25,000 to 100,000. The most reliable study on this subject shows 35,300 current periodicals. To this number, however, may be added approximately 8,000 technical reports of government and commerce, and 9,000 to 11,000 house organs and related publications which usually do not contain material of primary nature. The scientific and technical literature of the world is published currently in over sixty languages.

Supposedly, there are about 3,000,000 scientists and technologists in the world today (at least we know there are approximately 1,000,000 in the United States). Estimates are that this number will increase ten to fifteen times by the end of the century. But if it now takes 35,000 periodicals to provide publication outlets for 3,000,000 scientists and technologists, then it is conceivable that ten times as many workers may require 350,000 journals. It is futile to estimate the number of articles, or the new information, appearing in a third of a million journals. How can scientists, librarians, and others cope with this tremendous increase in the scientific literature?

Studies indicate that the average scientist reads with comprehension at a speed of 200 to 300 words a minute. Reading as slowly as he does in his own field, the scientist can hardly make a dent in his "required reading" these days, to say nothing about future requirements if we think in terms of one-third million journals.

We have reached a period in science somewhat similar to that encountered by our colleagues of 300 years ago. Creative and inventive minds must now discover new methods for coping with the scientific literature. If this is not done, science will face a real crisis within a generation and may suffocate from its own immense production.

—J. R. PORTER
in *Bacteriological Reviews*,
Vol. 28, No. 30.

The author of the report above is Professor of Microbiology at the College of Medicine, State University of Iowa, and president of the American Society for Microbiology. The text reproduced here was excerpted from his presidential address of 1964, originally printed in "Bacteriological Reviews" and reprinted in SR with the permission of the copyright owner, the American Society for Microbiology. Several years of work went into preparation of this 300th birthday commemoration by Professor Porter, whose interest in scientific journals was stimulated by a decade of service as editor-in-chief of the "Journal of Bacteriology." For a more extensive account, he commends to readers the Scarecrow Press book, "History of Scientific Periodicals," by David A. Kronick.

The Accumulation of Scientific Knowledge—II

STORING SPARKS TOMORROW

When scientists turned to the printed page as a receptacle for the information they collected about their experiments and, incidentally, about themselves, they had to begin elimination of confusion by agreeing on standards of phraseology, page format, fonts of type, and mathematical symbols. As they turn today to the practice of storing data in smaller space in the form of numbers reduced to electrical sparks and set down magnetically on memory tapes of computers, the old problem of confusion arises again. Below the chief executive of one of the best known computer builders, David Sarnoff of Radio Corporation of America, defines the new situation and suggests a solution.

NEITHER the operators nor the machines we have built for the processing and transmission of information can yet speak to each other in a commonly understood and accepted language. The means of preparing data, of forwarding and entering data in the machine, and of instructing the machine in its use differ sufficiently from one make of equipment to the next so that none can readily accept the product of another.

We function today in a technological Tower of Babel. There are, by conservative count, more than 1,000 programming languages. And there are languages within languages—in one instance, twenty-six dialects, and in another, thirty-five dialects. There are eight computer word lengths in use. There are hundreds of character codes in being, at a ratio of one code for every two machines marketed. Four magnetic tape sizes are employed with at least fifty different tape tracks and codes.

Standards have not been accepted even for commonly used symbols, instruction vocabulary, or program development procedures. Words which have currency throughout the industry assume different meanings, depending on whether a man has trained in Pasadena, Poughkeepsie, or Camden. We have yet to produce a universally accepted computer glossary.

No means have yet been perfected for a program in one basic language to be run efficiently into computers of different makes. The result has been needless duplication, delay, and waste—both to the manufacturer and to the user—in cost, in equipment, in operating efficiency, and in manpower and skills.

Incompatibility has compelled the manufacturer to build optional choices into peripheral equipment for the input and output of data. It has required him to maintain various types of the same equipment, or to build to a customer's specifications on each order. It has diverted needed engineering and programming talent from the vital work of new product and systems development.

The burden of incompatibility has been even more onerous to the user. It has meant the extra cost of providing hardware and programs to handle the differences between incompatible systems, the cost of extra machine time to process data set for another computer, the cost of training people to do things differently, the cost of not being able to do the job immediately.

Last year, an estimated $2,000,000,000 was spent by American business and government for privately developed computer programs, representing thousands of man-years of effort. Yet, when a change to new equipment is made, portions of this effort must be thrown away because they have no validity to another make of machine, or they are retrievable only at further cost.

I have heard it said that even a degree of standardization and compatibility might inhibit the progress of the art. In my judgment, this argument is without substance. The nature of a computer is such that its operation is governed far less by its internal construction than by the program that is given to it.

The effort to bring order to the flow of computer intelligence need not affect competition either in creating programs or in seeking new generations of increasingly efficient machines. On the contrary, the result could be a greater concentration of effort toward this primary goal.

—DAVID SARNOFF
in *The Promise and Challenge of the Computer* (1964 Fall Joint Computer Conference).

OUR WEAKNESS IN SPACE

By FRANK DRAKE

THE AUTOMATIC spaceship Mariner 4 is well started on the way from earth to Mars. If it holds to its present course, the ship will sail between the two planets, at a distance of 5,400 miles from the southern hemisphere of Mars, in mid-July 1965. If all the instruments aboard perform according to instruction, nine different scientific observations will be taken simultaneously. Eight of the nine will give simple "yes," "no," or "I count this many" answers to questions previously posed. These will affirm or deny what scientists already believe to be true about Mars. So all will add something to current understanding of Mars. But it is the ninth instrument that promises the greatest potential excitement of the Mariner 4 voyage. It is the only one possessed of great versatility in detection of the unexpected.

This ninth instrument has the function of the human eye. It is a TV camera. During the half hour of Mariner 4's closest approach to Mars, the TV eye will record what it sees for eventual transmission to earth.

Readers of *SR* have studied in these pages some stunning examples of Ranger 7's brilliant TV picture-taking mission on the moon last summer. In about fifteen minutes—half the time allotted to Mariner 4's TV assignment—4,316 photographs were snapped and returned home. In the clearest of them, objects only three feet in size were visible.

Now fair allowance must be made for the fact that Mariner 4 will snap its photos of Mars while passing thousands of miles from the surface of Mars, whereas Ranger 7 did its lunar picture-taking en route to a crash landing on the moon. Furthermore, Mars will be 150,000,000 miles away from earth next July while the moon was only 238,000 miles away from earth when Ranger 7 landed. Nevertheless, it is disappointing to discover that the best we can expect from Mariner 4, with twice the exposure time of Ranger 7, is a total of twenty-two photographs, none intended to show any detail of the Martian scene sharper than details of the moon's face now revealed in pictures taken through the strongest earthbound telescopes.

The prospect is especially frustrating because we now actually possess the practical means of obtaining pictures of Mars with clarity equal to that of the Ranger 7 pictures of the moon.

Why aren't we going to get them?

The answer is that we lack a reasonable system of interplanetary expense accounting, derived from the principle that the one meaningful purpose behind exploration of the space beyond our home planet is acquisition of knowledge.

Spending for design and construction of ever more powerful rockets for exploratory voyages makes sense only insofar as the rockets can gather proportionately more knowledge recoverable by man.

Our recent preoccupation with the moon has obscured this fundamental truth. The moon is so close to us that communication of data has never been a serious problem. Our signal transmission and reception devices are, in fact, capable of handling information that cannot yet be obtained from the moon because our rockets are not yet sufficiently powerful. It would, for example, be possible to transmit consecutive TV pictures of the entire equatorial circumference of the moon—if we had rockets with enough thrust to enter the lunar neighborhood and then maneuver into orbit around the moon in a plane suitable to the equatorial picture sequence.

As our spaceships venture farther from home, however, the situation changes. The same rocket that reaches the moon can carry the same payload to Mars with only nine per cent more push. Though similar proportions might be expected to hold in the sending of news from the spaceship back to earth, they actually do not. The messages weaken according to the square of the distance. Thus, when Mariner 4 passes Mars next July, the Mariner will be 570 times farther from earth than Ranger 7 was when the Ranger met the moon. But the radio signals from Mariner 4 at that point in space and time will, because of the inverse square law, be 325,000 times fainter than were the signals Ranger 7 sent from the moon.

An obvious solution to this communication problem would be to step up the power of the radio transmitter aboard Mariner 4. However, the Mariner's present transmitter weighs 300 pounds and accounts for half the total weight of the spacecraft. Mariner's scientific instruments, on the other hand, weigh only sixty pounds. To make room for a radio big enough to compensate for the signal attentuation would be impossible . . . even a trivially modest increase in transmitter would require serious reduction or perhaps even abandonment of the observing devices, the source of the messages, the justification for the voyage.

An alternate solution to the communication problem can be explained by a close analogy. Suppose you are listening to someone speak in a language with which you are only mildly conversant. If sentences are rapidly rattled off, the slurring of the words, the hissing of the voice, the clickings of the tongue against the teeth, the redundant parts of speech all clutter the context of the message. But if the speaker enunciates each word

—Cornell.

THE WRITER OF THE ACCOMPANYING CRITIQUE of interplanetary exploration is, while still in his early thirties, one of the most famous astronomers alive. Though best known as originator of Project Ozma, the first try at communication with intelligent life on the planets of stars other than the sun, Frank Drake is no wild-eyed irresponsible. He has been head of the telescope operations division of the National Radio Astronomy Observatory at Green Bank, W. Va., and chief of the lunar and planetary sciences section of California Institute of Technology's Jet Propulsion Laboratory. He is now Associate Professor of Astronomy at Cornell University, a member of the astronomy center Cornell runs in partnership with the University of Sydney in Australia, and a member of the astronomical facilities panel of the National Academy of Sciences committee on science and public policy.