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SCIENCE

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SCIENCE/SCOPE

Computers are being called upon to help create the "super chips" that will give military electronics system a tenfold increase in data processing capability. Hughes is using computer-aided design programs to develop Very High Speed Integrated Circuits (VHSIC) and the systems in which these chips will be used. Computer help is essential because of the tremendous amount of circuitry per unit area. VHSIC chips are as complex as 100 Los Angeles street maps printed on a thumb tack, and they themselves are mere components of larger, more complex systems. Computer programs will help engineers design, lay out, and test a chip. They describe an entire system (a signal processor, for example) at many different levels of detail simultaneously to predict the system's performance under various operating conditions.

Intelsat VI will become the world's most sophisticated commercial communications satellite upon launch in 1986. The drum-shaped, spin-stabilized satellite will have twice the capacity of Intelsat V. It will be able to carry 33,000 telephone calls and four TV channels simultaneously. It will weigh more than 8200 pounds at launch, measure 12 feet in diameter, and deploy to 39 feet in height. Hughes heads an international team building Intelsat VI spacecraft for the International Telecommunications Satellite Organization.

A new software system can translate naval tactical messages into understandable form. Messages within a command, control, and communications (C^3) system are typically hard to understand because they are transmitted in telegram form and often omit subjects, direct objects, articles, prepositions, and punctuation. If grammatical errors creep in, messages can be rendered unintelligible. While conventional computer techniques can't make sense of a garbled message, a Hughes message understanding system called GRACIE can. Using artificial intelligence techniques, GRACIE understands general descriptions of flights of aircraft over ships, of attacks, and of encounters with hostile ships. It constructs grammatical sentences based on what it expects messages to be, referring when necessary to a "rule book" of examples. It can be adapted for other than naval use.

An improved process of growing silicon for laser detectors provides the highest-purity silicon available in the world. With the float zone crystal process, a polycrystalline silicon rod is heated in a vacuum chamber, producing a zone of molten silicon that passes from the bottom to the top of the rod several times, thus removing impurities and providing for growth of a highly pure crystal. The silicon can be used for laser seekers, designators, trackers, and range finders. Hughes developed the process for the U.S. Army and Air Force.

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ISSN 0036-8075

4 June 1982

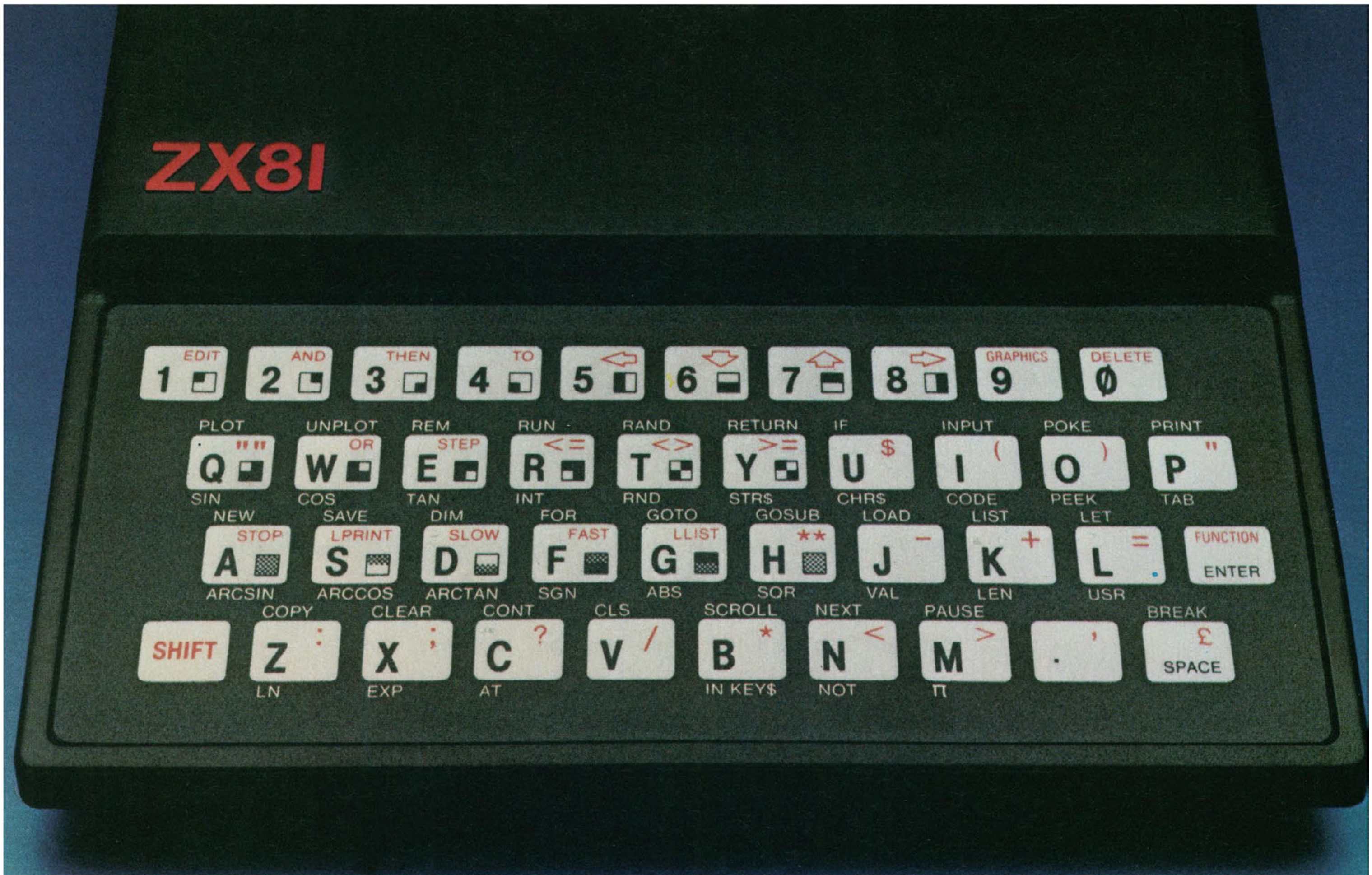
Volume 216, No. 4550

SCIENCE

SCIENCE is published weekly on Friday, except the last week in December, by the American Association for the Advancement of Science, 1515 Massachusetts Avenue, NW, Washington, D.C. 20005. Second-class postage (publication No. 484460) paid at Washington, D.C., and at an additional entry. Now combined with **The Science Monthly®** Domestic individual membership and subscription (51 issues): $48. Domestic institutional subscription (51 issues): $85. Foreign postage extra: Canada $24, other (surface mail) $27, air-surface via Amsterdam $55. First class, airmail, school-year, and student rates on request. Single copies $2.50 ($3 by mail); back issues $3 ($3.50 by mail); classroom rates on request. **Change of address:** allow 6 weeks, giving old and new addresses and seven-digit account number. **Postmaster:** Send Form 3579 to *Science*, 1515 Massachusetts Avenue, NW, Washington, D.C. 20005. *Science* is indexed in the *Reader's Guide to Periodical Literature* and in several specialized indexes.

COVER

Tier of smooth skirt clouds rims eruption column (about 2 kilometers in diameter) from Soufriere Volcano, St. Vincent, West Indies, 17 April 1979. The turbulent column, produced by the most powerful explosion of the 1979 activity, was observed to rise at an average velocity of 50 meters per second to an altitude of about 18 to 20 kilometers. The rising column apparently entrained and deformed preexisting subhorizontal layers of moist and less-moist air from lower altitudes and carried them to levels where the moist layers condensed to form the visible skirt clouds. See page 1105. [Photographed by K. C. Rowley, University of West Indies, from a low-flying aircraft piloted by Duncan Richardson]



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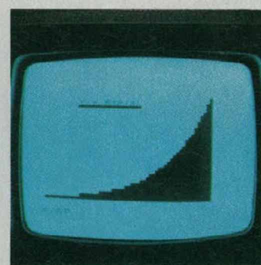

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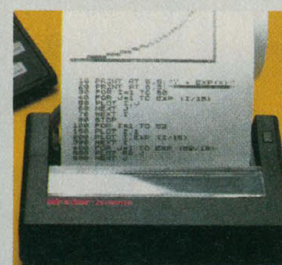

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THE LEADING EDGE

#3 in a series of reports on new technology from Xerox

Xerox introduced the first xerographic copier, Model 914, in 1959. The 914 and xerography were great surprises to the world. They revealed and then satisfied an immense latent demand for plain paper copying. And they surprised scientists and engineers by demonstrating practical applications of physical phenomena that had not been thought to have much practical value. They used large page-sized sheets of semiconducting selenium to capture entire images by the phenomenon of photoconductivity. What's more surprising, they found a practical use for "static electrification," which is the transfer of electric charge that occurs when, for example, one rubs a cat on a dry day.

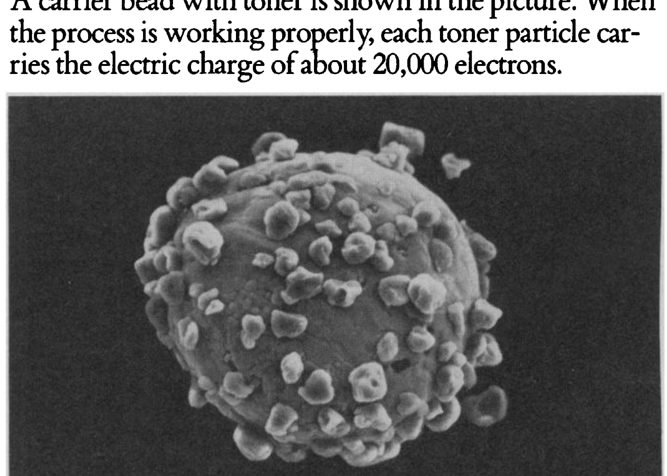
This fundamental part of the xerographic process was not at all understood scientifically. Early technology work was by trial and error.

Some years ago a few of us in Xerox Research became aware that as the demands on xerography increased, trial and error methods of xerographic design would become increasingly risky. We undertook a small, deliberate research program on the fundamentals of the xerographic process.

THE XEROGRAPHIC PROCESS

A xerographic image—a copy—is made of about 100 million carefully arranged bits of pigmented plastic called toner particles. The whole xerographic process is simply the means of arranging toner particles into faithful patterns, then transferring the patterns to paper and making them permanent by melting.

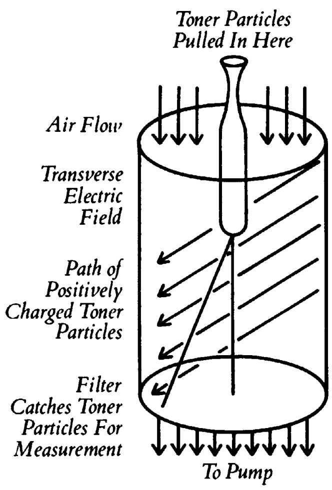
The process works as follows: First, a photoconductor, a paper-thin layer of glassy selenium coated on aluminum, is given a uniform electric charge on its top surface. Usually this is done with a spray of positive ions from a wire or point at high voltage. In darkness selenium is a good electrical insulator so the electric charges are stable. Next, the image of a document to be copied is projected onto the photoconductor discharging it in light-struck areas and leaving charge patterns corresponding to the black letters and marks of the original document. Finally, this latent electrostatic image is developed by attracting oppositely charged toner particles to it. Here is where static electrification becomes crucial. Toner particles get their charges by repeated rubbing against the surfaces of larger particles called carrier beads. A carrier bead with toner is shown in the picture. When the process is working properly, each toner particle carries the electric charge of about 20,000 electrons.



The photo shows a single carrier bead with toner clinging by electrostatic force. A xerographic copier might hold about three kilograms of carrier which itself binds 50 to 100 grams of oppositely charged toner. The combination is a xerographic developer.

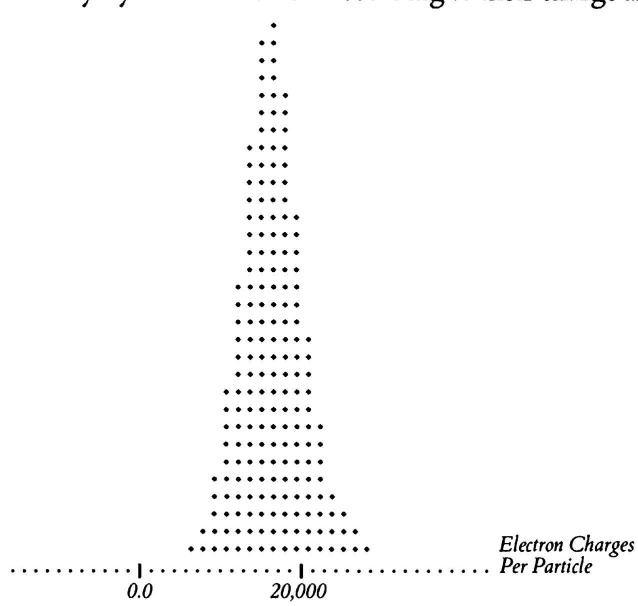
THE CHARGE SPECTROGRAPH

The trouble was that we had no way to make certain that a xerographic developer was in fact working properly. We could not measure the charge on individual toner particles to be sure that all of them had the right charge. We suspected that wrong-charge particles might often be present and responsible for poor copy quality and for at least some of the dirt contamination of xerographic equipment. A reversed-sign particle will go in exactly the wrong place—the white areas—and only a small percentage of these in the whole toner population can produce a visible flaw. A particle with no charge is uncontrollable. By measuring charge distributions on toner we could characterize xerographic developers independently of copier hardware. We hoped also that charge distributions would eventually provide insight into the physical mechanisms responsible for static electrification.

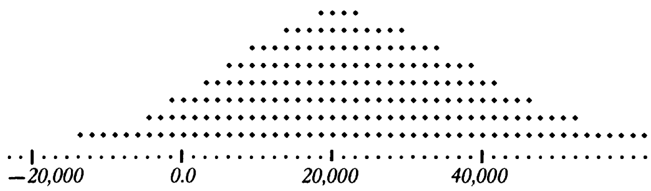


With these things in mind, E.W. Connors, R.F. Koehler and I built the charge spectrograph sketched here.

It's a kind of low-speed wind tunnel with a uniform electric field across the direction of air flow. Toner particles are stripped from carrier beads with a tiny air jet and introduced on the axis of the instrument. As they move downward with the air flow, they are pulled laterally by the electric field according to their charge and size and finally caught on an exit filter for examination. Afterwards, the filter is removed and the drift distance and size of each toner particle is read through a microscope by an automated analysis system.



Example 1. *The charge distribution on the 10 micron size class of toner particles. This is a fairly sharp distribution.*



Example 2. *Charge on the 10 micron toner particles in a worn-out developer. Note the reverse-sign and uncharged toner.*

Experimental results are in the form of distributions or histograms, which are plots of the fractions of the toner particles having various charges. Here we show only a particular size category, the toner particles with measured diameter of 10±1 micron. The first example is free of low-charged or reverse-charged toner particles. This xerographic developer performs well in equipment.

The second distribution is from a developer that has been used to make too many copies. This developer is worn out; the charge-exchanging character of its carrier surfaces has changed.

And in cases that we haven't shown by example, the charge on each toner particle is proportional to its surface area; and in some others, it is proportional to toner diameter. These and other regularities, once seen, beg for explanation. These explanations lead to completely new developer designs which work as predicted.

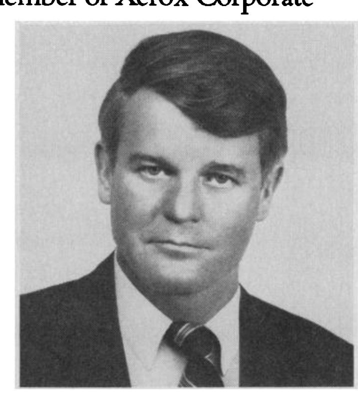
The most satisfying outcome is that we are beginning to understand the underlying physics well enough to formulate rules for the design of xerographic materials.

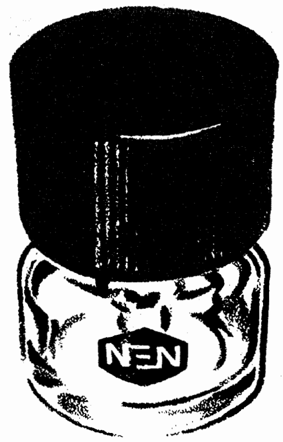
Over many years we have examined hundreds of developers under many conditions of use. A few have already gone to market and others are on the way.

The charge spectrograph is only one example of how we can make xerography work even better in future generations of copiers and printers. During the past ten years people have sometimes said that xerography was a mature technology. We never believed it.

ABOUT THE AUTHOR

R.B. Lewis is a member of Xerox Corporate Staff specializing in electronic printing strategy. The work described here was done when he was manager of the Imaging Physics and Materials Laboratory at the Xerox Webster Research Center. He holds a B.A. degree from Yale and a PhD degree in physics from Princeton.




NEN

a number of alternatives in a proposed rule indicated EPA's lack of a favored approach, and certainly the absence of a predetermined outcome. The issue before EPA is not whether lead is good or bad but whether the current regulatory approach is the most appropriate way to achieve our goal of reduced lead exposure, since in the long term continued growth in unleaded gasoline use will result in a reduction in the use of lead in gasoline.

With regard to the meeting between the administrator of EPA and representatives of the Thriftway company, Marshall does not indicate that a report of the inspector general of EPA, after an investigation requested by Representative Moffett, failed to find any wrongdoing on the part of the administrator. As established in guidelines that have been in existence since 1979 (44 Fed. Reg. 58953, 12 October 1979), one factor used to determine whether or not any penalty is appropriate for violation of the lead standard is economic hardship. My staff is evaluating the claim of economic hardship presented to the administrator, and we will treat Thriftway in accordance with our existing guidelines and appropriate enforcement procedure.

As EPA's assistant administrator in charge of this program, I can assure *Science*'s readers that no decision has been made on whether changes to the lead phase-down regulations are appropriate. We plan to make a sound decision based on the record before us; we invite readers to supply any information they believe would be helpful in enabling us to reach a well-founded decision.

KATHLEEN M. BENNETT
Office of Air, Noise and Radiation, Environmental Protection Agency, Washington, D.C. 20460

Science Instruction and Religion

In response to the letters by J. C. Hickman and R. M. Joyce (16 Apr., p. 242) concerning the teaching of evolution, I do not advocate mixing religion with science instruction or teaching the assertions of Genesis literalists. I do advocate teaching concepts of evolution in a manner that avoids unnecessary strife and misunderstanding. Most of some 40 million American Christian "fundamentalists" still take a dim, if not hostile, view of Darwinian evolution, largely because they mistakenly perceive its emphasis as anti-God. This impression can rather easily be corrected. Judge Overton (19 Feb., p. 938) makes the essential point as follows: "The theory of evolution assumes the existence of life and is directed to an explanation of *how* life evolved. Evolution does not presuppose the absence of a creator or God. . . ." I would add that concepts of creation and evolution are quite compatible if evolution is viewed as a creative process continuing over many millions of years. Individual writers or lecturers could, of course, say much more about divergent beliefs or theories concerning origins, depending on the audience. The integrity of science is not compromised by stating that the *ultimate* origins of matter and life are unknown and open to conjecture. Indeed, evolutionary scientists, among whom I count myself, could well take greater care in separating facts from conjecture.

W. H. HILDEMANN
Department of Microbiology and Immunology, School of Medicine, Center for the Health Sciences, University of California, Los Angeles 90024

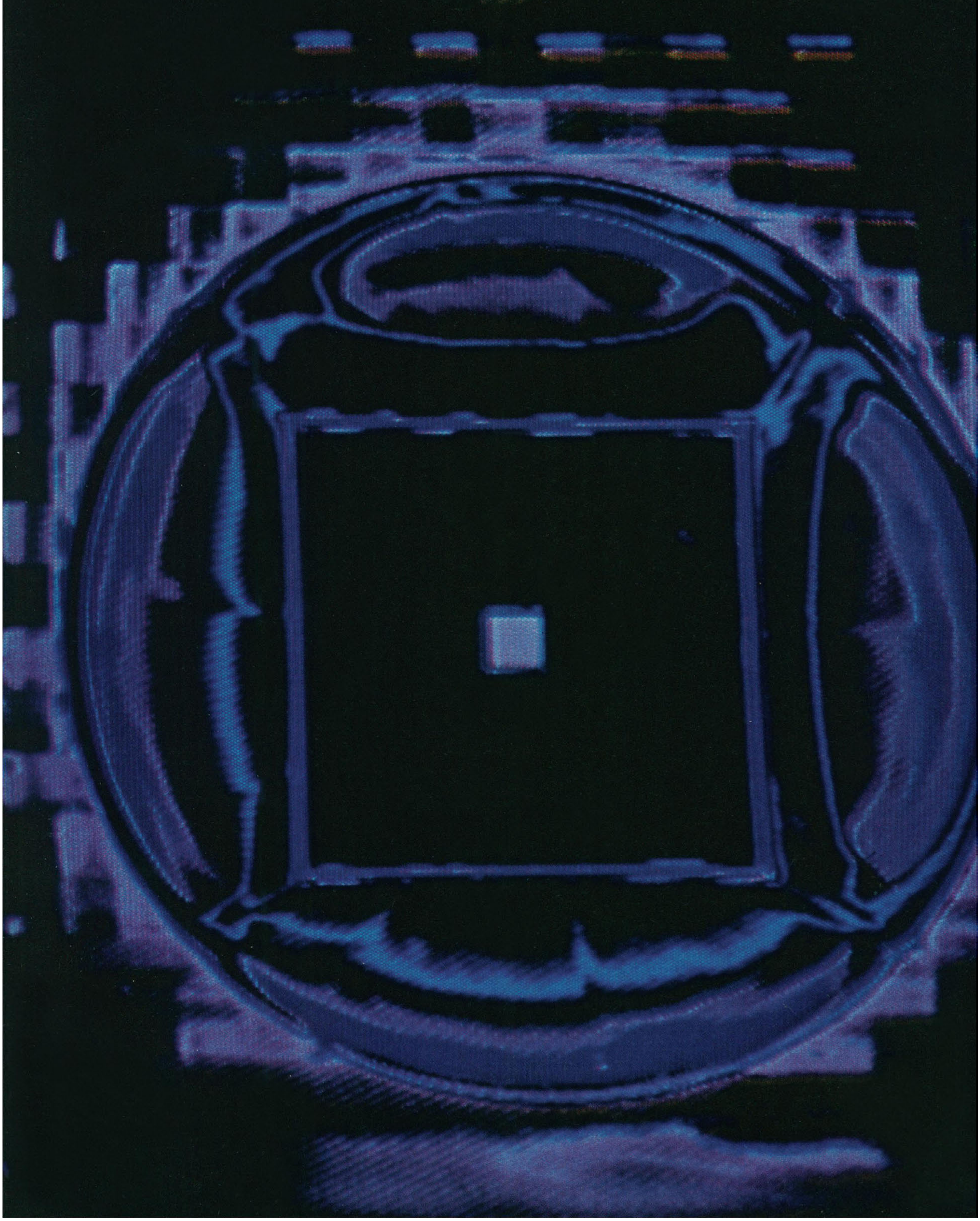
Journal Prices

James E. Heath (Letters, 14 May, p. 684) raises several important points regarding the cost of new journals; however, the problem of the cost of journals to institutional libraries applies equally to established journals. The majority of research journals (old and new) impose higher subscription rates to libraries than to individuals. Publishers seem to forget that their relationships with libraries are symbiotic. The researcher/scholar requires the collections and services of libraries in order to research a topic, produce a paper, and provide the publisher with publishable material. Why then do publishers seek to punish that which provides them with their income?

As journal prices escalate, libraries are forced to cancel more and more subscriptions, thus providing poorer collections for the scholar. Although the library market accounts for only a small income, without this reliable base income publishers cannot exist. Witness the demise of many secondary publications and publishers, and falling circulations. Increasing prices without an equivalent increase in quantity or quality is not the answer.

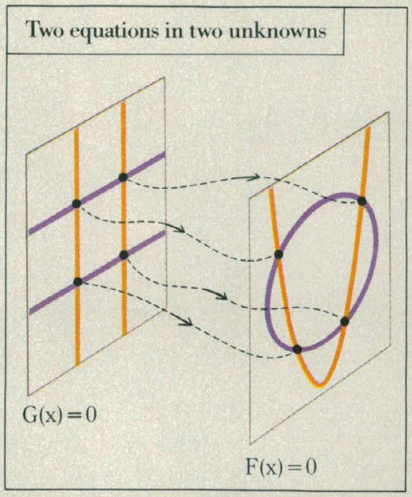
NINA J. ROOT
Department of Library Services, American Museum of Natural History, Central Park West at 79th Street, New York 10024

The Continuation Method



The Continuation Method

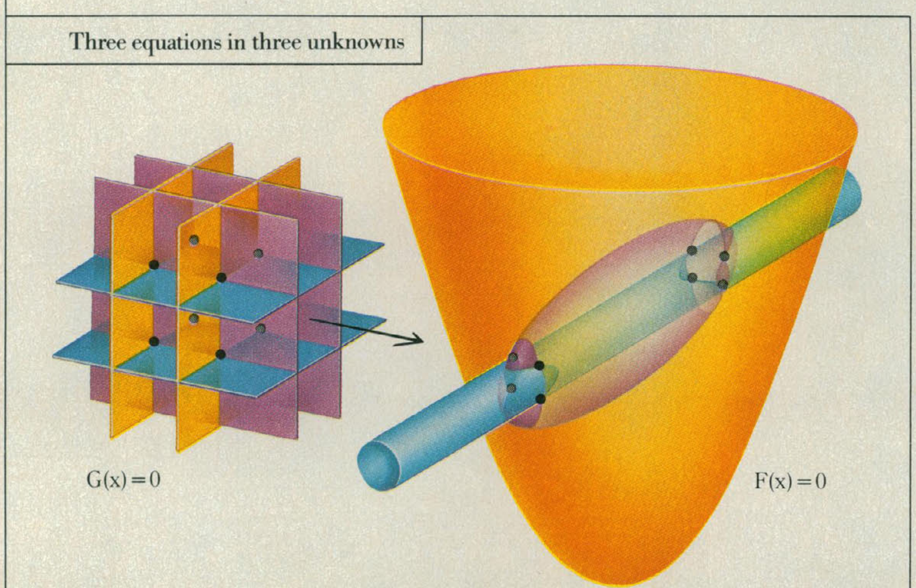
The need to solve systems of polynomial equations arises in pursuits ranging from geometric optics to chemical kinetics. A practical method of solution, developed at the General Motors Research Laboratories, provides designers of mechanical parts with a new capability.



The two pairs of parallel lines of G(x) = 0 evolve into the parabola and ellipse of F(x) = 0.

The three pairs of parallel planes of G(x) = 0 evolve into the paraboloid, ellipsoid and cylinder of F(x) = 0.

CLASSICALLY difficult non-linear equations—those made up of polynomial expressions—can now be solved with reliability and speed. Recent advances in the mathematics of continuation methods at the General Motors Research Laboratories have practical implications for a wide range of scientific and engineering problems. The immediate application at General Motors is in mechanical design. The new method finds all eight solutions to three quadric equations in a few tenths of a second—fast enough for computer-aided design on a moment-to-moment basis. Algorithms based on this method are critical to the functioning of GMSOLID, an interactive design system which models the geometric characteristics of automotive parts.



Systems of non-linear equations have been solved for many years by "hit or miss" *local* methods. The method developed at General Motors by Dr. Alexander Morgan is distinguished by being *global* and *exhaustive*. Local methods depend on an initial estimate of the solution. They proceed by iterative modifications of this estimate to converge to a solution. However, success is not guaranteed, because there are generally no practical guidelines for making an initial choice that will ensure convergence. Reliability is further compromised when multiple solutions are sought.

Global methods, by contrast, do not require an initial estimate of the solution. The continuation method, as developed by Dr. Morgan, is not only global, but also exhaustive in that, assuming exact arithmetic, it guarantees convergence to all solutions. The convergence proof rests on principles from the area of mathematics called differential topology.

Here is the way continuation works. Suppose we want to solve a system $F(x) = 0$. We begin by generating a simpler system $G(x) = 0$ which we can both solve and continuously evolve into $F(x) = 0$. It is important that we select a G properly, so the process will converge. Dr. Morgan has devised a method for selecting G which gives rapid convergence and reliable computational behavior. He first applied a theorem established by Garcia and

Zangwill to select G. However, the resulting algorithm could not achieve the speed and computational reliability necessary for several applications. Next, he utilized some ideas from algebraic geometry—"homogenous coordinates" and "complex projective space"—to prove a new theorem for selecting G. The result of Dr. Morgan's efforts is a practical numerical method based on solid mathematical principles with innate reliability.

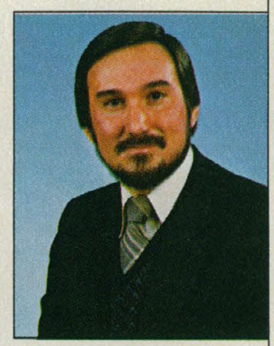
Reliability is the critical element for mathematical methods embedded in large computer programs, because errors may not become evident until after they have ruined a large data structure compiled at great expense and effort. Speed is also important to economical real-time implementation. This method has proved to be reliable and fast in solving problems involving equations up to the sixth degree in three or four variables. However, there are obvious practical limitations on the number of equations and their degree, due to the limited precision of computer arithmetic and computer resource availability.

THE FIGURES illustrate the transition from simple $G(x)=0$ to final $F(x)=0$. In both figures, the "simplicity" of $G(x)=0$ is reflected graphically in its linear structure—seen as lines and planes. The non-linearity of $F(x)=0$ is seen in the curvature of the final shapes in each figure.

In figure 1, the four dots on the left plane represent the set of simultaneous solutions to the system of equations $G(x)=0$. The four dots on the right plane represent the set of simultaneous solutions to the system of equations $F(x)=0$. The dashed lines represent simultaneous solutions to intermediate systems whose graphs would show the evolution from one configuration to the other. With the addition of a third dimension in figure 2, the number of dots representing simultaneous solutions doubles. Representation of the transitional points, as in figure 1, would require a fourth dimension.

"Continuation methods, although well known to mathematicians," says Dr. Morgan, "are not widely used in science and engineering. Acoustics, kinematics and non-linear circuit design are just a few fields that could benefit immediately. I expect to see much greater use of this mathematical tool in the future."

THE MAN BEHIND THE WORK



Dr. Alexander Morgan is a Senior Research Scientist in the Mathematics Department at the General Motors Research Laboratories.

Dr. Morgan received his graduate degrees from Yale University in the field of differential topology. His Ph.D. thesis concerned the geometry of differential manifolds. Prior to joining General Motors in 1978, he taught mathematics at the University of Miami in Florida and worked as an analyst at the Department of Energy's Savannah River Plant in South Carolina.

While serving in the U.S. Army, Dr. Morgan participated in the development and analysis of simulation models at the Strategy and Tactics Analysis Group in Bethesda, Maryland.

Dr. Morgan's current research interests include the qualitative theory of ordinary differential equations and the numerical solution of non-linear equations.

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7th R&D Colloquium Washington, 23 & 24 June 1982
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Wednesday & Thursday, 23 & 24 June, at The Shoreham Hotel, 2500 Calvert St., N.W., Washington, D.C.

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Shoreham Hotel Reservation—AAAS Colloquium (23 & 24 June)

(Reservations received after 23 May cannot be guaranteed)

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City ______ State ______ Zip ______ City ______ State ______ Zip ______

Room: ___Single ($70*) ___Double ($84*) ___Twin ($84*)

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Arrival: Date ______________ Time ______________

Departure: Date ______________ Time ______________

Be sure to list definite arrival and departure date and time. Hotel reservations will be held only until 6 p.m. unless otherwise specified. Check out time is 1:00 p.m.

Please indicate any special housing needs due to handicap ______________

Enclose separate check, made out to The Shoreham Hotel, for first night's room deposit **or** indicate major credit card number:

Credit card name______________ Number______________ Expires______________

Cardholder's signature ______________

4 June 1982, Volume 216, Number 4550

SCIENCE

The Fate of School Science

The erosion in precollege teaching of mathematics and science has become a matter of national concern. The National Academies of Sciences and Engineering and the AAAS held major meetings on the topic in mid-May; the National Science Board has created a Commission on Precollege Education in Mathematics, Science and Technology.

A great deal is being done already. The North Carolina School of Science and Mathematics, in Durham, is a residential public high school open at no cost to students who are qualified. Florida and California, which led the nation in relaxing high school graduation requirements in the 1960's, have reversed those policies; California, for example, intends to require a minimum of 3 years of mathematics and 2 years of science, and more from the college-bound. With corporate help, the Houston school district is providing a $2000 annual supplement to the salaries of teachers certified in specialties such as science and mathematics.

But salutary as these efforts are, we are in trouble. Half of the mathematics and science teachers hired last year were certified provisionally or on an emergency basis. Thirty-eight states report a shortage of mathematics and science teachers. While the proportion of students scoring 700 or above on the Scholastic Aptitude Test has stayed about the same in the past decade, the proportion scoring at low levels—about 300—has risen.

The danger is not in failing to train the gifted who wish to be scientists and engineers; they still seem to receive the requisite education and opportunities. Rather, it is in raising a generation of Americans who lack the education to participate in a technological age; in failing to assure the scientific literacy of Americans, whatever their future vocation. "Literacy" here does not mean that all students should be able to draw the structure of DNA. They should, however, have a basic understanding of the world of technology in which they will live and in which a rising proportion will make their living. They should understand what computers actually do and what their limits are. The world of the present decade will use a new language: robotics, CAD, CAM, integrated circuits, and the like. Those who do not understand that language are in for a difficult time.

Federal officials at the Academies' convocation saw the need for "partnership" efforts with states and local authorities and with industry, asserting that education in the American system remains a local enterprise. State and local officials accepted their central role, but wondered where to find the money to compete with the higher salaries offered by industry and to equip schools with modern and effective curricular materials.

Whatever the perspective, there was concern about how science, mathematics, and technology are taught. "People are being taught that they are too dumb to understand science," Carl Sagan said. Too many textbooks emphasize the student's ability to memorize, to remember facts, to regurgitate information rather than to think.

Science teaching may have become too abstract. It may have become astronomy without the stars, botany without the flowers, geology without the mountains and valleys. We may be teaching abstractions to students who do not understand the physical ties. One can understand why half of all high school graduates have taken no mathematics or science beyond the tenth grade.

There were repeated calls at the convocation for a reexamination of how and what we teach our children: the "how" formed by the rapid advances made in the cognitive sciences in understanding how children learn, and the "what" by the enormous transformation of the sciences—the emergence of so many new fundamental concepts—in the past two decades.

We need, in short, to reaffirm the commitment that Jerrold Zacharias asked of us more than 20 years ago: "A permanent, sustained commitment of the American scientific community to enlarge its presence in the American classroom."—FRANK PRESS, *President, National Academy of Sciences, Washington, D.C. 20418*