will have to house 35 million people.

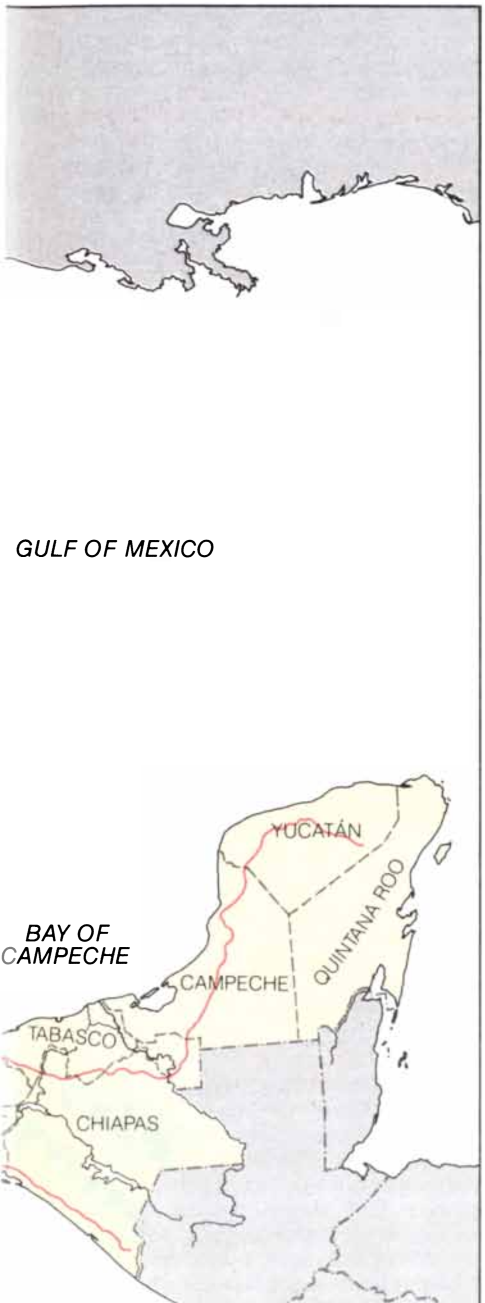
An intensive program of family planning that was started by the government in 1972 envisions a decline in the rate of population growth amounting to .5 percent this year and from 1.1 to 2.2 percent between 1985 and 2000. If this prediction proves to be correct, the population will rise to only 100 million by the year 2000. Demographers believe the growth rate has declined, but they cannot affirm that the projection will materialize.

The controversial matter of popula-



UNITED STATES OF MEXICO consists of 31 states and the Federal District, which is the site of the capital, Mexico City. The blue rectangle that includes Mexico City indicates the area shown in the Landsat photograph on the preceding page. Mexico's history has been much colored by the proximity of the U.S., with which the country shares a boundary almost 1,300 miles long. Mexico encompasses

tion growth should not be left there. Although the high rate of growth has caused problems of unemployment, insufficient services and a high rate of dependency (3.5 dependents for each employed person), it also represents part of the nation's strength. Many people believe that, as in other countries, the growth of the economy, the distribution of income and the increase in standards of living will be the most important determinants of a decline in the birth rate.



1,972,544 square kilometers (761,600 square miles). The country has no major river, and in many regions water is chronically scarce.

In any event Mexico's population density of 31.3 inhabitants per square kilometer (in 1976) is far below that of countries with a much higher standard of living, such as France (96.7), West Germany (247.4) and Japan (302.9). Indeed, some years ago the director of the Commission for Studies of the National Territory declared: "Mexico's potential resources can support a population of 300 million."

Among the indicators of development in Mexico, uneven though it has been, are a decline in the mortality rate from 23.2 per 1,000 inhabitants in 1940 to 7.3 in 1976, a decline in the rate of infant mortality from 125.7 per 1,000 live births to 49 over the same period and a rise in life expectancy (from 40 to 63 years for men). The ratio of urban to rural population has shifted greatly: the urban population (defined as people living in communities of 2,500 or more inhabitants) has grown from 35.1 percent of the total in 1940 to 64.9 percent in 1978. This indicator is strongly associated with literacy, health and nutrition.

As for the rural areas, cultivated land is minimal in proportion to what could be cultivated. (In Latin America 11 percent of the arable land is cultivated, compared with 88 percent in Europe and 83 percent in Asia.) Mexico has about 24 million hectares of agricultural land and could cultivate 3.3 million additional hectares over the next five years. It is also feasible to increase agricultural productivity considerably. Mexico has before it the example of the U.S., which cultivates 51 percent of its usable land and is the world's leading producer of grain.

The structure of capital and labor in Mexico is similar to that in other Latin-American countries in many respects. It is distinguished, however, by one significant feature. The old landed oligarchy lost a major share of its properties and power as a large group of small landowners was built up after the revolution of 1910–17. In other Latin-American countries the landed oligarchy controlled the capitalization of the countryside and the cities as well as a good proportion of the industrial and financial growth. In Mexico this old oligarchy lost its dominant role.

The rural bourgeoisie that began to develop after the revolution grew out of a social structure in which at first industrial capital and later financial capital maintained a leading role in the economy. These two forms of capital were allied with or supported by the government. The rural bourgeoisie depended on markets for goods and capital that were controlled by the state and by foreign enterprise, including banks and largely monopolistic companies.

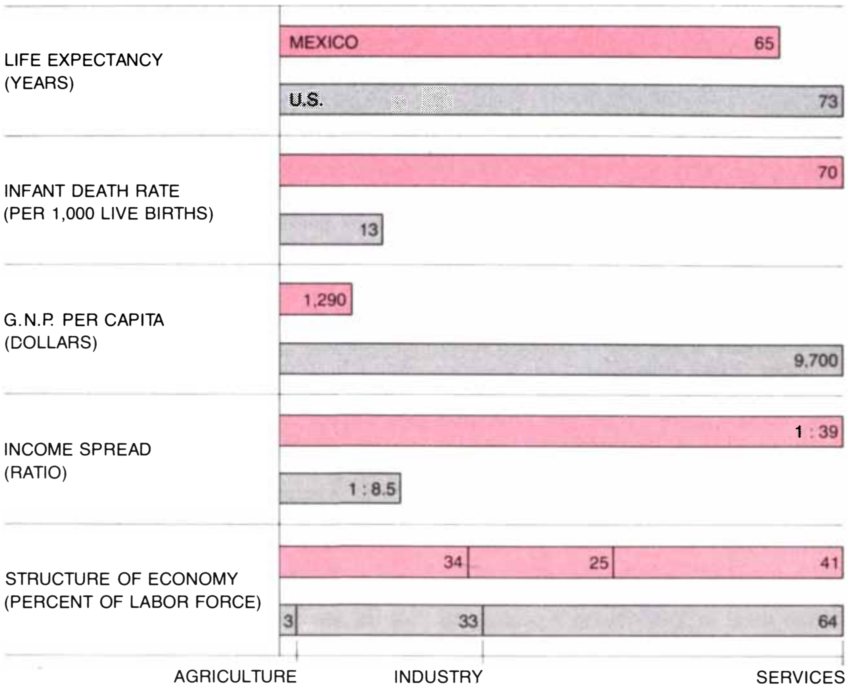
These relations altered the course of the country's economic and political development. One reason was that instead of the rural sector's capital generating the capital of the industrial and financial sectors, as was the case in many other countries, the latter sectors generated capital for the rural sector, with the assistance of the state and later of multinational corporations. Moreover, the state in association with industrial and mercantile capital undertook the development of the internal market in such a way as to create a class of salaried workers who also cultivated their own land during part of the year. By increasing the supply of foodstuffs these workers brought down the real cost of industrial production without increasing the cost of agricultural output.

This mechanism or model was not the result of pure economic rationale. It was the indirect result of an agrarian revolution that involved the largest group of peasants in all Latin America. The demand of the peasants that their need for land be satisfied preceded the beginning of the new type of development of capitalism.

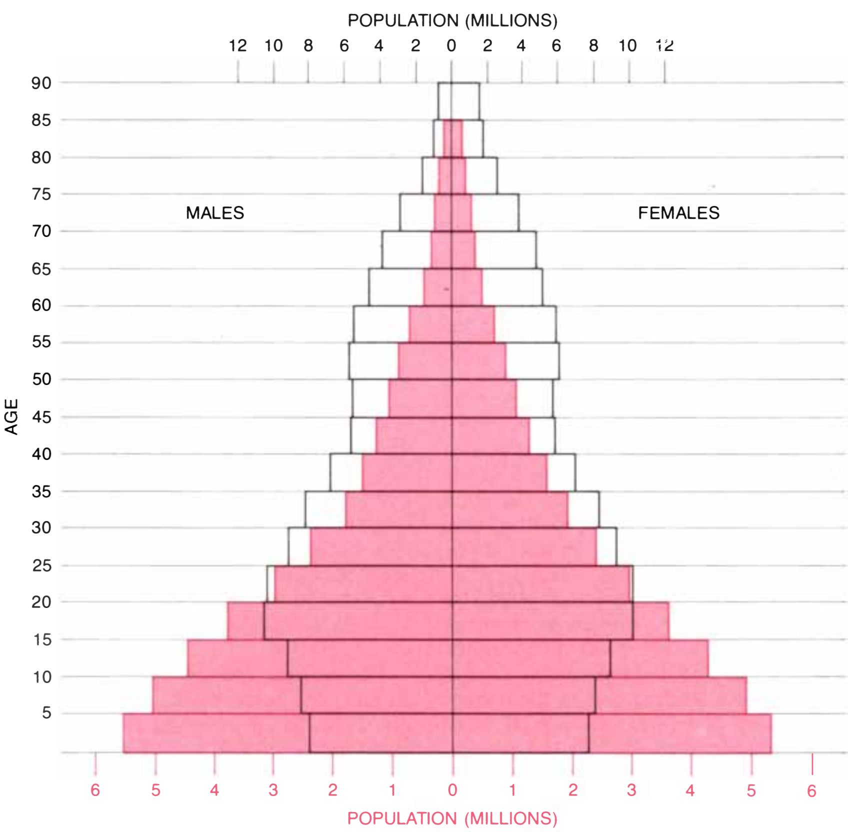
Seventy years ago 1 percent of the population held 97 percent of the land and 96 percent of the population held only 2 percent of the land. When the revolution succeeded, the peasant leaders and the government found that they needed to distribute land to the armed peasants. The distribution of the land reached a peak during the presidency of Lázaro Cárdenas (1934–40). Between 1915 and 1940 more than 1.7 million peasants were given land; 800,000 of them received it during the Cárdenas administration. Even today the political and economic influence of the worker-owners of the countryside remains considerable, and it provides in much of the Mexican countryside a more commercial, bourgeois and civil atmosphere than is found in many other Latin-American countries.

Because many peasants remain without land and many landowners are poor the Mexican countryside supplies large numbers of workers to the industrial and urban enterprises of Mexico and to the international labor market, particularly the U.S. In the period from 1910 to 1970 the proportion of the economically active population engaged in agriculture declined from 72 percent to 41. In absolute terms, however, the number of agricultural workers in Mexico has increased by more than 1.5 million since the revolution.

The landless peasants, and those who simply left their piece of land, were drawn to the cities during the period of rapid industrialization in World War II. They became integrated into the industrial work force, rising at first rapidly from 14 percent of the economically active population in 1940 to 18 percent in 1950 and then more slowly to 19 percent in 1960 and 24 percent in 1970. Starting in the 1950's, however, they began to join the disadvantaged population of the



FIVE INDICATORS for Mexico are compared with the indicators for the U.S. in much the same way as the comparisons made in the preceding articles on China, India and Tanzania. The "equity" data compare the income ratios of the top 5 and bottom 10 percent of the population in Mexico and the U.S. Many Mexican indicators have improved. Forty years ago life expectancy was 40 years for men and the infant-mortality rate was 125.7 per 1,000 live births.



POPULATION PYRAMID of Mexico is compared with the differently shaped one of the U.S. The pyramids show the number of males and females in various age groups. The Mexican pyramid is in color, the U.S. one in black. Mexico's population profile is characteristic of many developing countries in that the young greatly outnumber the old, so that the pyramid slopes regularly from the bottom to the top. The Mexican data are based on estimates for 1979.

cities. Mexico does not differ from other countries of Latin America in this respect.

Mexico is also like other Latin-American countries in terms of the returns to capital and labor. The wages of workers amounted to only 15 percent of the gross product from manufacturing in 1979 (30 percent if wages, salaries and benefits of both white- and blue-collar workers are included). More than two-thirds of income goes to the corporation and less than one-third to the employees. Capital and labor in Mexico maintain the same characteristics found in the less developed countries and in the countries that are peripheral to the capitalist world.

Without awareness of it the Mexican state is neo-Keynesian. Since the great depression of the 1930's the government has become part of a multifaceted financial system. It began to acquire companies, some by expropriation, and to establish others in a variety of sectors of production and services. Public corporations, and the public sector in general, contributed 43 percent of total investment between 1940 and 1954, 31 percent between 1955 and 1961, 40 percent between 1962 and 1970 and 44 percent between 1971 and 1978. The forms of the state's participation in the economy cannot be understood without considering the character of the country's popular history, which is that the development of the economy was increasingly dominated by monopolies and oligopolies.

Public investment is part of the state's power. It entails a capacity to generate jobs, goods and services and an ability to negotiate with other states, particularly the U.S. The state-owned companies, through the investments and outlays of the public sector, help to implement a policy of concessions and negotiations with the large private foreign and domestic companies, with smaller companies and with popular and political organizations. The public companies function as a stabilizing force, as a means of stimulating the economy during recessions and as a complement to the government's systems of stimulation and control.

The power of the Mexican state is, however, limited. It operates in a country that is dependent on a single market (the U.S.) for almost two-thirds (and sometimes more) of its imports and exports. In 1979 some 64 percent of Mexico's imports came from the U.S. and 69 percent of the exports went there. Although Mexico has diversified its economy and has achieved a relative autonomy, several factors tend to reinforce the pattern of a country that is peripheral to the capitalist world and dependent on it. They include the growth of Mexico's external debt, the magnitude of foreign investments, the size of monopolistic and

Physician, did you miss any of these significant developments in medical science?

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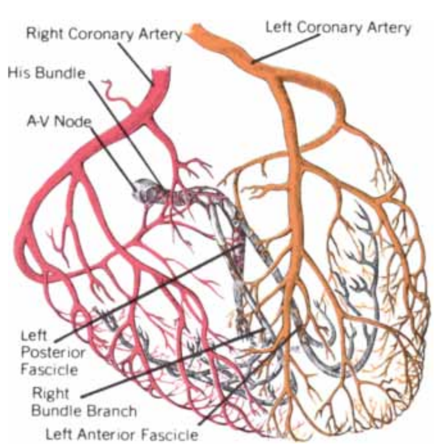

Branches of the right and left coronary arteries supply blood to the AV node and intraventricular conduction system.

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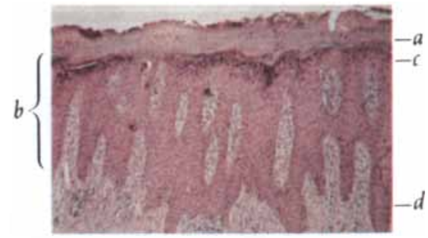

Histopathologic changes in psoriasis.

Extensive psoriasis (top) cleared completely (bottom) after four weeks of treatment with anthralin.

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12. Oncology

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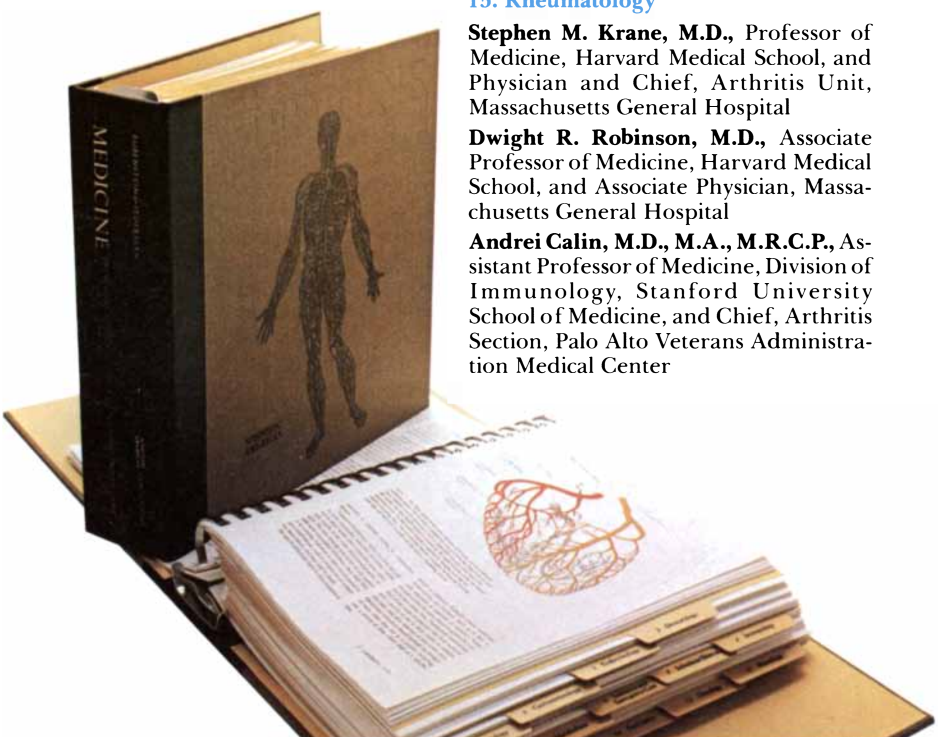

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Between 1940 and 1970 foreign investment in manufacturing was multiplied 65 times, increasing from 7 percent of all foreign investment to 74 percent. In a fair number of cases foreign investors contributed high percents of total investments: 67 percent in chemical products, 79 percent in electrical machinery, 84 percent in rubber and so on. Some 85 percent of all foreign companies were owned or controlled by multinational firms in 1979; in 1978 of 4,359 foreign companies 79 percent were North American. In 1971 multinational corporations covered 93 percent of the payments for imports of technology; 80 percent of the technology employed is still foreign.

This is not a case of a general dependence of one country on another but rather of the dependence of a country and its government on foreign- and domestic-owned corporations. The state's social objectives are sought in an economy where capital is concentrated in the hands of a few. The achievement of those objectives is subject to the pressures created by foreign and Mexican monopolistic capital. About 1.7 percent of the industrial enterprises create 42.3 percent of the employment and generate 53.7 percent of the industrial output. In 1970, more than 50 years after the agrarian reform, 11 percent of the landowners held 60 percent of the land for agricultural use. The oligopolization of the economy is a pervasive characteristic and constitutes an uninterrupted trend, particularly in the most dynamic sectors of the economy. Beyond all of this is the existence of corporate financial groups that are active in a variety of areas of production and finance and are associated not only economically but also politically and in the fields of information and diplomacy.

The power of such interests does not fail to influence in a significant way the decisions and the economic structure of the state itself. For example, it is estimated that between 1953 and 1972 Petroleos Mexicanos (Pemex), the state-owned oil industry, effected transfers worth 11.3 billion pesos to private companies, largely in the form of subcontracts. Government subsidies to private companies in the form of electric energy amounted to 26 billion pesos over the same period. Between 1970 and 1978 the federal government's subsidies to commerce, importers and exporters and organized industrialists totaled 54.1 billion pesos. Many of these subsidies were intended to counteract the effects of inflation on consumers without affecting the substantial profits of the corporations.

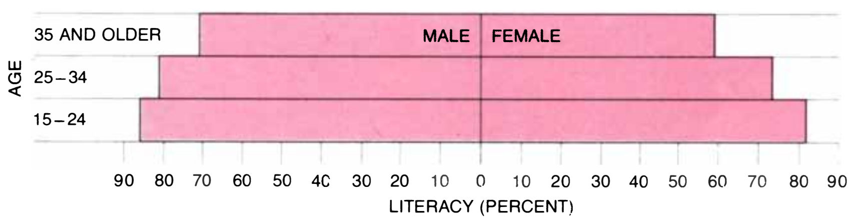
The chief returns to shareholders, including capital gains and dividends, amount to 100, 200 and even 300 percent per year. Multinational corporations occasionally obtain slightly lower but safer profits on their investments in Mexico than they do in other Latin-American countries. Between 1962 and 1975 foreign investment increased to 401 from a base of 100 and remittances from Mexico based on foreign investment rose from 100 to 582. Although foreign investment declined from the equivalent of $85.7 million in the first quarter of 1975 to $49.1 million in the same quarter of 1977, profits increased from $171.9 million to $237.5 million. Large profit remittances and payments in service of the external debt contributed powerfully to the rise in Mexico's balance-of-payments deficit from $217 million in the first quarter of 1975 to $574 million in the first quarter of 1977. By 1970 the servicing of the external debt was absorbing 60 percent of new indebtedness. Between 1970 and 1976 the external debt increased by more than 400 percent.

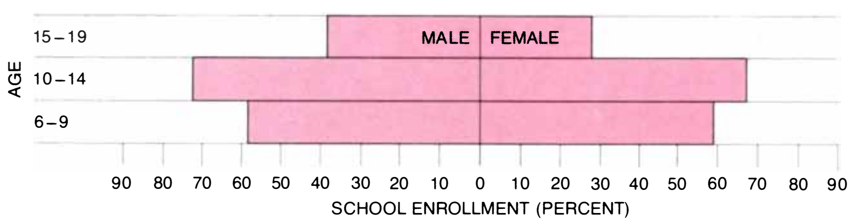
The concessions, subsidies, tax exemptions and transfers in kind from the public to the private sector impose on the state a large share of the costs of inflation. (The largest part of the cost of inflation is paid by fixed-income groups, particularly by the poorest, most disadvantaged and most exploited workers.) Government subsidies also limit the state's role in the conduct of public and private corporate relations because they increase the state's growing indebtedness. As a result the state's national and global directive functions are weakened, and the state is limited to an auxiliary role in the accumulation of wealth.

The government's attempts to impose laws to control foreign investment and to establish a progressive system of taxation (which among other things would have taxed the income on capital) have been frustrated. With all its political and economic stability, which is greater than that in many developed countries, the Mexican state still only fulfills the functions assigned to it on the outskirts of the capitalist world by capitalism. One result is an extremely unbalanced growth.

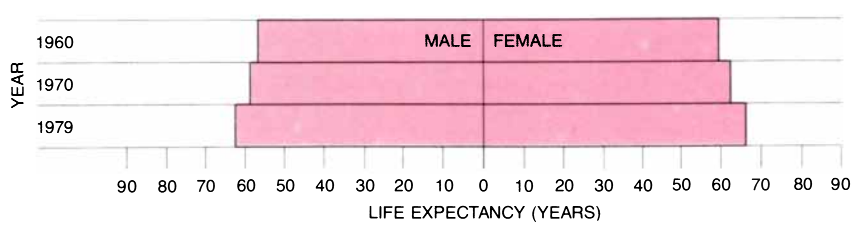
Regarded as a whole, Mexico has achieved a remarkable development, particularly since the nationalization of the petroleum industry in 1938. The first steps had been taken earlier. Between 1925 and 1939 the G.N.P. grew at a rate of 1.5 percent per year. Then the annual growth rates increased rapidly, averaging 5.8 percent between 1940 and 1954, 5.9 percent between 1955 and 1961, 7.6 percent between 1962 and 1970 and 5.4 percent between 1971 and 1977. This year the rate is expected to be between 7.5 and 8 percent.

The growth rates of the per capita G.N.P. are also high. They have been sustained over a fairly long period: 2.9 percent between 1949 and 1954, 2.7 percent between 1955 and 1961, 4 percent between 1962 and 1970 and 2 percent





EDUCATIONAL DATA on the Mexican population are presented by age and sex. The top diagram shows the extent of literacy (defined as the ability to read and write) among people 15 years old or more. The bottom diagram shows the proportion of school-age people in school.



RISE IN LIFE EXPECTANCY of Mexican men and women since 1960 is charted. The figures for 1960 and 1970 are based on vital statistics; the figures for 1979 were extrapolated.

between 1971 and 1977. In 1980 a per capita growth rate of from 4.3 to 4.8 percent is foreseen.

From 1939 to 1978 the gross investment per inhabitant increased from 21 (in 1960 pesos) to 7,163. The volume of industrial production increased from 3.2 in 1940 to 273.9 in 1972 on an index with 1960 as 100. Installed electric-energy capacity increased from 629,000 kilowatts in 1937 to almost 13 million in 1976. The highway system was 9,929 kilometers in 1940 and 200,060 in 1977.

In addition to the increase in life expectancy and in the urban population another indicator is strongly correlated with the standard of living: literacy. Between 1930 and 1979 literacy increased from 33 percent of the population to 84 percent. The number of people receiving primary, secondary and university education has increased at a far higher rate than the population as a whole. In 1979–80 more than 15 million students were in the elementary school cycle, almost four million in the secondary school cycle and almost 800,000 in higher education.

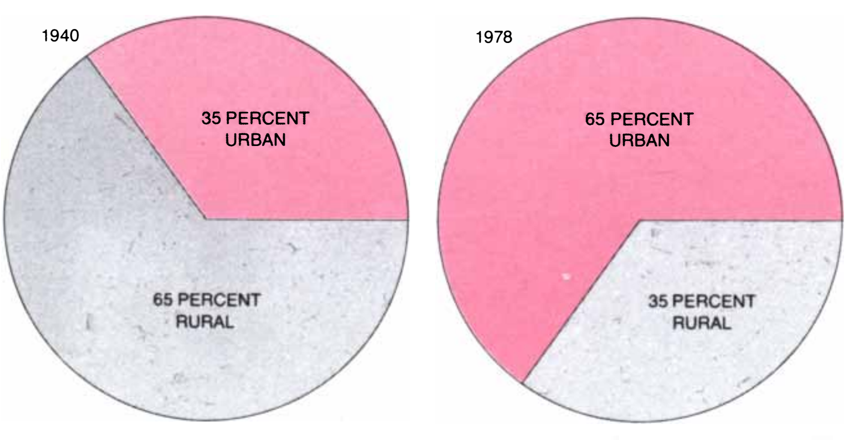
Mexico's income per capita (above $2,100 this year) is matched by such indicators as the number of physicians per inhabitant, the percentage of the population that has electric light and the number of nutritional calories consumed. Indicators detailing changes in the middle-income strata reveal considerable growth.

Nevertheless, the speed of development, its absolute and relative figures and the position the country occupies among other nations in Latin America and the world cannot conceal the fact that development has been more unbalanced in Mexico than it has in many other countries and that the imbalance is growing. For example, in 1958 the income of the richest 5 percent of families was 22 times greater than that of the poorest 10 percent; in 1970 it was 39 times greater. In 1977 the poorest 10 percent received 1 percent of the national income and the richest 5 percent received 25 percent. Among all families 32 percent received the minimum income needed to satisfy the most elementary necessities, and 14.5 percent received less than the minimum. Even among those in the economically active population 40 percent received less than the minimum. This sector of the population is the one most strongly affected by unemployment, underemployment and exploitation.

In 1979 the population excluded from the benefits of development was larger in absolute terms than it had been in 1940. The illiterate amounted to 16 percent, 44 percent did not receive education and 20 percent did not wear shoes. There are also some relations that date back to the colonial era and now combine with the more recent forms of development and of monopolistic capital. The people speaking indigenous languages (some three million Indians) suffer most from this kind of exploitation, created simultaneously by internal colonialism and dependent capitalism. The group is larger if certain mixed-race inhabitants who are treated as Indians are counted.

Some 18 million underprivileged people in rural areas live in extreme misery; 40 million Mexicans have a nutritionally inadequate diet, and 30 percent of the population consumes 10 percent of the food produced while the 15 percent with the most buying power consumes 50 percent. Only 35 percent of the population is covered by the social-security system. Medical care represents only 2 percent of the G.N.P. The housing deficit is five million units. Forty percent of the heads of households never finished primary school.

Side by side with the growth of factories, technologies, centers of development and neighborhoods of the wealthy is the growth of shantytowns and the number of extremely poor, superexploited and unemployed people. The exploitation of nature itself and the disorganized growth of the cities, where the poor are crowded, the concentrations of automobiles are enormous and the development of public transportation and public services is meager—all of this reflects an extremely unbalanced development that combines the oldest forms of exploitation and domination with the most modern. It is only the combination of these inequalities and their ordering into a unique economic, political and social system that explain the long-lasting stability of the country. Yet the stability is threatened at times by crises brought on by the same combination.



STRONG TREND TOWARD URBANIZATION is reflected in diagrams that show the percent of people who lived in rural (*gray*) and urban (*color*) areas of Mexico in 1940 and in 1978.

Unrest among students and other segments of the population in 1968 was the clearest indication of a deep crisis in the social order. As in other Latin-American countries, guerrilla movements had begun to appear in Mexico, and some acts of sabotage and terrorism had occurred. An entire political and social foundation and a power structure that had been built on two essential elements were entering into a crisis. The elements were capital and labor engaged in industry, communications and transportation.

Beginning in 1940 the state, which had evolved from popular coalitions that were originally revolutionary, had pursued a policy of controlling the labor organizations that belonged to the coalition. Constant attempts were made to reduce the strength, independence and demands of the unions of the railroad workers, the electrical workers, the miners, the petroleum-industry workers and above all the organized workers in manufacturing. The government gradually did achieve political and economic control over the unions, but not entirely by repression. Acts of repression were countered by pay increases and concessions aimed at ensuring the stability of the country. This stability was attained above all after widespread strikes in 1958 and 1959, but even before then the state was able to improve its position of power in each confrontation, protecting and stimulating the process of capital growth even as it was granting wage increases and making other concessions to the workers. In this way the costs of the economic model were borne by the workers and the unorganized, disadvantaged masses, which grew spectacularly.

The tensions were accentuated when the hopes and demands of the recently evolved middle classes for more income and services (particularly educational) were threatened because the state was unwilling to touch big capital and unable to further impoverish the disadvantaged population. Thus was generated the most severe political and ideological crisis ever to affect the Mexican state.

This crisis began in 1966, when the government was following an economic policy that favored business interests and adversely affected the middle classes. Public investments diminished

from 13.1 to 6 percent of the G.N.P. while the state-owned enterprises transferred a growing amount of resources to the private sector. The government also levied extremely low taxes, far lower than those of any developed country.

These policies gave rise to increasingly higher public deficits. At the same time inflation almost doubled while the prices of agricultural products for domestic consumption were frozen. The people most affected were the worker-owners of the countryside, particularly the poorest ones.

A year after the change of government in 1970, when Luis Echeverria Álvarez became president, the policy was modified and the real income and expenses of the middle classes and the minimum-wage earners rose considerably. Since other factors were left unchanged, an unprecedentedly severe inflation set in. The rise in the price index increased from 3.3 percent in 1970–72 to 22 percent in 1976. External indebtedness increased further. International inflation, speculation, hoarding, high profits with lower levels of production and demand, together with the growing economic weakness of the state, increased the concentration of capital and income while decreasing consumption. Unemployment and underemployment rose to extreme levels.

In 1976 inflation continued. Just before the government changed, with the external debt reaching critical levels, a devaluation of the currency was hinted at, with a flight of capital resulting. On August 31, 1976, the peso was devalued almost 100 percent after having maintained parity with the dollar for 20 years. As was to be expected, the devaluation enhanced the inequality of income distribution among Mexicans. It increased the cost of imported components of production to the detriment of small and medium-size firms and to the advantage of the monopolistic and multinational corporations.

The rediscovery of oil, that is, the recognition that Mexico has far larger reserves of petroleum than had previously been thought, renewed the strength of the government. It put forward a plan for the development of the economy with a larger emphasis on investments that would create jobs and more agricultural products for the domestic market. By last year it was apparent that the crisis would be resolved. Starting in 1978 the growth rates of public and private investment rose to 19 and 13 percent respectively in real terms. In 1979 both increased by 18 percent. The trade balance improved, mostly because of exports of petroleum and manufactured goods, which rose by 16.5 percent. Employment grew more than the population. The G.N.P., which in 1976 had increased by only 2.1 percent, rose by 7 percent in 1978 and 8 percent in 1979.

From 1978 to 1979, however, the average real wage decreased by 2.4 percent, currency in circulation increased by 35 percent and the consumer price index rose by 20 percent. There were other limitations to the country's recovery. Although organized labor began to obtain significant wage increases, most of the population still suffered from the high rate of inflation. Exports increased by 43 percent while imports rose by 48.5 percent, mainly because more foods and capital goods were being imported. The negative balance of payments almost doubled ($2.3 billion in 1978, $4.2 billion in 1979).

Recovery accompanied by inflation created contradictory effects. The state's power was undeniably enhanced, as was its ability to grant concessions to the organized sectors of society. Inflation also made evident, however, the need to prevent Mexico from becoming merely an oil-producing country, thereby making the nation more dependent and bolstering the profits of monopolistic and private capital.

Today the crisis of the Mexican economic model continues within a broader crisis of capitalism both nationally and internationally. In Mexico the crisis seems to have been skillfully deflected from its more serious tendencies toward disorder, although once again the cost is paid by the poorest sectors of the economy.

In concrete terms a confrontation is taking place between two policies, neither of which calls for an end to the capitalist-monopolist system, at least not at the moment. One policy proposes a democratic, liberal and national model coupled with increasing intervention by the state. The other wants to keep the present system.

The first policy encompasses forces that are powerful but deeply divided. They could reorganize the country only through the unified and increasingly democratic action of the mass of the population. It would also be necessary to fashion new policies whereby industrial workers and their unions would formulate measures of national scope that transcended the interests of labor.

The revolutionary and more radical organized forces almost unanimously accept a policy of transition that does not attempt to impose socialism now. It seeks to broaden the social and democratic basis of the political parties and the trade unions while using the country's petroleum resources for a new policy of social and industrial development. In the midst of a worldwide political and economic crisis affecting capitalism Mexico seems to be one of the stabler countries. Only an act of intervention, which presumably could only be fostered by jingoist groups in the U.S., can alter Mexico's course. Such a move would surely solidify the nationalist and revolutionary forces in Mexico.

The World Economy of the Year 2000

The first input-output model of the world economy suggests how a system of international economic relations that features a partial disarmament could narrow the gap between the rich and the poor

by Wassily W. Leontief

The term "world economy" (*Weltwirtschaft*) first appeared in Germany on the eve of World War I, when Kaiser Wilhelm II was preparing to challenge the political and economic domination of the British Empire. It was at about the same time that the German economist Bernhard Harms, with the backing of Germany's newly created steel and heavy-chemical industries, founded the Institute for World Economics in Kiel, the first large institution devoted to economic research on a global scale. These two signs of impending change proved to be reliable. Over the next 60 years Germany would lose two wars, Britain would lose its empire and the notion of a world composed of self-sufficient, autonomous national economies would recede into the realm of conventional abstractions.

A dramatic demonstration of the degree of global interdependence that exists today is provided by the current "oil crisis," whose direct and indirect effects are felt in the farthest corners of five continents. The world economy has become a tangible reality, and at the present time its dominant feature is the gap in income (and thus standard of living) between the poorer, less developed countries of the world and the richer, highly industrialized ones. In this article I shall discuss the prospects for accelerating the rate of growth of the less developed countries of the world under some of the most frequently proposed scenarios for world economic development.

In 1973, to provide a quantitative basis for such an investigation, the United Nations, with special financial support from the Netherlands, commissioned the construction of a general-purpose model of the world economy. To transform the vast collection of microeconomic facts that describe the world economy into an organized system from which macroeconomic projections of future growth could be made the model was to rely on the method of input-output, or interindustry, analysis. The input-output method depicts the structure of an economy in terms of the flows among its producing and consuming sectors, real transfers of goods and services. Such transfers can be displayed in a statistical input-output table for the economy. This table in turn gives rise to a set of structural equations whose simultaneous solution provides a numerical picture of a possible future state of the economy. In order to generate such a projection from the input-output model it is necessary to make a certain number of assumptions about some of the factors that will determine the pace and the shape of the economy's future growth, that is, some of the variables in the set of equations must be fixed. Hence by trying different assumptions it is possible to project a series of alternative paths for the development of the economy. In this way input-output analysis provides a means of taking the quantitative measure of hopes and plans for the future.

In the nearly 50 years since the input-output method was first introduced its practical applications have proliferated, and it has become a standard tool for investigating the economic structure of countries and of smaller systems such as states, cities and even corporations. The compilation of national input-output tables has become part of the official statistical program of all the developed countries and many of the less developed ones. By 1973, when the construction of the world model was begun, there were input-output tables for more than 60 countries, several of which (including the U.S., Japan and Norway) were publishing their own tables at regular intervals.

A national input-output table describes the web of technologically determined interindustry relations that constitute the economic fabric of a country. Naturally many of the threads of the fabric (the quantities of goods produced or the services provided) cross geographic borders and are woven into the fabric of another country, but until recently such threads had always been left hanging loose. No attempt was made to tie the various national tables together, an omission that not only prevented the systematic application of the input-output method to investigating the structure of international economic relations but also introduced an element of uncertainty into the study of national economics. This problem is solved in the input-output model of the world economy in a simple way: the world is visualized as consisting of 15 distinct geographic regions, each one described by an individual input-output table, and these tables are then linked by a network of interregional commodity flows.

Even though the overall design of this multiregional model—the first input-output model of the world economy—is simple, constructing it was complex. To begin with, the results of information-gathering efforts throughout the world had to be combined to create a detailed picture of the input-output structure of each regional economy in 1970 (the model's designated base year). The re-

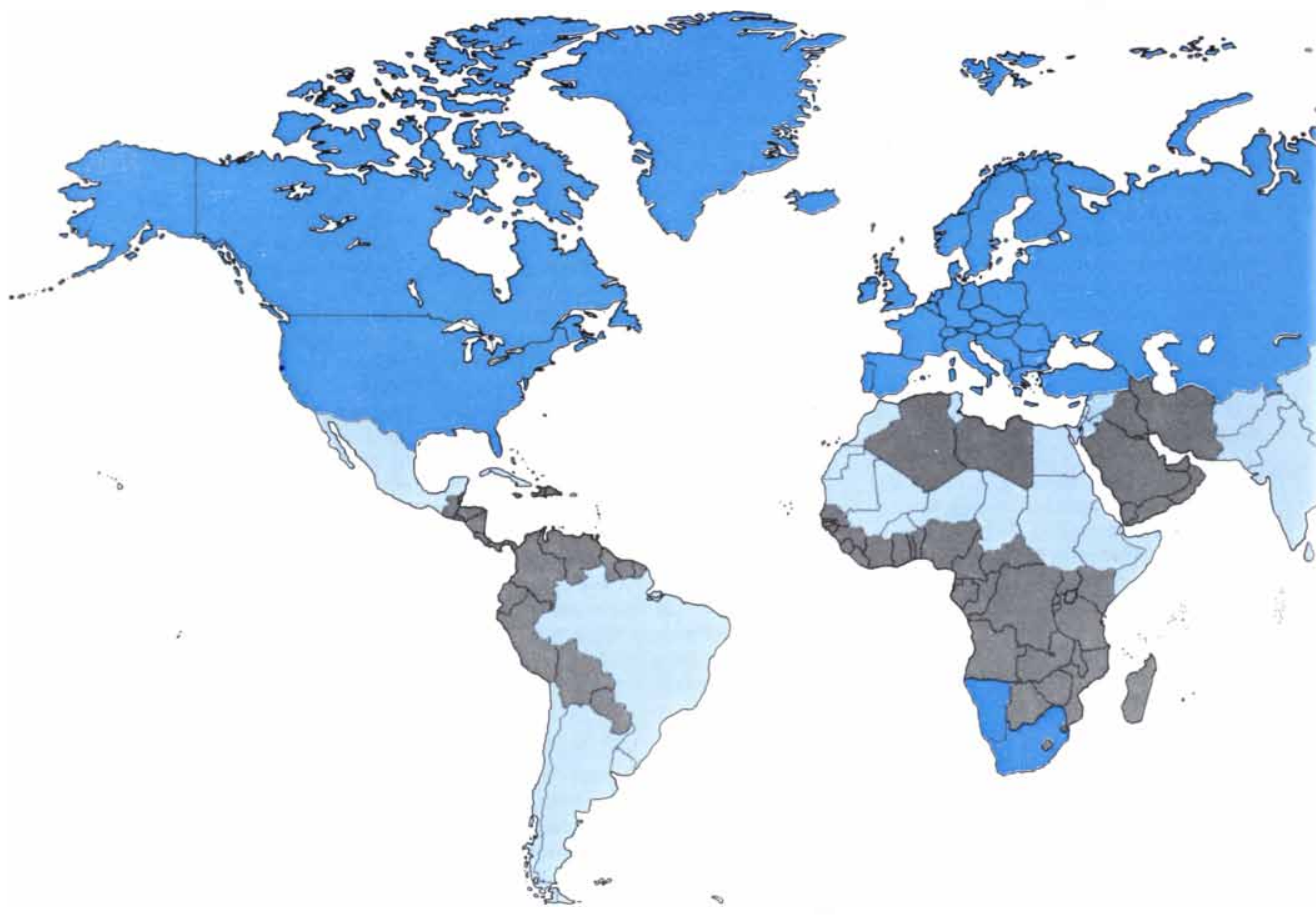
TECHNOLOGICAL INNOVATION plays a key role in the economic development of nations by creating what are essentially new resources. An example is the reclaimed arable land visible as a pattern of hexagonally close-packed red dots in the false-color Landsat image on the opposite page, which shows a desert area near the Oases of Kufra in Libya. Dots are circular fields of crops grown under center-pivot irrigation. Each dot is almost a mile in diameter.

sulting arrays then had to be arranged in a single vast data bank and stored in a computer. (Some national input-output tables are so large that they cannot be printed out.) Finally, complex computer programs had to be written to implement the model, that is, the structural information contained in the data bank had to be transformed into an appropriate system of equations and then the equations had to be solved simultaneously in order to obtain projections of future development.

In 1978 a set of detailed projections made using the multiregional input-output model appeared under the title *The Future of the World Economy.* These projections, all of which begin with the base year 1970, provide comprehensive descriptions of the state of each of the 15 regions in the world model and the relations among them for the benchmark years 1980, 1990 and 2000. The division of the world into 15 geographic regions with a reasonable degree of economic homogeneity was achieved by first ranking all the countries of the world in decreasing order of their average annual per capita income and then grouping those that seemed to be at about the same stage of economic development and to have a comparable endowment of natural resources.

For the purpose of presenting and interpreting the results of global economic projections carried out in regional detail it was convenient to further group the 15 regions into three main categories: the developed regions, the resource-rich less developed regions and the resource-poor less developed regions. In 1970 the developed regions of the world, including (in decreasing order of their average annual per capita income) North America, Oceania (mainly Australia and New Zealand), Western Europe, Japan, the U.S.S.R., Eastern Europe (other than the U.S.S.R.), South Africa and Mediterranean Europe, had a total population of 1.108 billion and an average per capita income of $2,534. The resource-rich less developed regions, including low-income Latin America and the oil-producing states of the Middle East and tropical Africa, had a total population of 358 million and an average income of $278. The resource-poor less developed regions, including medium-income Latin America, arid Africa, the centrally planned nations of Asia and low-income Asia, had a total population of 2.154 billion and an average income of $186 [*see illustration below*].

What are the objective possibilities of closing the gap between the income that can be expected in a developed country and the income that can be expected in a less developed country poor in natural resources? Can such growth be achieved under the current policies regulating credit and trade balances among nations? Could a radical revision of those policies serve to accelerate the growth of the poorer less developed nations? And what effect could an international agreement to limit military spending have on the income gap? The multiregional input-output model, whose pro-

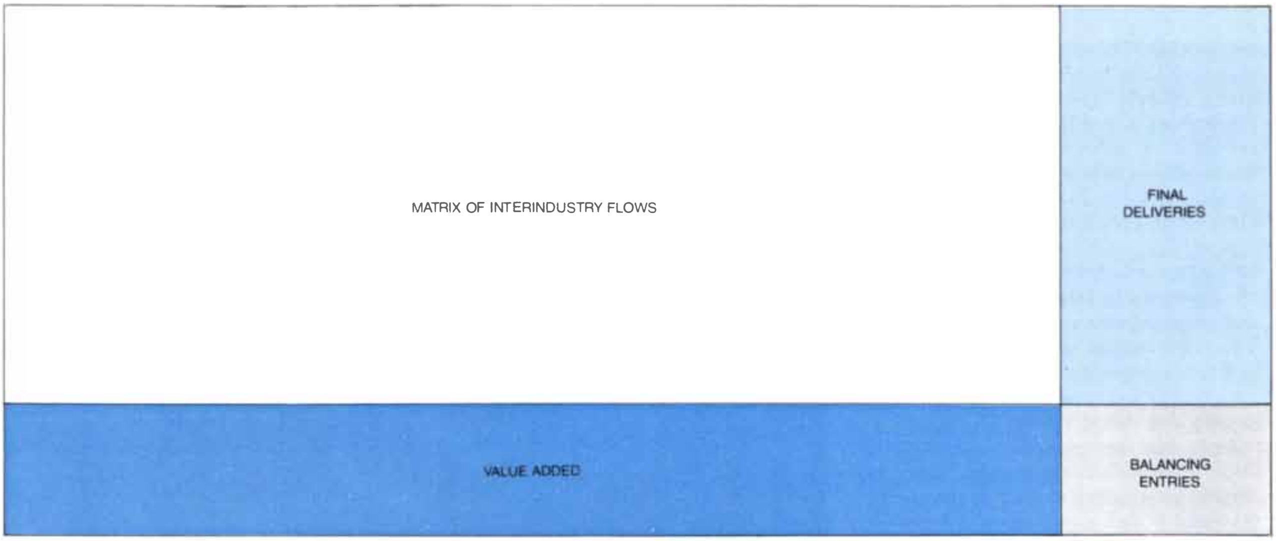


WORLD MAP shows how the nations of the world can be divided into three economic categories: developed (*dark color*), resource-rich less developed (*gray*) and resource-poor less developed (*light color*). For the purpose of projecting future economic development the input-output model of the world economy analyzes 15 homogeneous regions that make up these categories. In 1970, the model's base year, the eight regions classified as developed, with 31 percent of the world population, had an average annual per capita income of $2,534. Three resource-rich less developed regions, with 10 percent of the population, had an average income of $278. Four resource-

jections are grounded in the real data of the world economy, provides a reliable means of exploring these questions (and many others). To understand how the projections are made it is necessary to consider the structure and workings of the model in more detail, and so I shall explain how input-output analysis is applied to an economic system.

The input-output method analyzes an economy in terms of its production and consumption of goods and services. The total output of each of the goods and services produced and consumed in a particular national economy is divided among the "final users," such as consumers and governments (which consume commodities directly), and the various producing sectors of the economy (which consume commodities indirectly, as inputs to their respective industrial or agricultural processes). The total dollar value of all the goods and services delivered to final users is the gross national product. The magnitude

poor less developed regions, with 59 percent of population, had average income of $186. In the model each region is described by an input-output table, and tables are linked by a network of interregional commodity flows.



Industry number		Livestock and livestock products	Agricultural crops	Forestry and fishery products	Agricultural, forestry and fishery services	Iron and ferroalloy ores mining	Total interindustry use	Personal consumption expenditures	Gross private fixed capital formation	Exports	Imports	Federal Government purchases	State and local government purchases	Total final demand	Total industry output
	Industry number	1	2	3	4	5		80	81	82	83	84	85		
1	Livestock and livestock products	11,316	870	—	188	—	41,958	1,454	—	111	—259	4	71	1,381	43,339
2	Agricultural crops	10,088	1,129	—	52	—	27,160	4,580	—	4,763	—630	—982	189	7,920	35,080
3	Forestry and fishery products	—	—	9	11	—	2,696	848	—	105	—1,152	—533	7	—725	1,971
4	Agricultural, forestry and fishery services	1.222	1,289	49	106	—	3,361	125	—	19	—2	14	49	205	3,566
5	Iron and ferroalloy ores mining	—	—	—	—	24	1,775	—	—	102	—619	—25	—	—542	1,233
6	Nonferrous metal ores mining	—	—	—	—	3	2,466	—	199	32	—414	—7	—	—190	2,276
7	Coal mining	—	1	—	—	4	4,749	125	—	496	—1	48	22	690	5,439
8	Crude petroleum and natural gas	—	—	—	—	—	19,439	—	53	1	—2,763	—	—	—2,709	16,730
9	Stone and clay mining and quarrying	1	88	—	1	6	3,046	5	—	90	—179	—2	—49	—135	2,911
10	Chemical and fertilizer mineral mining	—	46	—	—	—	459	3	—	79	—96	—2	49	33	492
11	Maintenance and repair construction	224	304	—	55	33	26,995	—	—	6	—	2,079	7,337	9,422	36,417
12	Ordnance and accessories	—	—	—	*	—	399	457	80	325	—81	5,742	16	6,539	6,938
13	Food and kindred products	5,324	1	46	26	*	46,802	73,276	—	2,862	—4,857	310	2,229	73,820	120,622
14	Tobacco manufacturers	*	*	*	*	*	2,377	6,087	—	839	—71	—	—1	6,854	9,231
15	Broad and narrow fabrics, yarn and thread mills	—	10	—	—	—	16,950	639	—	432	—895	26	58	260	17,210
16	Miscellaneous textile goods and floor coverings	13	54	52	43	—	4,391	1,513	606	156	—586	16	3	1,708	6,099
17	Apparel	—	—	—	—	—	9,767	22,563	—	260	—2,638	131	82	20,398	30,165
18	Miscellaneous fabricated textile products	—	19	23	13	—	2,824	2,775	—	103	—134	145	49	2,938	5,762
19	Lumber and wood products except containers	6	3	—	—	3	22,424	384	5	850	—2,073	30	27	—777	21,647
20	Wood containers	1	121	—	17	—	446	—	—	3	—4	13	—	12	458
I	Total intermediate inputs	33,776	15,480	704	1,833	721	—	—	—	—	—	—	—	—	—
VA	Total value added	9,563	19,600	1,267	1,733	511	—	—	—	—	—	—	—	—	1,182,766
EC	Compensation of employees	1,854	2,556	395	1,249	247	—	—	—	—	—	—	—	—	717,663
BT	Indirect business taxes	794	701	59	108	60	—	—	—	—	—	—	—	—	110,981
PTI	Property-type income	6,914	16,343	813	375	204	—	—	—	—	—	—	—	—	354,122
T	Total	43,339	35,080	1,971	3,566	1,233	—	738,072	181,931	72,794	—76,199	102,126	150,693	1,182,766	—

INPUT-OUTPUT FLOW TABLE, which provides the statistical basis for input-output analysis, depicts all the real transfers of goods and services within a particular economy over a given period of time. As is shown in the diagram at the top, the bulk of a flow table is taken up by the "matrix of interindustry flows," in which the entries in each row describe the way the output of the sector corresponding to that row is distributed to all the producing sectors of the economy (including that sector itself). For example, in the flow table whose four corners are shown at the bottom the interindustry structure of the U.S. economy is described in terms of the flows among 79 producing sectors. (In this table, which was compiled for 1972, all entries represent millions of fixed 1972 dollars, and asterisks indicate transactions valued at less than $500,000.) Section at the upper right of a flow table lists the deliveries of the output of each sector to final users, or those that consume commodities directly instead of as inputs to the production of other commodities. In the U.S. table these "final deliveries" go to satisfy such demands as personal consumption, government purchases, exports and imports (which, since they reduce the aggregate domestic demand for a commodity to be satisfied by domestic production, must be entered in the table as negative values). Just as the distribution of the output of any sector can be read across the corresponding row of the flow table, so the combination of inputs that a sector requires for the production of its particular commodity or service can be read down the corresponding column. The section at the lower left of a flow table lists those inputs that are not accounted for by interindustry flows. In the U.S. table these inputs include wages, taxes and rents, and they can be summed to obtain the "value added" to the commodity produced by a sector. The deliveries made to final users can be summed to obtain the final demand for each commodity, a quantity whose dollar value represents the contribution of the corresponding sector to the gross national product of the economy. In input-output analysis the total final demand for the output of each sector, which appears in the next to last column of the U.S. flow table, accounts not only for allocations to current private and public forms of consumption but also for additions made to the stocks of various components of fixed and working capital such as equipment and buildings. An input-output table of this type is balanced in the sense that the total output of each sector (which appears in the last column of the U.S. table) is equal to the sum of all its interindustry and final-use deliveries and also to the sum of all its interindustry inputs and its value added (which appears in the bottom row). The "balancing entries" that appear in the section at the lower right of a flow table depict the equilibrium between income and spending in the economy whose interindustry transactions are described by the table.

of the interindustry transactions in an economy obviously plays a large part in determining the levels of income and consumption within the economy. One important advantage of input-output analysis is that these transactions are brought into the model of the economy through the system of linear equations (equations with variables to the first power only) that serve to describe it.

In a system of input-output equations the variables represent unknown quantities that describe a particular state of the economy and the coefficients reflect the interdependence of the various producing sectors of the economy. These structural coefficients must be determined empirically, and they are generally derived from the numerical matrix—the input-output table—that describes the flow of goods and services within the economy over a given period of time. Each row in an input-output table shows the deliveries made by the sector associated with that row to all the different sectors in the economy (including itself) and to all the final users [*see illustration on opposite page*].

In the basic format of an input-output table the list of major producing sectors of an economy appears twice, once along the top of the matrix and again along the left-hand side, creating a square array of interindustry flows that is the bulk of the table. In other words, the figure that appears in row i, column j of this part of the table represents the part of Sector i's total output that is delivered as input to Sector j. The deliveries to final users, which include private households, government, exports, imports and investments in new productive capacity (that is, additions to the existing supplies of machinery, buildings and materials), are entered in the last columns of the matrix. And the last rows present the inputs that are not accounted for by intersectoral flows, including the cost of labor, interest payments, rents, taxes and so on. For each sector these last inputs can be summed to obtain the "value added" by that sector to the raw materials, energy and all other intermediate inputs received or purchased from the other sectors of the economy. Similarly, the last deliveries for each sector, or those parts of its output that go to final users, can be viewed as components of the "final demand" for the commodity the sector produces.

(All the commodity transfers shown in an input-output table involve physical quantities such as bushels of grain or tons of steel. In most cases, because of the absence of information about such physical quantities, the various inputs and outputs in the table are described in terms of their "fixed dollar" value. The advantage of expressing flows in this way can be seen by comparing two input-output tables for the same economy in different years. Suppose an examination of the tables reveals that the cost of the copper required to produce $1 million worth of television sets increased from $10,000 to $15,000 in the time that elapsed between the construction of the two tables. This change might be due at least in part to changes in the price of television sets or changes in the price of copper or both. If in both tables both the inputs and the outputs are measured in fixed prices, however, then the change in the cost of the required copper represents a real change in the input-output balance of the television-producing sector, one that arises from a real change in the technology.)

An input-output matrix of the type described above is called a flow table, and it is not hard to see that such a table is balanced in the sense that the total output of each sector is accounted for by the sum of all its interindustry and final-use deliveries and by the sum of all its interindustry inputs and its value added. And summing either the final demand for each sector's output or the value added to each sector's inputs over all the sectors yields the G.N.P. (It is important to note that imports, which reduce the aggregate demand for a commodity to be satisfied by domestic production, must be entered as negative quantities if the table is to balance.)

Hence in the schematic picture of an economy presented by the input-output flow table the allocation of all the goods and services generated by the economy (including the distribution of all the primary resources such as oil, ores and labor) is revealed when the table is examined row by row. The fundamental technological relations that control the transfer of goods and services within the economy, on the other hand, become apparent when the table is examined column by column. These structural relations are even more clearly revealed if the information in the flow table is recast by dividing the output delivered from one sector to another by the total output of the sector receiving the input. In this way a matrix of input coefficients is created in which the entry in row *i*, column *j* represents the part of the output of Sector *i* that is absorbed by Sector *j* for each unit of Sector *j*'s total output. Thus the set of coefficients contained in each column of the new matrix is equivalent to the recipe followed by the sector associated with that column in the production of its particular commodity. Indeed, multiplying the total output of the sector by each of these input coefficients in turn reproduces the corresponding column of the flow table: the set of input flows the sector had to receive from other sectors in order to produce the total output.

The combination of the various inputs a particular sector needs in order to produce its total output is governed essentially by technical considerations, and so the matrix of input coefficients is called a structural, or technical-coefficient, input-output table. It is the coefficients in this structural matrix that give rise to the system of linear equations that are the core of the input-output model of the economy, the equations that describe the balanced relations between the levels of output in all the productive sectors of the economy and the quantities of their respective products delivered to final users.

In the condensed notation of matrix algebra the system of equations can be expressed in the form $x - Ax = y$, where A is the square interindustry section of the technical-coefficient matrix, x is the column vector, or one-dimensional matrix, that lists the total output of each of the producing sectors of the economy and y is the column vector that lists the part of each sector's total output delivered to final users. Thus Ax describes the contributions made by the various sectors to fulfilling the intersectoral input requirements of the economy, and so the equation $x - Ax = y$ conveys the fact that an economy's G.N.P. (y) depends on the difference between its total output (x) and its interindustry transactions (Ax). (A description of the matrix arithmetic by which the simple equation $x - Ax = y$ is converted into the large system of linear equations that describe in detail the interrelations of the various sectors of the economy is provided in the illustration on page 216.)

Industry number		Livestock and livestock products	Agricultural crops	Forestry and fishery products	Agricultural, forestry and fishery services	Iron and ferroalloy ores mining
	Industry number	1	2	3	4	5
1	Livestock and livestock products	0.26110	0.02481	-	0.05278	-
2	Agricultural crops	.23277	.03218	-	.01444	-
3	Forestry and fishery products	-	-	0.00467	.00294	-
4	Agricultural, forestry and fishery services	.02821	.03673	.02502	.02959	-
5	Iron and ferroalloy ores mining	-	-	-	-	0.01972
6	Nonferrous metal ores mining	-	-	-	-	.00268
7	Coal mining	-	.00002	-	-	.00357
8	Crude petroleum and natural gas	-	-	-	-	-
9	Stone and clay mining and quarrying	.00001	.00251	-	.00034	.00511
10	Chemical and fertilizer mineral mining	-	.00130	-	-	-
11	Maintenance and repair construction	.00517	.00867	-	.01534	.02637
12	Ordnance and accessories	-	-	-	.00003	-
13	Food and kindred products	.12284	.00003	.02855	.00729	.00008
14	Tobacco manufactures	.00001	.00001	.00005	.00011	.00008
15	Broad and narrow fabrics, yarn and thread mills	-	.00027	-	-	-
16	Miscellaneous textile goods and floor coverings	.00030	.00154	.02649	.01195	-
17	Apparel	-	-	-	-	-
18	Miscellaneous fabricated textile products	-	.00055	.01142	.00367	-
19	Lumber and wood products except containers	.00013	.00009	-	-	.00203
20	Wood containers	.00002	.00345	-	.00468	-
VA	Total value added	22066	.55872	.64273	.48588	.41493
EC	Compensation of employees	.04276	07285	.20020	.35031	.20065
IBT	Indirect business taxes	.01833	.01997	.02979	.03037	.04901
PTI	Property-type income	.15957	.46589	.41274	.10520	.16528
T	Total	1.00000	1.00000	1.00000	1.00000	1.00000

TECHNICAL-COEFFICIENT TABLE, derived from the input-output flow table for a particular economy, reveals the economy's internal structure. As is shown by these sections of the 1972 technical-coefficient table of the U.S. economy, each entry in this type of table is the ratio between an input to a particular sector and the total output that sector produces. Thus each column in the matrix displays the combination of inputs that the corresponding sector requires to be able to produce one unit of output, a recipe that is essentially governed by technology.

The power of input-output analysis lies in the fact that the equation $x - Ax = y$, or rather the system of linear equations it implies, can be applied in a variety of ways, depending on which variables are fixed and which are considered unknown quantities. For example, an economist, knowing the limited production capacity of the economic system described by A, might want to consider the vector x (or at least some of its entries) as being given and solve the equation for the vector y to project the maximum G.N.P. the system can achieve. Another analyst, seeking to determine the implications of a change in government purchases or consumers' demand on the economy described by A, might assign values to y and solve the equation for x, in other words, project the amount of output from each sector needed to attain the desired G.N.P.

Besides explaining the physical flows of inputs and outputs in a particular economy, the input-output system described above also serves to clarify the relation between prices and costs in the economy. A vector of technical coefficients that describes, say, the amounts of ore, coke, flux, labor and other inputs

TIME CONTROL

Attractive wood-grain unit adds to any decor and will Time Control your entire home. Measures: 5¾"x5¼" x3 1/8"

Now, a new computer development lets you control and time your entire home even when you're 1,000 miles away!

In the fall of 1978, an English company, BSR Electronics introduced a remarkable new product, the X-10 Space Controller. The X-10 allowed you to page up to 16 appliances and lights throughout your house remotely from any location. It was an instant success and rightly so. But the most vital part of the system was still in development. Not any more — with Time Control —the system is complete.

Now you can turn your lights or appliances on and off anytime, even when you're on vacation. It can program your TV or radio to wake you and start your coffee all before you get out of bed every day. These are just a few of many things that Time Control does to increase your security and convenience. It can do much more!

IT'S REALLY QUITE SIMPLE

BSR's X-10 Space Controller is really quite simple. It's made up of a central transmitter and receivers, all of which are plugged into your 110 volt wall sockets. You press a number on the calculator-type keyboard of the central control and an electronic signal is transmitted through your existing house wiring to remote modules in which lamps and appliances are plugged.

Simple plug-in modules. No wiring required. Operates over existing in-house wiring.

Outside or overhead lights are controlled by installing a wall switch module that also receives commands from the central controller. Each remote module has a numbered thumb dial. The digital controller activates only those modules set to the desired number. You can control one or up to 16 modules with the system. Time Control adds the missing dimension to Space Control.

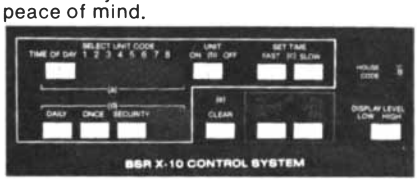
NOW THERE IS TIME CONTROL

Time Control consists of a computer memory and digital clock. You can now program the exact time you want a light or appliance to turn on or off. One mode allows you to even produce a random pattern automatically to make your home appear occupied when you're away.

SPACE AGE ROBOT

Time Control is your own space age robot with four-in-one modes for up to 16 separate functions in your home. Time Control will add conveniences and it may save you thousands of dollars when you're not at home.

• **Security Mode** is used primarily when you're away either one day or the entire summer. Selected lights and appliances are sequenced on and off to give that lived-in appearance. First, a light in one room and then another, a radio in a third, plus the den TV, all can be programmed to fool any would-be burglar "casing" your home. You just select the lights or appliances and the times you want each to be on. Time Control can be programmed in minutes using the calculator type keyboard. One avoided robbery and Time Control pays for itself many fold. Think of the increased peace of mind.



Easy to program Time Control keyboard times lamps, appliances and even outside or overhead lights.

• **Daily Timer** Select any one or all of 8 modules to time daily, then set in any time you want each to turn on and then off. Program your TV or radio to come on to wake you each morning. Turn the outside lights on at 7:00 p.m. and off at 6:30 a.m. Timed to the exact minute of each day automatically. Turn your coffee pot on each morning and shower while your coffee is brewing. Your life may never be the same again.

• **Quartz Clock** Digital Quartz accuracy in an attractive wood-grain finish. Attractive enough to add to the decor of any room. Accuracy unsurpassed by expensive chronometers costing $200 or more. With large easy to read green numbers. May be worth the price of the unit for this feature alone.

• **Panic Button** This bonus feature allows you to turn on all of your lights from your bedside to frighten away peeping toms or intruders. Further peace of mind when you're away and your spouse is home alone.

NO WIRES NEEDED

One of the nice features of time control is that no wires are required. All appliances and lamp modules simply plug into your wall sockets. For outside or overhead light control, you merely change your existing light switch with BSR's wall switch module. Time Control takes it from there.

BUILD YOUR OWN PERSONAL SYSTEM

If you already have a BSR X-10 Space Controller, all you may need is the timer at $74.99. If not, we recommend a starter kit at $119.95 consisting of the timer, two lamp modules and one appliance module. You save $6. We sell all BSR X-10 Accessories so you can add additional modules as you need them to Time Control your *entire* home.

30 DAY NO-RISK TRIAL

Test the Time Control for 30 days at no risk. If Time Control does not provide the convenience and peace of mind we say it can, or for *any* reason, return it to us. We will promptly refund your purchase price. What have you got to lose?

WARRANTED FOR ONE FULL YEAR

Time Control is an all solid state unit. It should provide you with many years of trouble-free service. If in the unlikely event anything should go wrong during one full year, it is factory warranted by a sizable company, BSR.

HURRY! QUANTITIES ARE LIMITED

When we were given the opportunity to introduce Time Control in this country, we jumped at the chance. We also knew quantites would be limited this year. BSR has set aside quantities of Time Controls for us. But there may not be enough. So to be assured of being one of the first to get your Time Control—Don't wait, order now!

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- Send me the following modules. Add $1.00 shipping & handling.

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_______Appliance Modules at $15.99

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that are required to produce a ton of steel can be employed to set up an equation describing the necessarily balanced relations between the prices of all these ingredients and the price of steel. More precisely, the price of steel must be equal to the combined costs of all the inputs plus the normal profit the steel industry must earn per unit of its output. Without going into further detail, it is important to point out that in parallel to the system of equations representing the balance and therefore the interdependence among all the commodity flows in an economy a "dual" system of price-cost equations can be formulated, describing the balance between the costs and the prices of all the goods and services produced and consumed throughout the economy. The same large, square matrix of technical coefficients appears in both systems of equations, although it enters into the two in somewhat different ways.

The multiregional input-output model of the world economy consists of 15 technical-coefficient tables of the type I have described here. Each region is visualized as a set of 48 sectors of economic activity that include four different agricultural sectors (including "Livestock products," "Grain," "High-protein crops" and "Roots") and 22 manufacturing sectors (including "Food processing," "Textiles," "Fertilizer" and various types of machinery and equipment). There are individual sectors devoted to "Utilities," "Construction," "Transportation," "Communications" and other service activities such as medical care, education, repairs and trade. And inputs of nine minerals, including five metals and four types of fuel, are also treated.

Long before the construction of a world model was undertaken input-output analysis had been extended into areas generally considered to be outside the network of conventional economic transactions. For example, to reach out into the area of environmental protection it is only necessary to include in the basic structural matrix of an economy additional rows of technical coefficients describing either appropriate pollution-abatement technologies or pollutants (say the amount of particulate matter released into the air by a blast furnace per ton of pig iron produced or the amount of dirty water released into a river by a steel plant per ton of steel produced). Included in the description of the economic activities of each of the 15 regions in the world model are five types of pollution-abatement activity and the emission of eight major types of pollutants.

In addition to describing the flows of current inputs to each sector of a particular region the world model describes the degree to which each sector relies on existing "stocks" of buildings, machinery, auxiliary equipment, raw materials and finished and partly finished products. Economic growth involves a rise in productive capacities in the form of appropriately proportioned additions to the various components of these types of fixed and working capital, and an input-output model such as the multiregional world model that reflects the structural relations between stocks and flows is said to be dynamic rather than static.

In a dynamic input-output model the technical structure of newly created productive capacities is specified in an auxiliary matrix called a capital-coefficient table, whose entries represent the additional stocks of capital goods that (at a given state of the technology) each sector of the economy would have to acquire in order to increase the productive capacity of its plant by one unit of output [*see illustration on page 220*]. To take these capital coefficients into account a set of input-output equations more complex than those described above is constructed. It will not be necessary to describe the nature of this system of equations here. It is important to note, however, that since the multiregional model of the world economy is a dynamic one, the introduction of new technology into industrial processes registers in it as changes in both capital coefficients and input coefficients, and so technological changes are reflected in the equations from which projections are computed.

In the system of input-output equations derived from the capital and input coefficients for the world model there are only two types of variables: those representing sectoral outputs and those representing the final demands for goods and services. Obviously there are many other factors that determine the state of the world economy at any given time, and such factors do enter into the world model, through a subsidiary set of equations that serve to compute the final demand for each commodity in the economy. Overall more than 200 variables enter into these equations, ranging from the traditional macroeconomic aggregates and demographic quantities to geological variables that describe the condition of the land and the reserves of natural resources in the 15 regions of the world model. In this way a detailed representation of the world economic system is ensured.

To create a structural input-output table for the world economy the 15 sets of coefficients describing the technical structure of the different regions in the world model are arranged (in decreasing order of the per capita income of their respective regions) along the diagonal of a large, empty matrix [*see illustration on page 222*]. Each of these individual building blocks consists of 175 rows and 275 columns: the square technical-coefficient matrix for each re-

Industry number		Livestock and livestock products	Agricultural crops	Forestry and fishery products	Agricultural, forestry and fishery services	Iron and ferroalloy ores mining
	Industry number	1	2	3	4	5
1	Livestock and livestock products	1.45776	0.04320	0.01794	0.10723	0.00131
2	Agricultural crops	.36926	1.04669	.01665	.06182	.00119
3	Forestry and fishery products	.00203	.00065	1.00493	.00363	.00067
4	Agricultural, forestry and fishery services	.05760	.04167	.02585	1.03749	.00122
5	Iron and ferroalloy ores mining	.00063	.00061	.00123	.00070	1.02225
6	Nonferrous metal ores mining	.00090	.00134	.00140	.00111	.01340
7	Coal mining	.00251	.00226	.00160	.00244	.01091
8	Crude petroleum and natural gas	.01624	.02317	.01686	.01950	.01784
9	Stone and clay mining and quarrying	.00194	.00400	.00067	.00185	.00651
10	Chemical and fertilizer mineral mining	.00118	.00284	.00041	.00093	.00049
11	Maintenance and repair construction	.02547	.02522	.00875	.02886	.05205
12	Ordnance and accessories	.00003	.00003	.00003	.00007	.00003
13	Food and kindred products	.22235	.01087	.03972	.03916	.00357
14	Tobacco manufactures	.00010	.00007	.00012	.00021	.00017
15	Broad and narrow fabrics, yarn and thread mills	.00230	.00252	.01588	.00764	.00172
16	Miscellaneous textile goods and floor coverings	.00262	.00300	.02839	.01329	.00117
17	Apparel	.00049	.00034	.00101	.00085	.00048
18	Miscellaneous fabricated textile products	.00087	.00101	.01100	.00409	.00072
19	Lumber and wood products except containers	.00463	.00479	.00523	.00778	.00726
20	Wood containers	.00172	.00375	.00026	.00488	.00011

INVERSE COEFFICIENT TABLE, derived from the technical-coefficient table for a particular economy, shows the direct and indirect relations among the various producing sectors of the economy. Each column of the matrix lists the increases in the total output of the various sectors of the economy that would be required to deliver to final users an additional unit of the output of the sector associated with that column. The interdependence of all the sectors of a developed modern economy is so great that each sector contributes if not directly then indirectly to the production of every commodity delivered to final users. Hence, as is shown in this section of the 1972 inverse coefficient table of the U.S. economy, inverse table has no zero entries.

gion is made rectangular by the addition of the coefficients corresponding to supplementary variables. The dimensions of the larger matrix are somewhat more than 15 times 175 by 275, however, so that space is provided for two additional blocks of trade coefficients, which depict the flow of goods and services among the various regions in the model. This complex linkage mechanism describes not only the exports and imports of some 40 classes of goods and services but also capital flows, aid transfers and foreign interest payments, and the precise character of the coefficients in the linkage mechanism is based on the introduction of imaginary world "trade pools" into the analysis of interregional exchanges.

More precisely, in a world input-output model although the production and consumption of those goods and services that are not involved in interregional trading must be balanced within each

$$x \quad - \quad Ax \quad = \quad y$$

$$\begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} - \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} = \begin{bmatrix} y_1 \\ y_2 \\ y_3 \end{bmatrix}$$

$$\begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} - \begin{bmatrix} a_{11}x_1 + a_{12}x_2 + a_{13}x_3 \\ a_{21}x_1 + a_{22}x_2 + a_{23}x_3 \\ a_{31}x_1 + a_{32}x_2 + a_{33}x_3 \end{bmatrix} = \begin{bmatrix} y_1 \\ y_2 \\ y_3 \end{bmatrix}$$

$$\begin{bmatrix} x_1 - a_{11}x_1 - a_{12}x_2 - a_{13}x_3 \\ x_2 - a_{21}x_1 - a_{22}x_2 - a_{23}x_3 \\ x_3 - a_{31}x_1 - a_{32}x_2 - a_{33}x_3 \end{bmatrix} = \begin{bmatrix} y_1 \\ y_2 \\ y_3 \end{bmatrix}$$

$$\begin{aligned} x_1(1-a_{11}) - a_{12}x_2 - a_{13}x_3 &= y_1 \\ x_2(1-a_{21}) - a_{22}x_2 - a_{23}x_3 &= y_2 \\ x_3(1-a_{31}) - a_{32}x_2 - a_{33}x_3 &= y_3 \end{aligned}$$

SYSTEM OF EQUATIONS (*gray block*) from which projections of future economic development can be made are constructed from the empirically determined interindustry matrix of technical coefficients (*colored block*) for the economy under consideration. The matrix equation $x - Ax = y$ expresses the necessarily balanced relations among the levels of output of all the productive sectors of the economy (listed in the column vector x) and the quantities of their respective products delivered to final users (listed in the column vector y). This balance depends on the technical-coefficient matrix for the economy A, or more precisely on the vector Ax, which describes the goods and services absorbed in the production of the outputs listed in x. Substituting the appropriate matrixes into the equation $x - Ax = y$ (here those that symbolically describe a three-sector economy) and carrying out the required matrix arithmetic gives rise to a system of linear input-output equations. Since there are more variables than equations in the system, some of the variables must be fixed before the equations can be solved simultaneously. By fixing different variables and by changing the magnitude of fixed variables it is possible to apply the equations to generate a variety of projections concerning the development of the economy.

region, just as they are in a national input-output model, the production and consumption of commodities that are transferred from region to region have to be balanced only for the world as a whole. Thus a set of equations that express the existence of such a worldwide input-output balance for each of the interregionally traded commodities must be tied into the internal commodity-balance equations of the 15 regions of the world model. The coefficients for these trade equations are derived by treating the quantity of each particular type of commodity exported from a given region as a predetermined share of the aggregate world exports of that commodity and the quantity imported into the region as a fixed proportion of the total amount consumed in that region, as if all the exports of each interregionally traded commodity were delivered to a single worldwide trading pool from which imports were then drawn.

The coefficients for the equations that secure the balance between the production and the consumption of goods throughout the worldwide system are arranged in two blocks on the world input-output matrix, one running along the right-hand side and the other running along the bottom. (The large areas of empty space off the main diagonal of the matrix that are not accounted for by these two sets of coefficients can be considered to be filled with zeros.) The entries in the block to the right of the main diagonal are export coefficients, specifying the shares assigned to the different exporting regions by the imaginary international pools through which the trade in each particular commodity flows. The entries in the block below the main diagonal are import coefficients, specifying the regional import demands for each commodity calculated as a fixed percentage of each region's total domestic requirement for that commodity. (It is interesting to note that the process of "import substitution," which often plays an important part in discussions of industrialization, can be described concisely as a reduction in the magnitude of appropriate import coefficients.)

The introduction of imaginary world-trade pools into the world input-output model precludes analysis of the bilateral, or region-to-region, transfers that actually link the 15 regions in it, but this limitation should not be viewed as a weakness of the model. Analyzing trade balances and the international division of labor that sustains them presents problems that are best excluded from the workings of the model. Employing trade pools to describe the interregional flows of goods and services allows the world input-output model to be compatible with current theory with-

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out relying unduly on the practical applicability of such theory.

As one might expect, applying input-output analysis to the world economy presents practical problems as well as theoretical ones. Assembling the thousands of numbers needed to implement the model was a formidable task. In putting together the world input-output model the bulk of the information about the technical structure of modern manufacturing, mining, transport, service industries and agriculture—the set of input coefficients for a world structural matrix—was derived from the existing tables for the developed countries, in particular the U.S. table for 1967 and the version of that table updated to 1970. The usefulness of the tables for most of the less developed countries was greatly diminished by incompatibilities in both the schemes for classifying economic activities and the conventions for the measurement of various types of transactions. On the other hand, national-income accounts, foreign-trade statistics and demographic statistics compiled by the UN and its affiliated organizations turned out to be treasure troves of systematically organized data, without which it would have been impossible to complete a base-year description of the world economy.

		Agricultural Crops	
...		...	
...		...	
...		...	
Metal cans		0	
Metal barrels, drums and pails		0	
Metal sanitation and plumbing products		0	
Nonelectrical heating equipment		0	
Fabricated structural-metal products		0.010305	
Screw-machine products and stamping		0	
Coating and plating		0	
Miscellaneous fabricated-metal products		0.004004	
Engines and turbines		0.036121	
General industrial machines and equipment		0.005974	
Machine-shop products		0	
Farm machinery		0.321164	
Construction machinery		0	
Mining machinery		0	
Oil-field machinery		0.008339	
Material-handling machinery except trucks		0.002851	
Industrial trucks and tractors		0.001907	
Metalworking machinery		0.000381	
Special-industry machinery		0.008089	
Automobiles		0.064838	
Trucks, buses, etc.		0.036630	
Aircraft and parts		0.001048	
Ship- and boatbuilding and repairs		0	
Locomotives and rail- and streetcars		0	
Cycles, trailers, etc.		0.003954	
Electric measuring instruments		0.003985	
Electric motors and generators		0.000397	
Industrial controls, etc.		0.001573	
Electric lamps and fixtures		0.000128	
Electronic components and accessories		0.000183	
Miscellaneous electrical machinery		0.000232	
Service-industry machinery		0.026472	
Household appliances		0.008185	
Radio, television and communication equipment		0.008345	
Scientific instruments, etc.		0.001059	
Medical, surgical and dental instruments		0	
Watches, clocks and parts		0	
...		...	
...		...	

CAPITAL-COEFFICIENT TABLE is employed in conjunction with technical-coefficient table to create a dynamic model of a particular economy, that is, a set of input-output equations that reflect not only the absorption of current inputs of labor, energy and various services and materials but also the creation of additional productive capacities through the acquisition of machinery, buildings and other capital goods. With the same basic format as an input-output table, a capital-coefficient matrix displays in each column the stocks of capital goods that the sector of the economy associated with that column must obtain (from the other sectors including itself) in order to increase the productive capacity of its plant by one unit. For example, the section of the 1972 capital-coefficient table for the U.S. economy shown here depicts some of the investments that would be required to increase the productive capacity of the agricultural-crops sector. The level of the investment flows specified in a capital-coefficient table for a particular economy can be tied into the economy's network of input-output flows specified in the technical-coefficient table by means of an appropriate system of input-output equations.

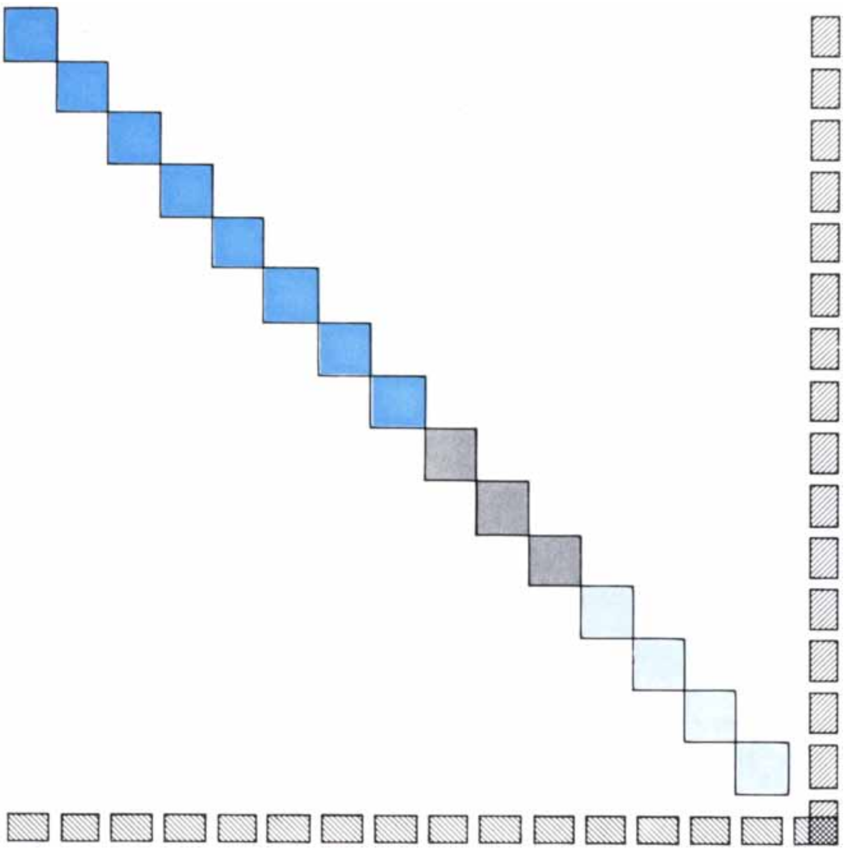
In the long run the most important aspect of economic development is probably the incorporation of technical knowledge into industrial and agricultural processes. For the developed countries this growth takes the form of the introduction of new technologies and even new commodities; for the less developed countries it generally involves the adoption or adaptation of technologies already incorporated in the industrial recipes of the more advanced countries. These transformations are reflected in the input-output structure of an economy by the continual replacement of old input and capital coefficients by new ones. In fact, since such technological transfer is closely associated with the economic advance of less developed regions (as measured by rises in their per capita income), in preparing a structural data base for implementing the world model it was also necessary to assemble series of what might be called structural templates: arrays of capital and input coefficients incorporating an increasingly advanced technology.

In the course of computing a projection, as the computer programs for implementing the world model advanced in their calculations from the base year 1970 to 1980, 1990 and finally 2000, the templates in these series were inserted one after the other into the world input-output matrix. A similar procedure was applied to estimate the prospective changes (for the most part decreases) in the magnitude of labor input coefficients resulting from the introduction of improved technology and also the prospective changes (for the most part increases) in the input and capital coefficients describing mining and other extractive industries reflecting future shifts to less accessible reserves of primary resources. Gradual changes in export shares and import coefficients were also registered in the model and played an important part in projecting the future flows of interregional trade. (In discussing changes in technical structure it is important to avoid confusing two related but essentially different notions: technology in the sense of technical knowledge and technology in the sense of such knowledge incorporated into working industrial processes. The development of the first type of technology necessarily precedes that of the second.)

The multiregional input-output model—the complex data bank and the set of linear equations describing the world economic system together with the computer programs devised to make use of them—is not a special-purpose

tool but one that, when it is provided with sufficient data, can be applied to a wide variety of tasks. In what follows I shall describe three alternative projections of world economic growth that have been carried out with the model. Each of these projections has a direct bearing on the future of the resource-poor less developed regions, which in 1970 accounted for 59 percent of the world's total population but produced only 15 percent of the total goods and services delivered to final users.

The first projection describes the development of the world economy through the year 2000 on the assumption that international economic relations will continue to be ruled by what might be called the old economic order. This is a conservative scenario in which it is assumed that the economic relations (in terms of trade, foreign aid and so on) between the developed and the less developed regions will be governed in the future as they have been in the past by financial and credit policies designed to maintain a strict balance-of-payments equilibrium for each region. More precisely, the scenario assumes that the annual difference between the total value of the goods and services exported from a particular region and the total value of those imported into it will continue to be financed exclusively by commercial borrowing in conjunction with what are currently considered normal levels of private capital transfers and governmental assistance. In other words, according to this scenario, in the future the richer, capital-exporting regions will transfer to the poorer, capital-importing ones approximately the same fraction of their national income (in the form of credits and foreign investments) that they did in the past, or before the base year 1970. Conversely, the poorer regions will have access to the same fraction of the worldwide pools of capital and aid provided by the richer regions that they did before 1970. (Since 1970 the resource-rich less developed regions have joined the developed ones in providing such funds.)



GLOBAL STRUCTURAL MATRIX, shown schematically, represents each region of the world model by a 175-by-275 matrix of technical, capital and other types of coefficients. These 15 dynamic input-output matrixes, representing the eight developed regions of the world model (*dark color*), the three resource-rich less developed regions (*gray*) and the four resource-poor less developed regions (*light color*), are arranged along the diagonal of the global matrix. The complex network of commodity flows that link these regions is represented by two blocks of trade coefficients (*hatching*), one appearing along the bottom of the global matrix and one along the right-hand side. Model of the world economy derived from this matrix includes both "domestic" equations, which secure the balance of goods and services that flow exclusively within a region, and global equations, which secure the balance of interregional imports and exports, capital flows and payments. (In global matrix empty spaces can be considered filled with zeros.)

The projection based on these conservative assumptions takes the form of a 20-page computer printout describing in detail the state of the individual regional economies in the world model as well as the relations among them. The results of the projection can nonetheless be summarized concisely. To begin with, under the old-economic-order scenario the average per capita income in each of the three main groups of regions can be expected to increase. On the other hand, the income gap between the developed regions and the resource-poor less developed ones tends to grow through 1990. Indeed, in spite of the fact that the rate of growth of the developed regions decelerates from 1990 to 2000, whereas the rate of growth of the less developed regions accelerates, by the year 2000 the difference in the incomes of the regions in the two groups is projected to be somewhat greater than it was in 1970, both in relative and in absolute terms [*see illustration on page 226*]. In fact, under the stringent but not unrealistic conditions imposed by the old-economic-order scenario some of the less developed regions of the world would face an absolute decline in their standard of living.

To what extent do these conclusions depend on the specific starting assumptions concerning future rates of population growth? The computations described above were based on the prediction that the population growth for each of the countries in the 15 world regions will follow the middle path of the three alternative paths generally projected by UN demographers, but an identical set of computations were also carried out, each one starting from a different combination of predictions about population growth in the three groups of regions. The period of 30 years from 1970 to 2000 is not long enough to allow the demographic structure of even a single region to adjust fully to the most drastic shifts in birth or death rates. Nevertheless, by studying the direction of the relatively small changes in developmental trajectories that can be distinguished in the resulting projections it is possible to make an assessment of the long-term economic repercussions of such shifts.

This set of projections demonstrates that the global per capita income obtained by averaging across the 15 regions in the world model is highest when the projected rates of population growth for both the developed regions and the two groups of less developed regions are low. The intermediate population-growth rates that were employed in computing the first projection result in a lower global income, and shifting to high population-growth rates reduces

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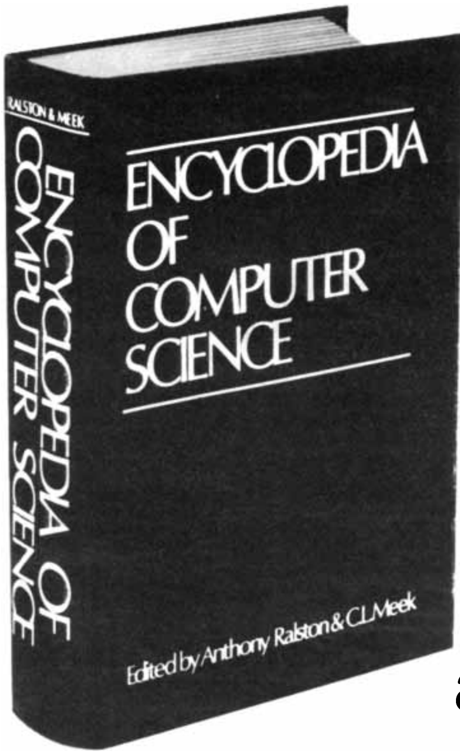

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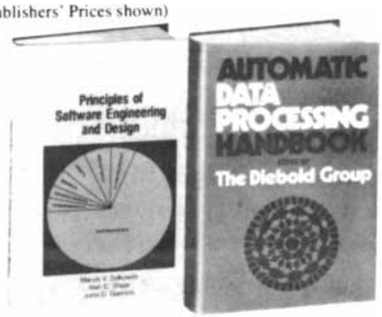

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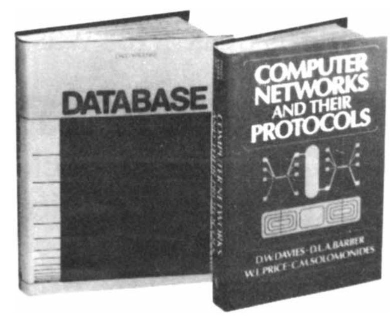

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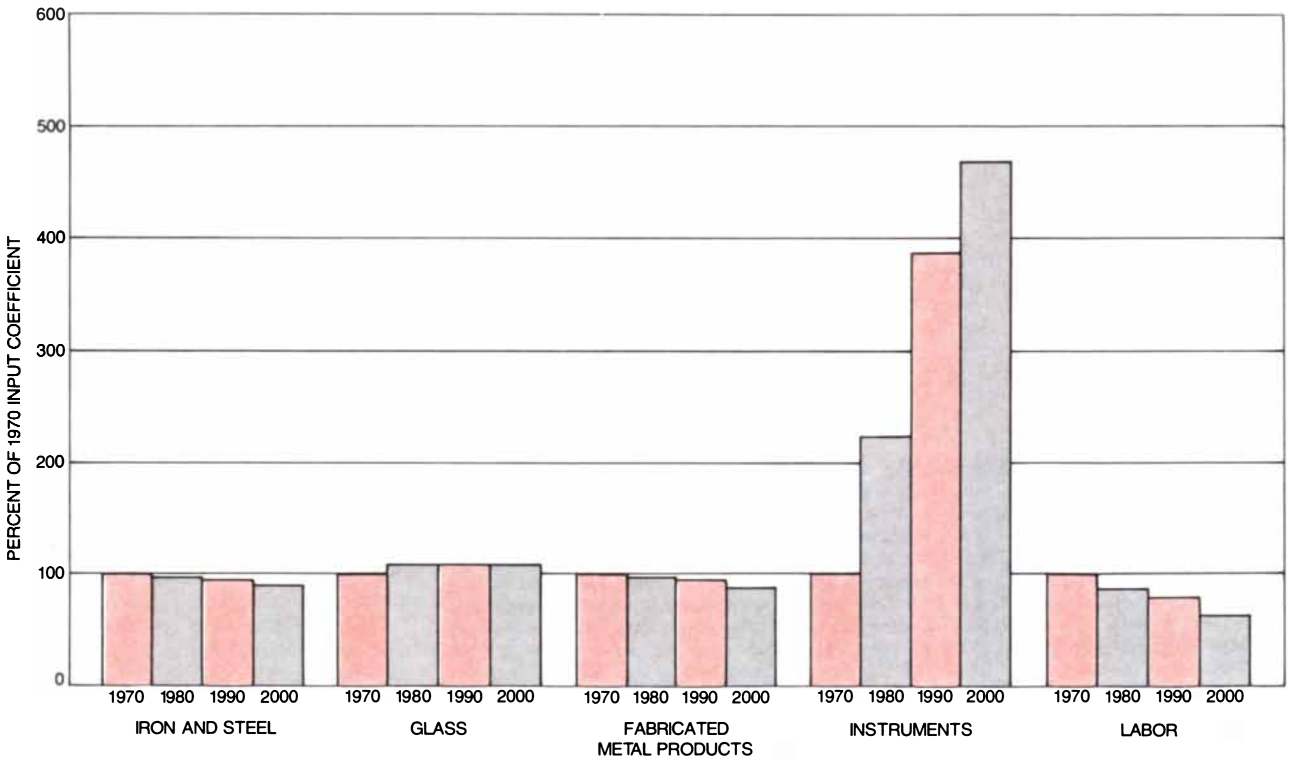
the global income still further. Moreover, if the rates of population growth in any two of the groups of regions are assumed to be constant, it can be shown that the same inverse relation between population growth and the global per capita income holds for the remaining group.

In addition, combining the resource-rich and resource-poor less developed regions into a single classification and comparing their projected growth in per capita income to that of the developed regions reveals that a shift from a low population trajectory to a high one in either of the groups invariably brings about an increase in the income of the other group. In other words, a change in the rate of population growth that has adverse effects on the economy sustaining it turns out to be quite beneficial for the other economies of the world. A plausible explanation for this phenomenon can be obtained by examining the corresponding total income figures (as opposed to the per capita ones) for the regions of the world model. An accelerated rate of population growth within a given region depresses that region's per capita income level, but it tends to raise the region's aggregate G.N.P. and total volume of external trade. This increased trade level in turn benefits the region's trading partners and increases their per capita income.

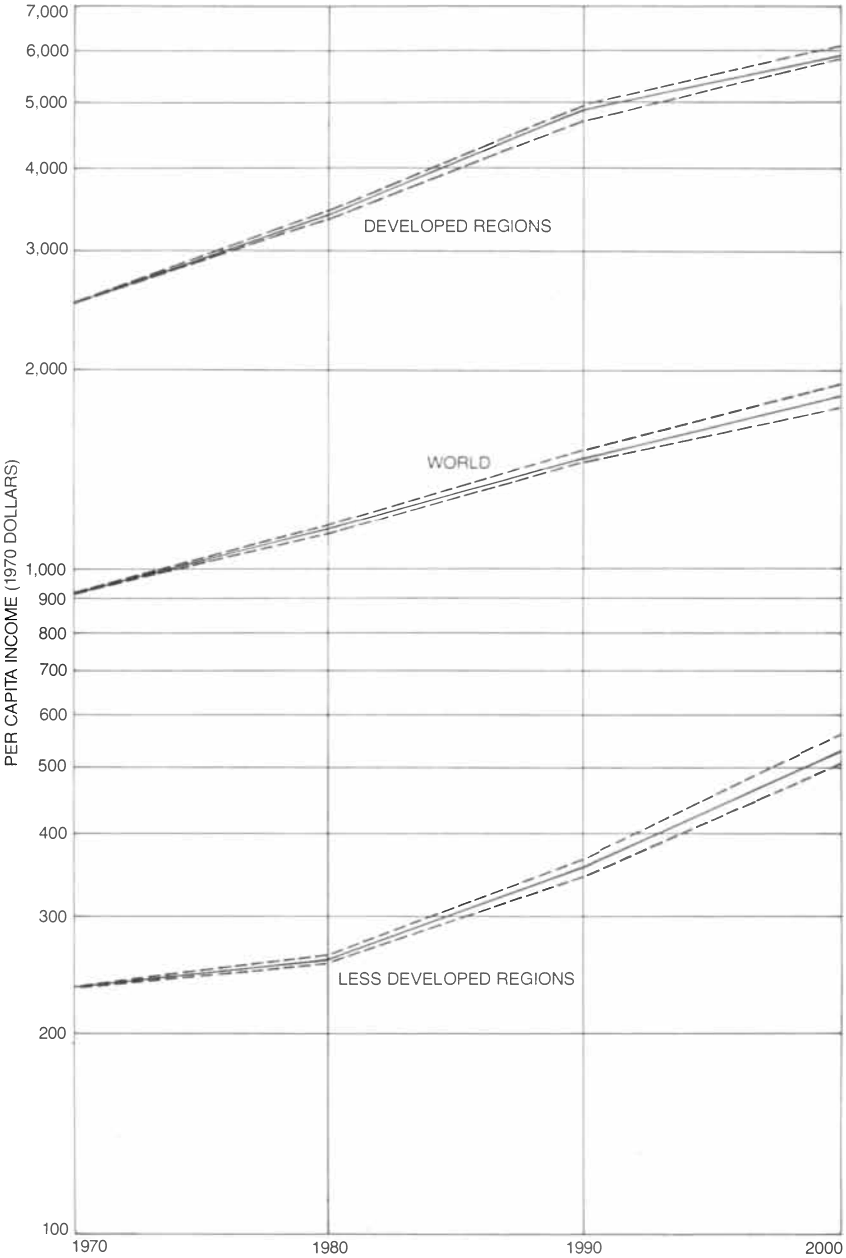
In spite of the variations in the projected income levels arising from different assumptions about the world's future population growth, the conclusions that must be drawn from the preceding projections are clear. Under the conditions imposed by the old economic order, although most of the less developed regions should advance economically and some can even be expected to develop quickly over the next decades, the gap between the developed regions and the resource-poor less developed ones can hardly be expected to diminish substantially by 2000.

There are, however, alternatives to the course of world development dictated by the old economic order. For the purposes of comparison the multiregional input-output model was also applied to prepare a projection concerning the future of the world economy under what might be called the new economic order. This is a highly optimistic scenario, which assumes that in the future the developed and resource-rich less developed regions will be willing to grant to the resource-poor less developed regions economic assistance in whatever amounts are required to reduce the income gap between the developed regions and the resource-poor less developed ones 50 percent by the year 2000. Whether this plan is politically viable, of course, has yet to be determined, but the multiregional input-output model can serve to calculate its economic implications.

To project the future of the world economy under the new economic order it was necessary to compute the changes in outputs, investments, personal and public consumption and regional imports and exports (starting from 1970 levels) that would be required from all regions of the world model to secure prespecified income targets for the resource-poor less developed regions by the year 2000. The attainment of these ambitious goals is made possible in this scenario by freeing the resource-poor less developed regions from the strict balance-of-payments requirements imposed on them under the old economic order. In other words, the quantities of goods and services imported into the poorer regions are determined by their developmental needs, not by their ability to pay for such imports. (In terms of the formal mathematical structure of



PROSPECTIVE CHANGES in technical coefficients relating to the production of automobiles in the U.S. between 1970 and the year 2000 are shown by these bars. Such significant changes, which arise from the introduction of advanced technology into the industrial and agricultural processes of an economy, play an important part in determining the economic growth of less developed regions. In order to make projections concerning future world economic development it was necessary to construct a series of arrays of capital, input and other types of coefficients incorporating increasingly advanced technology. These were inserted into the global structural matrix as the computer programs for implementing the world model moved in their computations from base year 1970 to 1980, 1990 and finally 2000.



PROJECTED GROWTH IN PER CAPITA INCOME for the developed regions, the less developed regions and the world as a whole is shown in this graph. (The vertical scale is logarithmic, so that curves with equal slopes represent equal percentage rates of growth.) Here the multiregional input-output model of the world economy was applied to the projection of future income levels under a set of conditions that can be called the old economic order. This scenario for world development assumes that economic relations between the developed and the less developed regions will continue to be governed by current strict policies concerning credit and balance of payments. The scenario also assumes that in the future the richer, capital-exporting regions of the world will transfer to the poorer ones approximately the same fraction of their national income (in the form of credits and foreign investments) that they did before 1970. The solid lines show the projections for this scenario based on the intermediate United Nations estimates of world population growth, in which between 1970 and 2000 the population of the developed regions is expected to grow from 1.108 billion to 1.435 billion and the population of the less developed regions from 2.512 billion to 4.813 billion. The set of projections demonstrates that with this conservative scenario in the year 2000 the gap in income between the developed regions and the less developed regions should be somewhat greater than it was in 1970, both in relative and in absolute terms. The broken lines show the corresponding projections based on the most extreme estimates of population growth for the developed regions and the less developed regions, demonstrating that assumptions about future population levels have little effect on the outcome of the old-economic-order scenario over this period of time.

the world model this means that some of the model's input-output equations, namely those expressing the strict balance-of-payments regulations, must be declared invalid and dropped from the system. On the other hand, fixing the future income levels of the resource-poor less developed regions reduces the number of unknown variables in the system. In fact, if no equations were dropped, the system would be overdetermined, that is, the number of equations would exceed the number of remaining variables, and no solution would be possible.)

To provide a quantitative measure of the amount of assistance the resource-poor less developed regions would have to receive year after year under the new economic order it was also assumed in the formulation of this scenario that the import surpluses, or equivalently the balance-of-payments deficits, of those less developed regions would be financed each year by extraordinary credits granted by the developed and resource-rich less developed regions: credits carrying a nominal annual interest rate of 5 percent on accumulated debts. The projected volume of such extraordinary noncommercial borrowing (or lending, if it is viewed from the vantage of the developed and resource-rich less developed regions) provides a measure of the cost of implementing the new-economic-order scenario.

The projection based on the new set of assumptions shows that since the developed regions would be required to work overtime in order to be able to provide the huge amounts of economic aid that would be required under this scenario, their G.N.P. would be somewhat larger in 2000 than it would be under the old economic order, but since a larger part of their total output would have to be exported, their per capita consumption of commodities would be slightly lower. (In general, the shift from the first scenario to the second has a smaller effect on the developed regions than it does on the less developed ones; after all, if one region has a total income of $1 billion and another has a total income of only $100 million, then a transfer of $50 million from the first to the second represents a 50 percent gain for the poorer country but only a 5 percent loss for the richer one.)

The projection also reveals that the massive developmental drive envisioned under the new economic order would call for the financing of an increasingly large part of the steadily growing imports of the resource-poor less developed regions by means of extraordinary loans. By the year 2000 the exports from these regions would pay for only 25 percent of their annual imports, and the other 75 percent would have to be obtained on credit. Indeed, by

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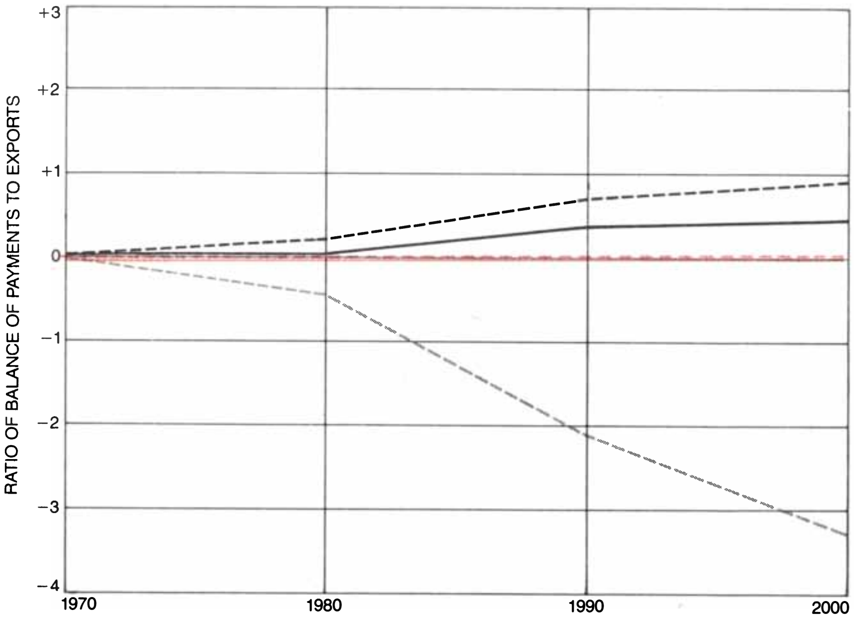
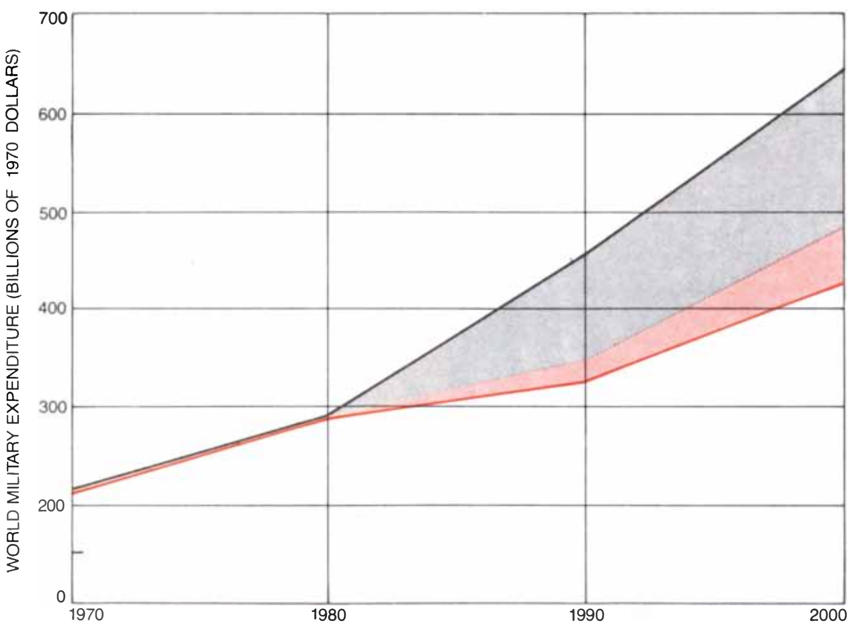
THE DIAL: The guide to public tv



RATIO OF BALANCE OF PAYMENTS TO EXPORTS is projected for the developed regions (*light color*), the resource-rich less developed regions (*black*) and the resource-poor less developed regions (*gray*) under two sets of assumptions about future world economic relations: the old-economic-order scenario (*solid lines*) and the new-economic-order scenario (*broken lines*). The new-economic-order scenario assumes that in the future the developed and resource-rich less developed regions of the world will be willing to allocate to developmental assistance whatever resources are required to reduce the income gap between the developed and the resource-poor less developed regions 50 percent by the year 2000. To make this goal attainable it is also assumed that the resource-poor less developed regions will be allowed to expand their imports as much as is needed to maintain their specified income targets, so that they will be released from the strict balance-of-payments requirements imposed on them under the old economic order. The steep decline in the curve representing the resulting ratio of the balance of payments to exports for the resource-poor less developed regions provides a measure of the cost of implementing the new economic order for the other regions of the world model.



ARMS-LIMITATION SCENARIO assumes that in the year 2000 the total world expenditure for the maintenance of military establishments (*colored line*) will be 35 percent less than it is projected to be under the old-economic-order scenario (*black line*). As is shown here, it is also assumed that the bulk of the resources made available by the limitation of military spending (*gray*) will be allocated to increase civilian domestic consumption and investment in the regions where they originated, mainly the developed ones. The remaining resources (*color*) would be allocated to increase nonmilitary foreign aid, mainly to the resource-poor less developed regions.

2000 it would be necessary for the developed regions to allocate 3.1 percent of their total G.N.P. to support such an effort. (The current figure is less than 1 percent.) On the whole this projection of the future development of the world economy under the new economic order suggests that the practical possibility of carrying out such an optimistic program must be seriously questioned.

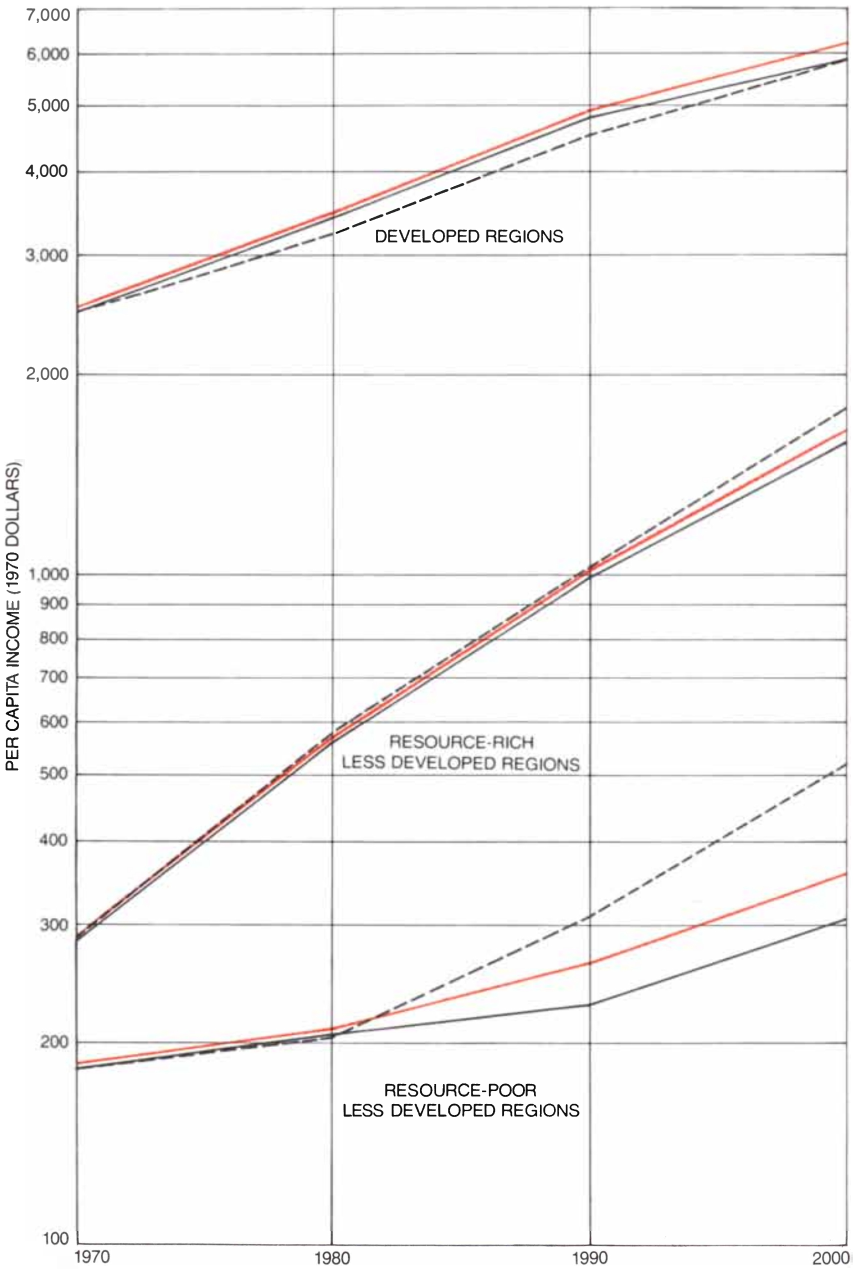
The last projection made with the multiregional input-output model of the world economy I shall discuss here is based on what might be called the arms-limitation scenario. The more than $450 billion per year currently spent on the maintenance of military establishments throughout the world (which is equivalent to $290 billion at the much lower 1970 prices) is the largest existing economic reserve that might be utilized to accelerate the growth of the resource-poor less developed regions. In addition some of the funds that would be made available by an international agreement to limit military spending could well serve to bring about marked improvement in the economic position of the lower-income groups within the developed regions.

The arms-limitation scenario specifies a hypothetical reduction in future military spending to levels below those that can be expected under the old economic order. According to the old-economic-order scenario, in the future all the regions of the world model will devote to military purposes the same fraction of their respective regional incomes that they did in 1970. Moreover, under this scenario a provision is made for the maintenance of parity in military spending between the U.S.S.R. and the U.S. (For strategic reasons the amounts allocated to military needs by the U.S.S.R. and the U.S. tend always to be about equal. At present, however, the national income of the U.S.S.R. is only slightly more than half that of the U.S., so that it devotes nearly twice as large a percentage of its income to military spending. On the other hand, according to most projections, the Russian economy will grow somewhat faster than the U.S. economy up to the year 2000, so that as long as military parity is maintained the difference between those two percentages will gradually decrease.)

For the purposes of the arms-limitation projection it was assumed that by the year 2000 the combined military expenditures of the U.S.S.R. and the U.S. will be reduced to two-thirds of the level they are projected to reach under the old-economic-order scenario. It was also assumed that all the other regions of the world model will cut their military spending 25 percent by the year 1990 and 40 percent by the year 2000. The arms-limitation scenario specifies that the "savings" realized in each region from the cuts will go first of all to the satisfaction of its own civilian needs but that by 1990 the developed regions will allocate 15 percent of the savings to developmental aid and that by 2000 they will allocate 25 percent. The redistribution of these savings, which gives rise to changes in the levels of production, consumption and investment for each sector in the world model with corresponding changes in the interregional commodity flows, is determined by the sets of technical and other structural parameters incorporated into the input-output model of the world economy.

An idea of the advantages of the arms-limitation scenario for world economic development can be gained by comparing the aggregate results of the projection based on these assumptions with the projections describing the world economy under the old economic order and the new [*see illustration at right*]. To begin with, given the developmental assistance provided under the arms-limitation scenario both the per capita income and the per capita consumption of the resource-poor less developed regions can be expected to increase far quicker than they would under the old economic order. (In the new-economic-order scenario such growth is of course fixed from outside the system.) In addition under the arms-limitation scenario, which provides for assistance to the resource-poor less developed regions in the form of direct aid, the projected trade deficit of those regions is smaller than it would be under the old economic order and naturally much smaller than it would be under the new one. Finally, since the arms-limitation scenario specifies that part of the savings resulting from reduced military spending must go to increasing civilian consumption and investment in the developed regions, the projected levels of per capita income of those regions are higher with this scenario than they are with either of the others. Therefore a comparison of the three sets of projections made with the multiregional input-output model of the world economy clearly indicates that the reallocation of economic resources arising from the kind of international arms-limitation agreement that has been suggested repeatedly, both formally and informally by individuals and organizations inside and outside the UN, is by far the most promising of the three schemes for world economic development.

Analysis of the kind that I have described here, dealing with the general prospects for development in the world economy, must of necessity draw pictures with only a few bold strokes, relying on aggregate figures such as average per capita incomes or net balances of payments to describe the economies of regions with hundreds of millions of people. The economic projections for these large regions and the factual data on which they were based, however, comprise tens of thousands of numbers describing the structure and the specific states of the world system in detail. Thus the construction of a multiregional input-output model of the world economy to some extent rescues economists from their traditional dilemma of having to choose between seeing the forest or seeing the trees. The model, which can describe the entire forest in terms of the individual trees (or at least in terms of the specified structural relations between small groves), serves as a valuable tool for tracing possible economic paths through the future.



PROJECTED ECONOMIC DEVELOPMENT of the developed regions of the world, the resource-poor less developed regions and the resource-rich less developed regions is shown to the year 2000 under the old-economic-order scenario (*solid black lines*), the new-economic-order scenario (*broken black lines*) and the arms-limitation scenario (*colored lines*). For the resource-poor less developed regions the levels of per capita income and consumption (not shown) grow much faster under the arms-limitation scenario than under the old-economic-order scenario, but not so fast as under new-economic-order scenario, where income targets are prespecified.

THE AMATEUR SCIENTIST

Billows in the ionosphere are tracked with transistor radios

by Jearl Walker

This month I shall describe an inexpensive apparatus designed by Douglas A. Kohl of Osseo, Minn., for the detection of gravity waves traveling through the ionosphere: the ion-rich layers of the earth's upper atmosphere. Although the waves are not fully understood, they are thought to be generated by such phenomena as the jet stream, severe thunderstorms and bombardment by solar particles. (They should not be confused with the gravitational waves that figure in general relativity and cosmology.) The waves travel more or less horizontally through the upper atmosphere, modifying the concentration of molecules and atoms. Therefore they also modify the concentration of ions, creating a traveling disturbance that causes variations in the reflection of radio signals by the ionosphere. Kohl monitors such variations and thereby detects the passage of the gravity waves.

The ionosphere is transparent to radio signals with frequencies higher than about three megahertz. The signals of the television and frequency-modulation (FM) radio bands have a higher frequency, and so they travel direct through the ionosphere. The signals of the amplitude-modulation (AM) radio bands have a lower frequency, and so they are reflected by the bottom of the ionosphere. For this reason gravity waves are normally detected by variations in the reflection of such lower-frequency radio signals.

Generating your own radio waves would be expensive and would also call for permission from the Federal Communications Commission. Kohl therefore relies on the signal broadcast by a local AM radio station. He suggests choosing a station that is within 30 miles of you and operates at full power 24 hours a day. Part of the signal broadcast by the station travels direct to the detector and another part travels to the ionosphere and then to the detector. The first objective of the apparatus designed by Kohl is to eliminate the direct signal so that only the signal from the ionosphere is detected.

The detector consists of a modified transistor radio with a ferrite-core antenna. The antenna is oriented until the reflected signal from the radio station is at its maximum. This optimum orientation is usually both horizontal to and perpendicular to a line between the receiver and the transmitting antenna. The orientation is necessary because the radio signal is polarized: its electric and magnetic fields oscillate along particular axes. When the electrons in the transmitting antenna oscillate, they radiate electromagnetic waves at the AM radio frequency. The wave traveling direct to the receiver has electric fields oscillating along a vertical axis and magnetic fields oscillating along a horizontal axis. Both sets of oscillations are perpendicular to the line along which the wave is traveling. This line is called a ray. The ferrite-core antenna of the radio responds to oscillations of the magnetic field, so that when it is receiving the incoming magnetic fields of the radio wave most efficiently, it is parallel to them. Hence it is horizontal and perpendicular to the ray. (The standard automobile antenna responds to oscillations not of magnetic fields but of electric fields, so that it receives AM signals most efficiently when it is vertical, which of course it usually is.)

Kohl eliminates the direct signal from the transmitter by moving the antenna of his radio until the signal from the station is at its minimum. The antenna could be horizontal and pointed in the direction of the transmitter, or it could be vertical. It receives little of the direct signal in either orientation, but it can still receive the radio signal reflected from the ionosphere because it is partially aligned with the magnetic fields in that signal.

Many disturbances of the ions in the ionosphere arise in the lower part of the ionosphere; they include long-period waves, variations in the chemistry of the ions and variations in the concentration of the ions because of a meteor shower. Kohl wanted to detect the disturbances due to gravity waves that last for a few hours. The passage of a gravity wave through the reflective layer shifts the altitude at which radio signals are reflected and thereby changes the strength of the response in the receiving antenna. When the altitude of the point of reflection increases, the response of a horizontal antenna increases because the magnetic fields of the reflected signal are better aligned with the antenna; the response of a vertical antenna drops because the fields are less well aligned.

I shall first describe how to build a detector that will monitor the gravity wave. Then I shall describe how the system can be improved by adding more radio sets so that additional features of the gravity wave can be detected. Kohl says you should choose a portable AM transistor radio that has a ferrite-core antenna at least six inches long. The longer the antenna is, the better your results will be.

If you intend to make measurements at night, the radio should also have a tuned radio-frequency stage so that it has enough selectivity to prevent interference from long-distance radio signals. Radio signals can be detected over much greater distances at night. When the sun sets, there is no longer sunlight to ionize atoms and molecules at the bottom of the ionosphere. As a result the number of ions decreases and the altitude at which the radio signal is reflected rises. This additional altitude of reflection means that a powerful radio signal can travel farther along the curvature of the earth.

Most portable AM transistor radios have the circuitry outlined in the top illustration on page 236. The circuit is first modified by cutting the connection at the place indicated on the diagram by an *x* and a *y* so that the automatic gain control can be converted to manual control. The cut is made next to the volume control of the radio. An additional circuit is inserted at that point to provide manual control for recording the signal reflected from the ionosphere. The weak-sensitivity section of the inserted circuit is necessary to restore the radio's sensitivity to weak stations. If the radio has *n-p-n* transistors instead of the *p-n-p* ones assumed in the diagram, the battery connection will be to the positive terminal rather than to the negative one. The polarity of the meter, the recorder and the "zero adjustment" I shall describe will have to be reversed for this type of radio.

The output signal from the manual gain control is amplified and filtered by the circuit shown in the bottom illustration on page 236. The low-pass filter eliminates the modulation of the voice and the music of the radio signal, since

SCIENCE/SCOPE

Water levels in cooling systems of nuclear reactors may be monitored more reliably, especially during an emergency core shutdown, by an innovative metal-coated optical fiber developed by Hughes. The thin glass thread, some 1000 of which would be placed around a reactor's core, is tipped with a sapphire retro-reflector. Unlike plastic-coated fibers, it can withstand the harsh reactor environment of temperatures as high as 350°C and pressures up to 1800 pounds per square inch. Compared to resistive level sensors now in use, the fiber is a model of simplicity. The sapphire tip, when dry, reflects light transmitted through the fiber; when wet, it reflects no light. Prototype sensors were developed under Nuclear Regulatory Commission sponsorship.

Doctors can look into the human body more clearly, quickly, and far more safely than ever before by using a new x-ray process called computed axial tomography. The process, considered by many in the medical profession to be as significant as the discovery of x-rays themselves, employs a sophisticated scanner to create x-ray pictures of one plane of the body. One benefit is that doctors have more detailed views of bones and organs. Also, because the scanner contains extremely sensitive photodetectors, patients receive much smaller doses of radiation. Hughes photodiodes with high responsivity and very low noise levels are used in these instruments to detect scintillations produced by the x-rays.

An experimental satellite earth station being built in Brazil will use a new communications power amplifier subsystem developed by Hughes. The subsystem will be used in conjunction with Brazil's domestic satellite system and the Intelsat IV-A system to transmit voice, television, and data signals. It consists of two 400-watt high-power amplifiers and an automatic switching and power combining unit to facilitate up to 700 watts of output power in the 5.9 to 6.4 GHz satellite uplink band. The unit was delivered recently to the Telebras organization in Campinas, Sao Paulo.

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A traveling-wave tube newly introduced for use in satellite earth terminal transmitters is capable of more than 250 watts of CW power in the 14.0 to 14.5 GHz frequency range. The device is a metal-ceramic tube with PPM focusing and forced-air cooling. A modulating anode allows beam current to be turned on and off quickly during normal operating sequencing and under fault conditions. Internal programming assures a proper TWT/power supply interface and simplifies field maintenance. The TWT is designated Hughes Model 881H.

Creating a new world with electronics

HUGHES

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you are interested only in the strength of the signal reflected from the ionosphere. The filter also eliminates any short-term clicks, pops and manmade interference caused by light switches, automobile ignitions and the like.

The filter does pass the variations in the strength of the reflected signal that materialize over several minutes. These variations, which emerge at the point labeled "Signal channel," are indicated on a strip-chart recorder connected to the other end of the low-pass filter. Kohl found that a recording speed of one inch per hour is sufficient, and so it is possible to use an inkless strip-chart recorder. The recorder should be rated at one milliampere of direct current. Since the recorder is meant to have a slow response to the radio signal, a meter ("Fast-signal meter") is installed ahead of the low-pass filter to indicate faster variations in the signal strength. This faster response enables the experimenter to adjust the gain controls as he is setting up the apparatus. The meter should also be rated at one milliampere of direct current.

Besides keeping track of the periodic variations indicated on the strip-chart recorder Kohl also monitors the "noise" of the ionosphere with another circuit connected beyond the low-pass filter. This circuit measures the frequency (in times per minute) with which the signal reverses polarity. Each time the strength of the signal crosses a predetermined base line an impulse is sent to the count-rate circuit. For example, if the ionosphere is relatively noisy, the signal strength may oscillate fairly rapidly around an average value several times per minute. This rapid variation will be counted. At quieter times the oscillation of the signal strength will be lower. The output of the count-rate circuit is sent through a filter and then through the "noise channel" to another strip-chart recorder of the same type as the one recording the strength of the signal.

Kohl employs the power-supply circuit shown in the illustration on page 238 to power all the circuits including the radio. Unless the radio has an unusually high current requirement the heat-sink tabs on the voltage regulators (LM 340T-8 and LM 320T-8) will not need to be mounted on heat sinks. Kohl warns against eliminating the .1-microfarad capacitors in this circuit. If they are left out, the rectifiers will interfere with the radio.

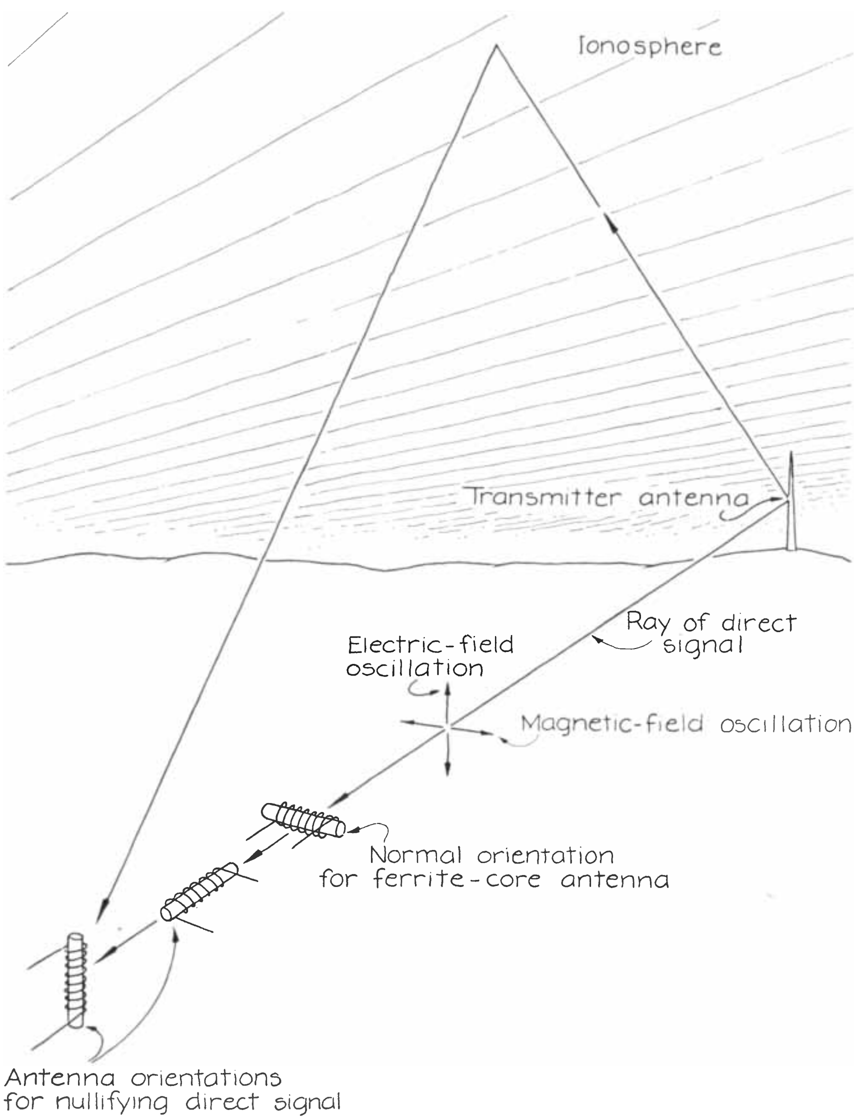
Once you are ready to monitor the ionosphere you begin by tuning the radio to a distant, weak station. (All the circuit modifications leave the audio part of the radio unaltered.) With the antenna horizontal adjust the weak-sensitivity control to maximize the sound from the station. That control is now set for the rest of the experiment.

Tune the radio to the local station you have chosen for the experiment. Rotate the antenna about a vertical axis until the sound level is at a minimum. (You may have to rotate the radio too if the antenna is firmly attached to the case.) Adjust the gain until the needle on the fast-signal meter is at about half scale. Check the antenna to be certain it is at the optimum orientation for the minimum sound level. If it is, the needle on the fast-signal meter should be fluctuating slowly and the sound on the radio should have varying amounts of distortion. What you are listening to is the radio signal reflected from the ionosphere.

If the detector is surrounded by a good deal of metal, as it would be in an office building or an apartment house, you may have difficulty eliminating the direct signal from the transmitter. Try different locations until you find a suitable one. You can determine the suitability of the location by watching the fast-signal meter. If the nullification of the direct signal is adequate, the needle on the meter will fluctuate steadily. The low-pass filter smooths these rapid changes so that the strip-chart recorder on the signal-channel output responds to slower variations in signal strength. It takes about five minutes for the recorder to trace out a change in the signal strength. The noise channel requires no adjustment.

A sinusoidal trace on the signal-channel output implies that a gravity wave is passing through the region where the radio signal is being reflected. According to Kohl, the pattern emerges out of small and seemingly random changes in the display on the recorder. The time between crests on the trace may be from five to 40 minutes, but usually it ranges from 15 to 25 minutes.

One shortcoming of the basic receiver



The principles of Douglas A. Kohl's detection system

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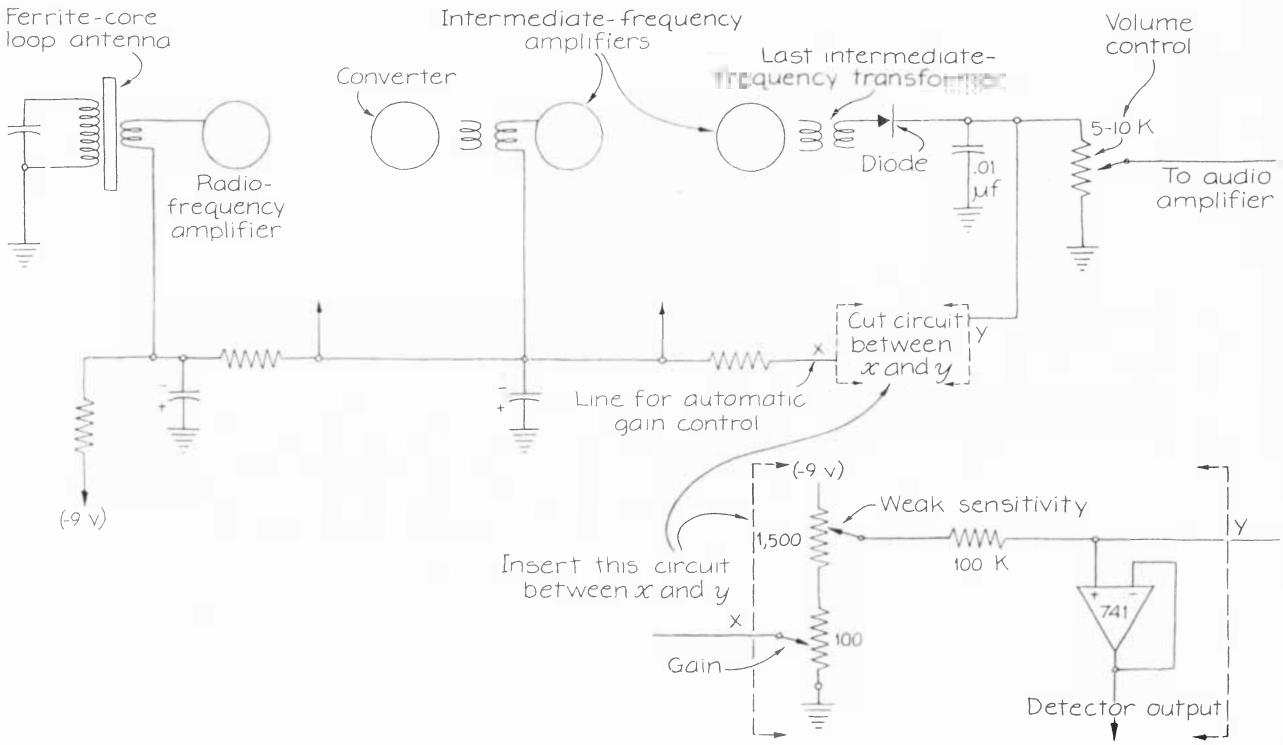
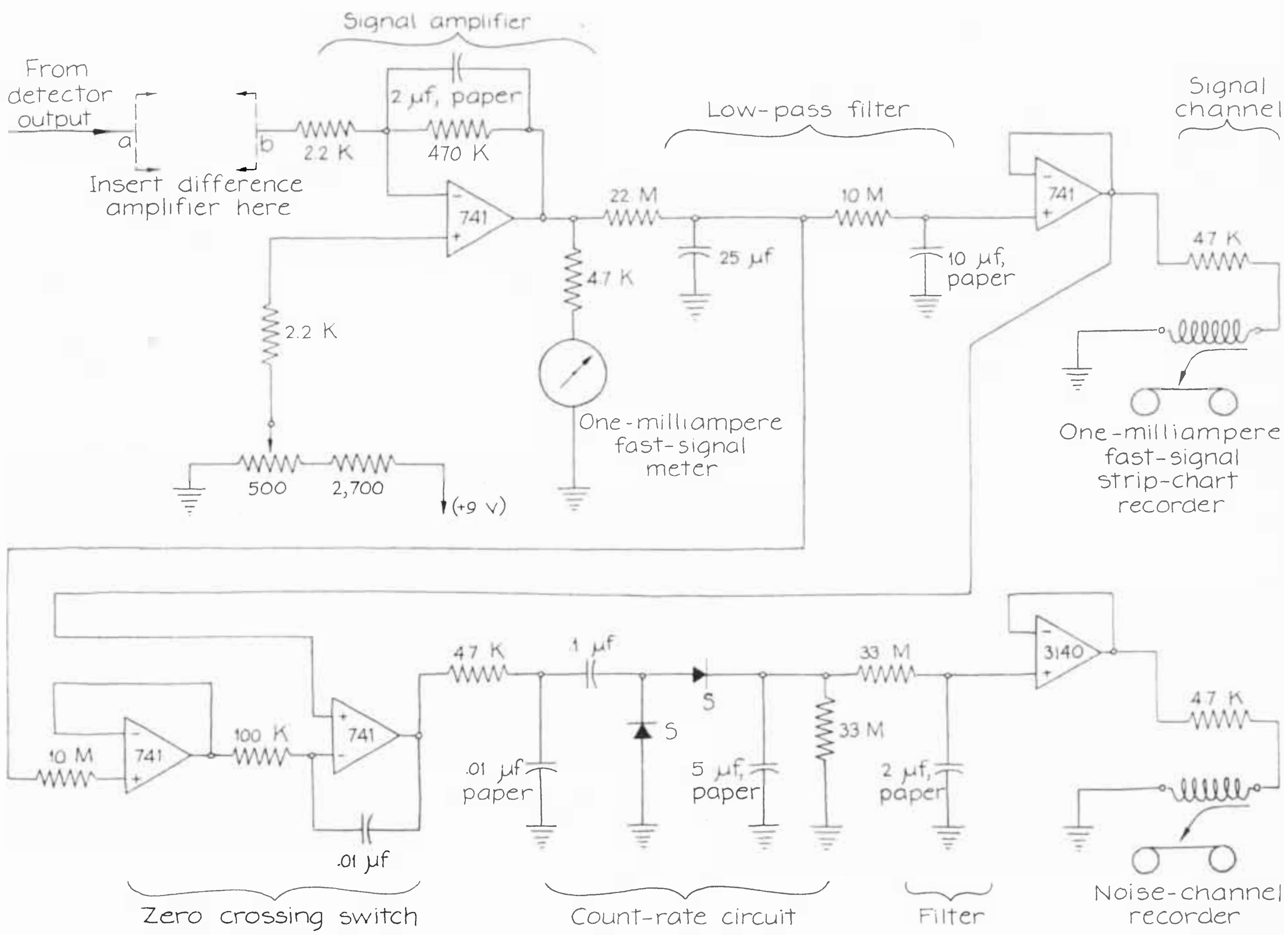


How Kohl modifies a transistor radio



The arrangement for obtaining the output of the signal channel and the "noise" channel

system is that it responds to interference from many sources, such as fluorescent lamps and strokes of lightning. To eliminate the interference Kohl sets up another detector system near the first one. The antennas of the two receivers are approximately parallel but the second antenna is tuned to a frequency that is different by about 100 kilohertz (but a frequency not used by a local radio station). The electrical signal in one antenna therefore does not stimulate a response in the other.

The first receiver still responds to the signal reflected from the ionosphere and to interference from other sources. The second set responds only to the interference. The outputs from the two sets are run through a difference amplifier, for which the circuitry is given in the third illustration from the top on page 240. The amplifier provides only the difference in the two signals from the receivers. As a result the final output lacks the interference signal and contains only the signal reflected from the ionosphere.

With two additional sets one can measure the altitude at which the signal was reflected in the ionosphere. The sets are identical with the first two except that their antennas are vertical. In a horizontal antenna the reflected signal induces a response proportional to the sine of the angle between the horizontal and the ray coming from the ionosphere. The response in the vertical antenna is proportional to the cosine of the angle. The tangent of the angle can be calculated by finding the ratio of the response in the horizontal antenna to the response in the vertical antenna. (The receivers should be identical or the ratio will be off.)

The ray being received left the transmitting antenna at roughly the same angle with respect to the horizontal. Calculate the altitude of the reflecting layer by estimating the horizontal distance to the transmitting antenna (on the assumption that between the detector and the transmitter the earth is flat). The altitude of the reflecting layer of the ionosphere is half the distance to the transmitter multiplied by the tangent of the angle.

The altitude of the reflection depends on the frequency of the radio signal. The higher the frequency, the greater the altitude at which the signal is reflected. One can monitor the gravity wave at two different altitudes in the ionosphere by tuning two basic receiver systems to two different frequencies. Each system has one radio receiver to monitor the reflected signal at the chosen frequency and another receiver for the purpose of eliminating the environmental interference. Kohl recommends working with the signals from two local radio stations that are in approximately the same direction from the apparatus. One receiver should operate at a frequency near

1,500 kilohertz, the other at one close to 600.

If the gravity-wave tracings are similar on the two sets, the wave extends over a rather large vertical distance. Dissimilar tracings would imply that the gravity wave was propagating through a relatively narrow layer. To do the experiment thoroughly you need eight radios, four operating at each end of the AM band. Two of each four have horizontal antennas. One set is tuned to a local station and the other acts merely as a receiver for the interference so that the interference can be eliminated. The other two radios in each set of four serve in the same way except that their antennas are vertical. By finding a ratio of the responses from the vertical antennas to those from the horizontal antennas the experimenter can determine the altitude at which the radio signal was reflected. The same kind of calculation can be made at the other end of the AM band. You will find that radio signals at different frequencies reflect at different altitudes.

The frequency dependence of the reflection is related to the way a radio wave is reflected by the ionosphere. The radio signal is composed of oscillating electric and magnetic fields, which interact with the ions. The primary interaction is through the electric fields, and so I shall ignore the magnetic ones. I shall also consider the radio wave to be linearly polarized, so that the electric fields oscillate along a single axis perpendicular to the ray of the radio signal. When the radio wave sweeps past the free electrons at these altitudes, its electric fields create an electric force on the electrons, causing them to share the axis of oscillation of the electric fields. (The motion of the heavier ions can be ignored; since their mass is larger, their oscillations are much smaller.) In the usual model of the interaction of radio waves and electrons the radio wave is said to be absorbed by the electrons and then reradiated by their oscillation. Unless the reradiated wave is reflected it travels in the same direction as the incident wave and appears to be a continuation of that wave.

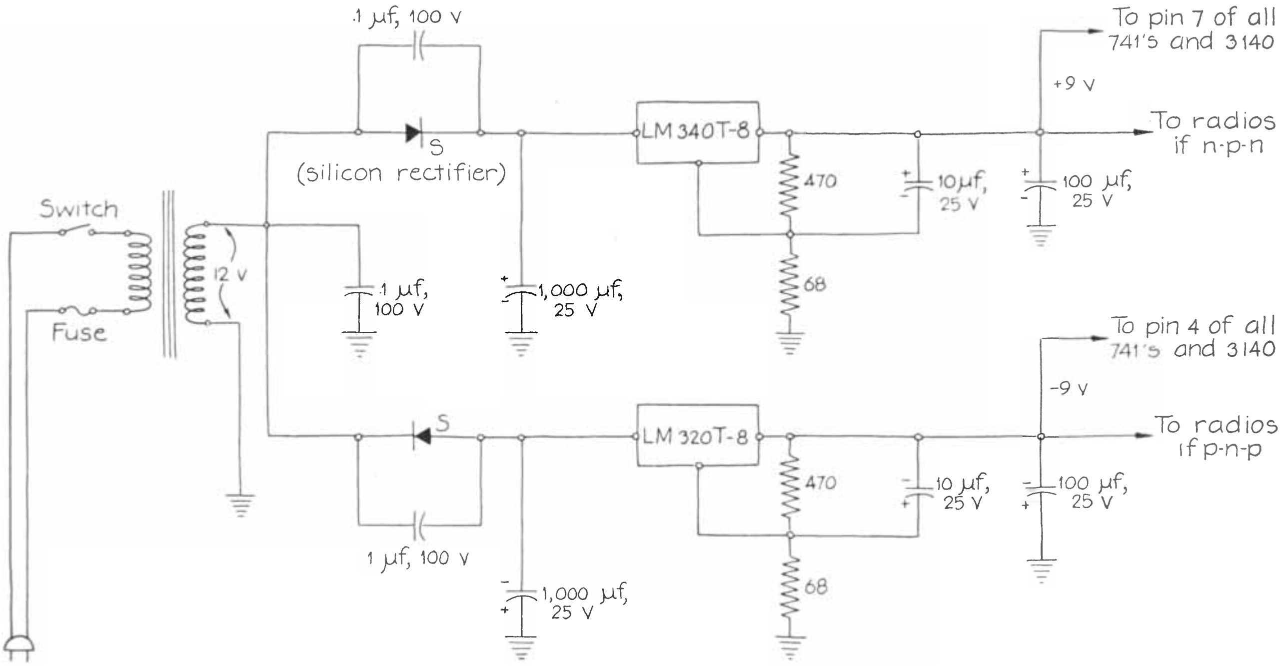
The electrons' frequency of oscillation is called the plasma frequency. If the frequency of the radio signal is higher than the plasma frequency, the signal continues to travel through the ion layer. If the radio frequency is lower than that critical value, it penetrates only a few centimeters and then is reflected. The plasma frequency in the ionosphere is approximately three megahertz; its actual value depends on the concentration of electrons. The greater the concentration, the higher the plasma frequency. At the bottom of the ionosphere the concentration of electrons increases with altitude. Hence a radio signal propagates upward through the ionosphere until it reaches an electron concentration large enough to reflect it. If the signal does not encounter such a concentration, it simply propagates through the ionosphere and out into space.

A radio signal at the low-frequency end of the AM band reflects from a relatively low point in the ionosphere. A signal at the other end of the band must travel higher before it is reflected. Kohl employs this relation to sample the effects of gravity waves at the two altitudes of reflection.

As I have mentioned, in one of Kohl's setups he nullifies the direct signal from the transmitting antenna by means of a vertical receiving antenna that does not respond to the horizontally oscillating magnetic fields in the linearly polarized signal. If the signal reflected from the ionosphere were likewise linearly polarized with its magnetic fields oscillating horizontally, it too would not generate a response in the antenna. Fortunately the polarization of the signal is altered by the reflection in such a way that it can generate a response. When electrons in the ionosphere are set in motion by the oscillating electric fields of the radio wave, they are also affected by a magnetic force resulting from the presence of the earth's magnetic field. The magnetic force comes into play only when the electrons have velocity, so that the force does not operate until the radio wave arrives. The magnetic force makes the charges circle the ray of the radio signal.

The interaction of the electric fields of the radio wave, the earth's magnetic field and the motion of the electrons is usually handled mathematically by imagining that the radio wave consists of two waves traveling in the same direction. Neither wave has the linear polarization of the wave from the transmitting antenna, but the two together mathematically give rise to it. The advantage in splitting the wave into two parts is that the polarization of the reflected wave is easier to explain.

The two imaginary radio waves are



The power circuit of the apparatus

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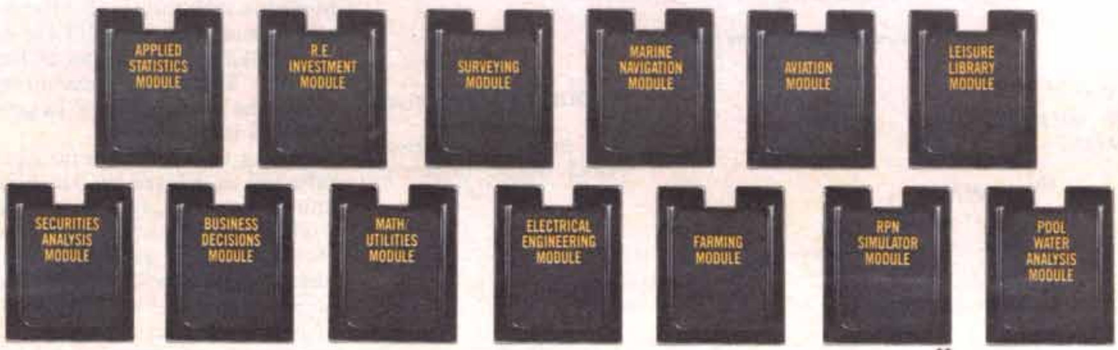

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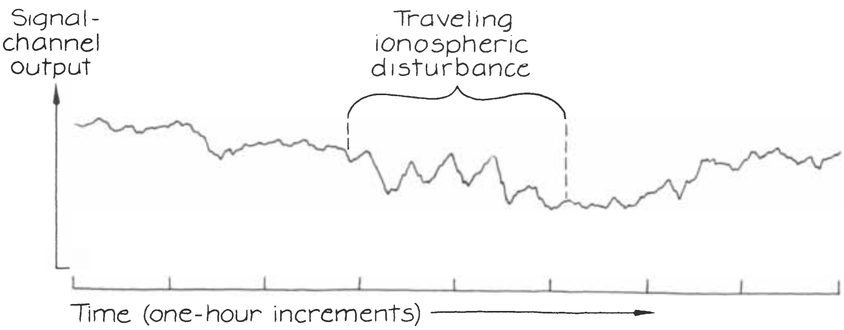
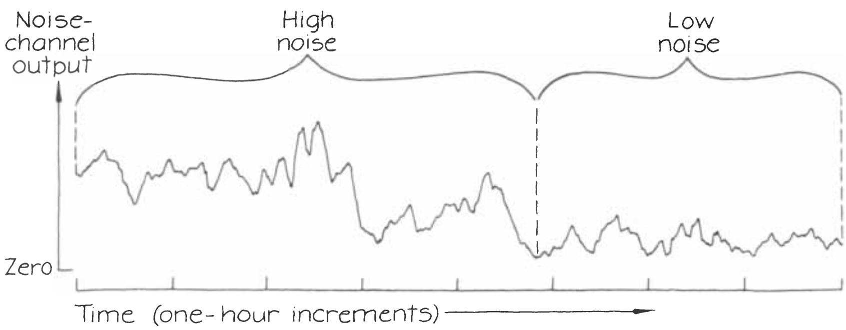
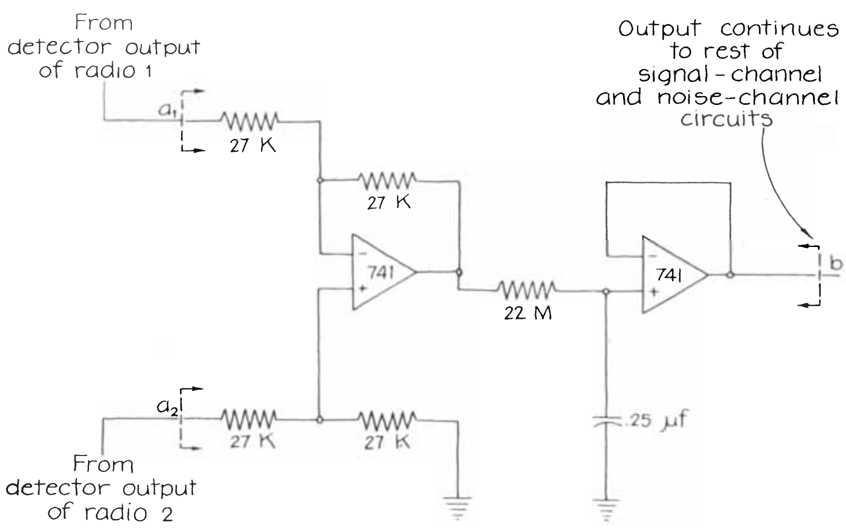


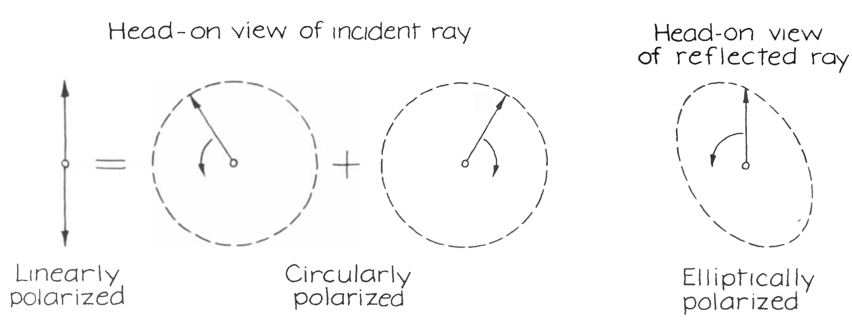
How a traveling ionospheric disturbance is represented on a strip-chart recorder



A trace from the noise channel



The circuitry of the difference amplifier for eliminating local interference



A change of polarization of a radio wave as a result of ionospheric reflection

polarized not linearly but circularly. The axis of polarization of one wave rotates about the ray of the radio signal in one direction, and the axis of polarization of the other wave rotates about the ray in the opposite direction. Because of the presence of the earth's field the two waves propagate through the ionosphere at different speeds. In the terminology of optics the ionosphere is birefringent.

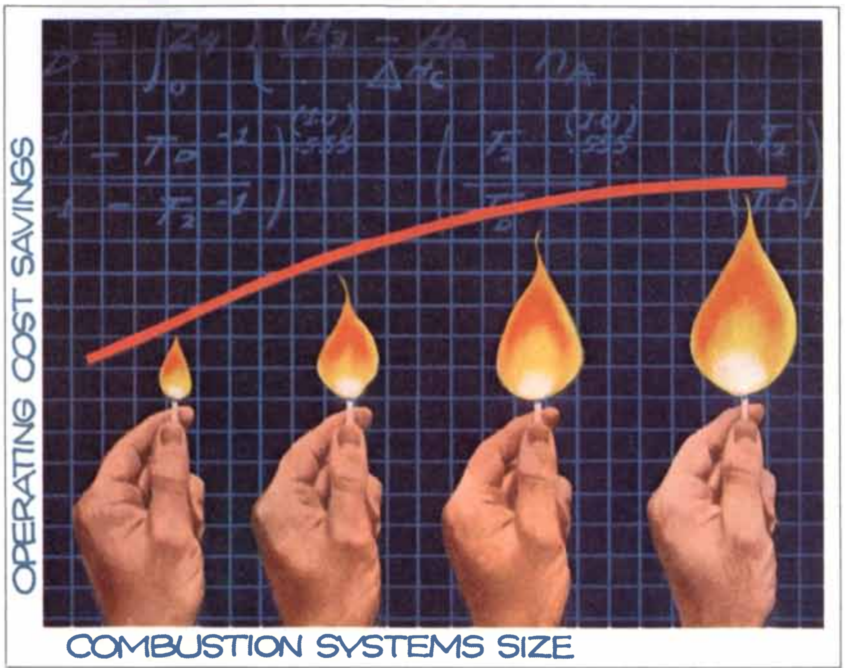
The two radio waves not only propagate through the ionosphere differently but also are reflected differently. In some cases one wave will be partially transmitted through the ionosphere and partially reflected. The other, having the opposite sense of circular polarization, may be completely reflected. The combination of the two reflections gives rise to an elliptically polarized wave: one whose electric fields rotate about the ray tracing out an ellipse rather than a circle. (The bottom illustration at the left represents one possibility for the reflected signal.) The point is that although a linearly polarized radio wave enters the ionosphere, an elliptically polarized wave is reflected. The magnetic fields of such a radio wave also trace out an ellipse and therefore will periodically be parallel to the antenna of the radio receiver. This is the phenomenon that causes the reflected signal to generate a response in the receiver.

During the day the radio signals are reflected in a layer of the ionosphere known as the *D* layer. At an altitude of from 60 to 90 kilometers, this layer is characterized by gas densities that are high and electron concentrations that are low compared with the atmosphere at higher altitudes. When the sun sets, the electron concentrations decrease in this layer because the ultraviolet radiation needed to produce the ions is no longer present.

At night the signals reflect from the *E* layer, which extends from about 90 to 150 kilometers. The temperature rises with altitude throughout the *E* layer, starting at a minimum near 85 kilometers that is known as the mesopause. Above the *E* layer is the *F* layer, which extends to an altitude of about 500 kilometers.

Periodic disturbances in the three layers have long been observed. In 1960 Colin O. Hines proposed that some of the disturbances could be accounted for by atmospheric waves. The waves are still not well understood, particularly with respect to their origin and energy. They may be initiated by thunderstorms, strong winds deflected by mountains, tidal waves, earthquakes, the auroral and equatorial electrojets, the jet stream and heating during auroral and polar substorms. At times the waves appear to be ducted, that is, trapped into propagating horizontally between two

WE ASKED OUR MATHEMATICAL MODEL HOW TO IMPROVE THE ENERGY COST EFFECTIVENESS OF A COMBUSTION HEATING SYSTEM. IT TOLD US: THINK BIG.



THE ENERGY-SAVING POTENTIAL OF OVERSIZED COMPONENTS IS ONE OF THE SURPRISING IDEAS WE'VE UNCOVERED IN DEVELOPING DIGITAL MODELS TO SIMULATE ENERGY CONVERSION SYSTEMS UNDER ACTUAL OPERATING CONDITIONS.

Just as the idea that "smaller is better" was beginning to gain universal currency, a Honeywell research team was getting its first look at data which suggested the opposite conclusion.

Our research results showed that, in a number of situations, high efficiency heating systems consume significantly less energy when they are sized with a larger heat exchanger surface per unit of energy input. This indicates that energy efficiency problems are complex, requiring individual case engineering rather than preconceived generalizations.

Engineering, however, has little to do with how our research efforts managed to stay one step ahead of conventional industry practice. The credit, in this case, goes to a research team headed by a physical chemist and a mathematician. With their unique combination of experience and skills, they developed a mathematical model which allows them actually to simulate and optimize the dynamics of a combustion heating system under field operating conditions.

So, without having to rely on lengthy and expensive field experiments, we can evaluate current and new options available to any combustion heating system. And quickly get an accurate idea of what the cost/efficiency trade-offs are.

This, and additional models for compression refrigeration equipment, gas-fired heat pumps, and process control systems, use inputs obtained from field measurements. And predictions based on data from these models have been verified by key experiments.

The insights gained from mathematical models help Honeywell engineers develop control systems strategies to do a better job of energy management.

In an imperfect world, the creation of mathematical models may be the key to identifying our most important problems. And solving them.

If you are interested in learning more about Honeywell's research work in mathematical modeling, you are invited to correspond with Dr. Ulrich Bonne. If you have an advanced degree and are interested in a career in systems analysis, solid state electronics, sensors, or material sciences, please write to Dr. W. T. Sackett, Vice President. Both may be reached at this address: Honeywell Corporate Technology Center, 10701 Lyndale Avenue South, Minneapolis, MN 55420.

Honeywell

Although Honeywell engineering is world-wide, the bulk of basic research and applied research is done in Minneapolis. The most recent *Quality of Life* Study conducted by Midwest Research Institute shows Minnesota to be one of the best places in the country to live and work considering cultural, social, economic, educational and political factors.

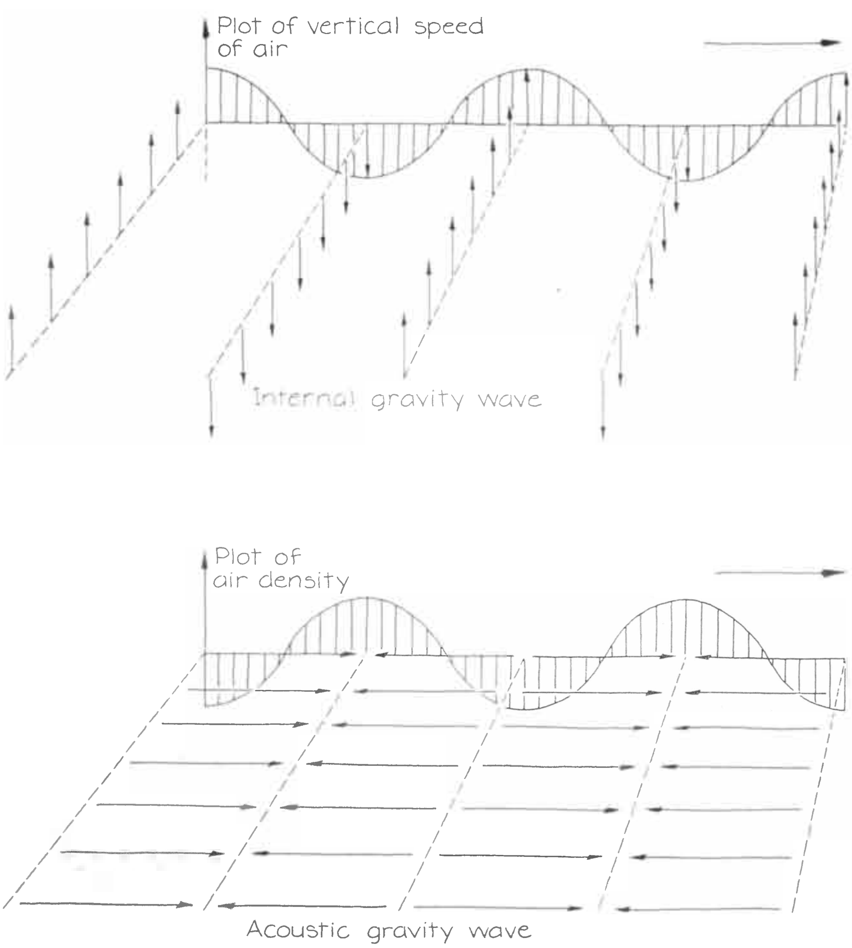
The Twin Cities is the home of many of America's advanced technology companies employing a great many scientists and engineers. This ideal research environment is further enhanced by Honeywell's ongoing program of affiliation with universities across the country: The University of California at Berkeley, MIT, Stanford, Carnegie Mellon, Illinois, Cornell, Waterloo of Ontario, Caltech, and Minnesota.

boundaries, one below the duct and one above it. Such waves may leak energy into the region above the duct and promote traveling ionospheric disturbances at higher altitudes.

The gravity waves detected by Kohl's apparatus are sometimes called internal gravity waves to distinguish them from acoustic gravity waves. The internal wave is considered to be a transverse one (the air oscillates perpendicular to the direction of travel of the wave) with a period of from 270 seconds to four hours. The acoustic wave is considered to be a longitudinal one (the air oscillates parallel to the direction of travel of the wave) with a period of less than 270 seconds. Both kinds of wave can be generated by large-scale disturbances in the atmosphere.

The acoustic gravity wave is a compression wave like a sound wave. The internal gravity wave, on the other hand, requires a gradient in the atmospheric density in order to exist and therefore is not found in the air at ground level. At greater altitudes the decrease in density is sufficient to support such a wave. When a parcel of air is displaced, either its buoyancy or its weight acts to return it to its initial height. If the parcel is displaced downward, buoyancy pushes it back upward. If it is displaced upward, its weight pulls it back downward. Through this mechanism a disturbance in the atmosphere can make the parcels of air oscillate around their equilibrium height and so can support a wavelike phenomenon moving through the air.

However the wave is initiated and sustained, one of its effects is on the concentrations of the electrons that are responsible for reflecting AM radio signals. Therefore the waves can be detected and monitored with Kohl's apparatus. You may be able to demonstrate horizontal propagation of the waves if you and a friend at a distance operate similar detection systems. Although the correlation of gravity waves with events such as large thunderstorms and solar flares is difficult, you may want to try. Kohl's apparatus can also be applied in the study of other ionization phenomena such as the irregular and transient ionization known as sporadic *E*, which is thought to result from the interaction of the earth's magnetic field with winds in the *E* layer.



The difference between an internal gravity wave and an acoustic one

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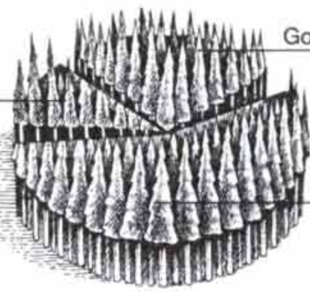
A report on the great American forest.

Good forest management means growing more trees. Not sharing shortages.

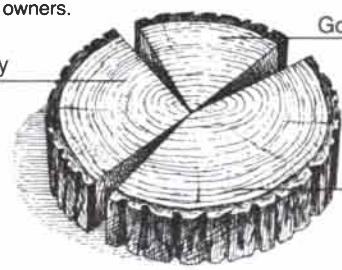
Who owns America's commercial forests?

Commercial forest acreage owned by the forest industry, government, and non-industrial private owners.



And how much do they produce?

Annual harvest from commercial forests owned by the forest industry, government, and non-industrial private owners.



Source: U.S. Forest Service

It's no accident that the most productive forests in America are those owned and managed by the forest industry.

Although they make up only 14% of the commercial forestland, they provide 29% of the annual timber harvest.

This is because the industry has learned that it's not only possible to grow more trees faster, but also imperative.

It's a race against time: Every year Americans need more lumber and plywood to build homes. More furniture to make them liveable. More paper and pulp to print the books and periodicals that educate, enlighten and entertain. More packaging and containers for thousands of essentials, from milk to machinery.

The sobering fact is that within 50 years U.S. demand for wood and paper products is expected to double.

Yet not all the nation's commercial forests are working equally hard to get ready.

What is a commercial forest?

Commercial forest, as defined by the U.S. Forest Service, is *all* forestland — whether owned by individuals, government or the forest industry — that is capable of, and potentially available for, growing repeated crops of trees for harvest. It includes land in National Forests but not in National Parks or Wilderness areas.

On all commercial forestland, tree growth per acre averages only 61% of potential, which is not good enough. The greatest room for improvement, however, is in National Forests, where trees now grow at only 48% of potential.

Yet as the industry has shown, the growth cycle can be speeded by applying such techniques as: encouraging natural regrowth, planting superior seeds and seedlings, fertilizing, thinning and protecting trees from disease, insects and fire.

How soon can we start growing more trees?

Since we clearly have the know-how to grow more and higher-quality trees, how soon can this nation get on with the job of increasing productivity on *all* commercial forestlands?

The first step is to understand the problem. If you'd like to learn more about the importance of America's forests and the challenges they face, send for a free booklet, "The Great American Forest." Write American Forest Institute, P.O. Box 873, Springfield, VA 22150.

The great American forest. Trees for tomorrow. And tomorrow. And all the tomorrows after that.

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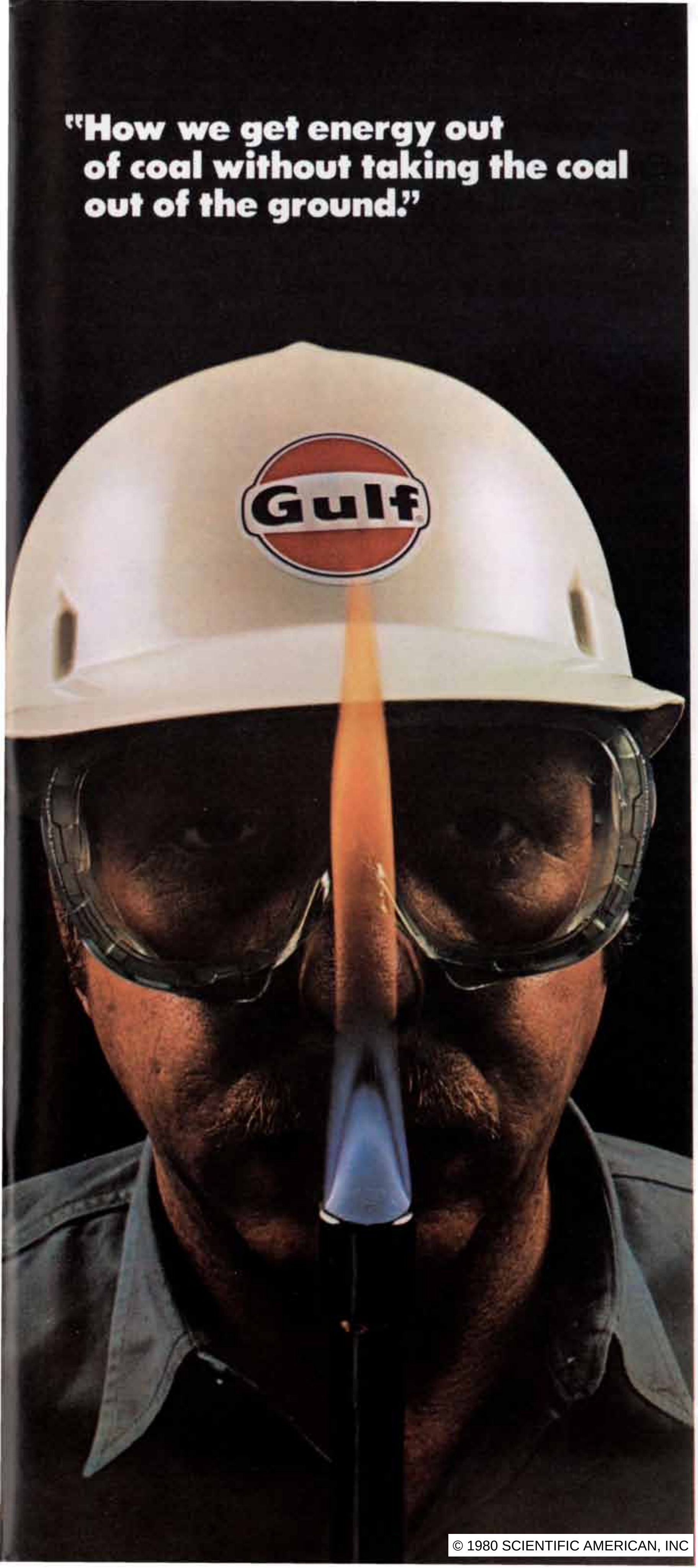


"A lot of coal in America—millions of tons, in fact—is too deep or too slanted to be mined by any conventional techniques," says Gulf Engineer Jerry Daniel. "At Gulf, we're working with the Department

Air through injection well supports combustion of coal at A, fire heats coal at B, which produces gas recovered through production well, C.

of Energy on a way to extract the energy from that coal without mining it. We drill an injection well to set fire to the coal. By burning some of the coal, we heat up the rest, which causes it to produce gas. That's why it's called underground coal gasification.

"We had a test burn here in Rawlins, Wyoming, late in 1979, and we're setting up another one. Our hope is that by 1990, industry will be able to use this kind of synthetic gas, which of course will make us less dependent on expensive imported crude oil as an energy source.

"At Gulf, our first priority is to get all the oil and natural gas we can out of resources right here in America. But we're working on a lot of other good ideas, too. Underground coal gasification is one of them; and we're working with synthetic fuels, tar sands, geothermal energy, and other alternative energy sources.

"Overall, you might say that the business we're really in is the business of energy for tomorrow."

Gulf

Gulf people: energy for tomorrow.

Gulf Oil Corporation

"Someday we may use gas from coal the way we now use natural gas."

Lockheed knows how.

The aircraft you see above—the SR-71 and the L-1011 TriStar—are worlds apart in performance, yet each represents a significant aerodynamic advance.

The SR-71 flies for the Strategic Air Command—higher, faster than any other aircraft. Look at the chines on the front of the SR-71 at the right. Without them, most of the "lift" would be in the rear—and the aircraft would dive as it flew. With the chines, lift also is spread across the fuselage, helping the SR-71 to cruise over 2000 mph. The SR-71 was the first operational aircraft to use chines. Now you find them on advanced fighters.

The Aerodynamic Fuel Saver.

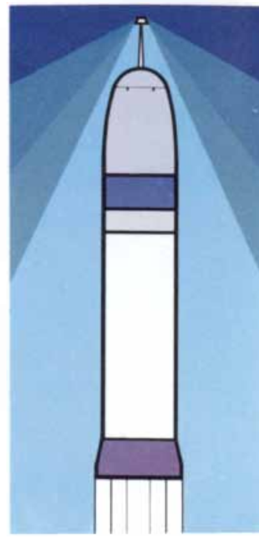
A unique aerodynamic advance on the L-1011 TriStar is helping airlines save fuel. Note those long wings. They've been lengthened nine feet since the L-1011 first flew.

An exclusive system of computer-driven Active Control Ailerons made this possible without costly, time-consuming redesign. Automatically, they work in flight to reduce wing structural loads, decrease drag, produce a smoother ride—and save enormous amounts of fuel over the life of each L-1011.

In the future, other jetliners will have Active Controls, long after they first appeared on the L-1011.

The Aerodynamic Range Stretcher.

The Navy told Lockheed that its newest fleet ballistic missile Trident, must have twice the range of the earlier Poseidon. But Trident's overall physical dimensions could not be any larger than Poseidon's.



This meant Lockheed had to give Trident a blunt nose. (Poseidon had employed a sharp, aerodynamically efficient nose.) This also meant more aerodynamic drag—and drag works against range.

The solution: fool Mother Nature. Lockheed engineers developed an ingenious telescoping spike that extends more than four feet and locks into place at a precise moment after Trident is launched.

Instead of flying through the atmosphere with the blunt nose slamming into air, a small disc

at the front of the aerospike diverts airflow and creates the aerodynamic illusion that Trident is bullet-shaped. This spike, along with other advances, enabled Lockheed to meet the Navy's requirement of doubled range.

The Airlifter Afterbody Champion.

Airlifters are a special breed. To airdrop large equipment, they need wide rear doors that create a flat, two-dimensional surface. To provide fast, easy loading, their cargo decks must

almost hug the ground—and this means airlifters need a highly upswept fuselage afterbody to let the tail clear the ground on takeoff, particularly short field takeoff. Both the flat rear surface and upswept afterbody create aerodynamic drag that you do not encounter in passenger jetliners.

This caused the first great airlifter, Lockheed's C-130 Hercules, to have 10% of its overall drag in the afterbody. Shrewd linking of structural, mechanical and aerodynamic efforts enabled Lockheed to reduce afterbody drag on the second great airlifter, the C-141 StarLifter, to 3%. In the third great airlifter, the huge C-5 Galaxy, Lockheed engineers chiseled afterbody drag down to an incredible 1%.

The Aerodynamic Lift/Drag Champion.

In aerodynamics, lift is good, drag is bad. The more lift and the less drag, the more efficient the aircraft. And that's where the U-2 reconnaissance aircraft stands out. Those long, slender wings give it the highest lift-to-drag ratio of any operational powered aircraft in the world. But there's even more to the U-2's stellar record. The wings are so successful, in part, because they are extremely light in weight. Manufacturing those feathery wings was as great a triumph as designing them.

The U-2 story is far from over. An advanced version, the TR-1 recently entered production at Lockheed.

What's next? Lockheed's past and present record says new advances are coming, in many forms of flight.

Lockheed