The Electronic Grapevine

Computer networks and fax machines accelerate the pace of scientific communication — for good or ill

By IVARS PETERSON

It didn't take long for mathematicians, computer scientists, and then the rest of the world to learn that two researchers had achieved a significant milestone last June in the factoring of large numbers. News of their accomplishment spread as quickly as electrons could carry the message along computer networks linking researchers all over the world.

"Communication is very, very fast," says mathematician Andrew M. Odlyzko of AT&T Bell Laboratories in Murray Hill, N.J., who first heard of the factoring feat directly from one of the researchers via telephone, and soon afterward saw the electronic announcement on his computer screen.

Electronic communication also played a major role in the factoring effort itself. Arjen K. Lenstra of Bellcore in Morristown, N.J., and Mark S. Manasse of the Digital Equipment Corp. Systems Research Center in Palo Alto, Calif., recruited scientists and mathematicians in the United States, Europe, Australia and Japan to help with the project. Each participant electronically received a copy of the necessary computer program and, in turn, supplied the answers to a specific piece of the factoring puzzle.

Manasse and Lenstra then collected the results and, using a powerful computer in Florida, put together all the bits and pieces to complete the factorization (SN: 6/23/90, p.389). The entire collaboration involved about 1,000 computers scattered throughout the world.

For a growing number of scientists, computer networks have become an indispensable part of any research effort, used for such tasks as discussing conceptual issues, exchanging software, revising publications and preparing and reviewing grant proposals. These researchers maintain that networked computers eliminate the distance factor, which so often interferes with collaboration among scientists. Computer networks create electronic communities that give people working thousands of miles apart the feeling of living in a small village, with all the intimacy and ease of communication that implies.

Many scientists and engineers, looking back just a few years, find it hard to imagine how they got along without their facsimile machines and networked computers. To stay current in a field, whether in mathematics, astronomy or electrical engineering, you must have access to a computer network such as Bitnet, they now say. Moreover, the integration of data collection, word processing and electronic mail in one system means that colleagues can read a paper or report, whether in final or draft form, as soon as it's finished — sometimes even as it's being written.

The amount of information carried by computer networks is now immense — and growing astronomically. In 1988, NSFNET, the national research network sponsored by the National Science Foundation, carried 100 million "packets" of information, each a collection of bits carrying an address. By February of this year, network traffic had reached 2.5 billion packets, and the quantity is still growing by an average of 20 percent per month. Incredibly, one recent month's traffic represented 10 percent of all the information ever sent across the network.

But that growth has not come without cost. Misinformation travels just as quickly as established fact. The specter of electronic vandalism hovers over the fragile networks. And the technology required for the long-term care, feeding and storage of electronic information remains rudimentary and largely untested.

To an astonishing degree, electronic mail carried over computer networks and documents transmitted by facsimile machines have already supplanted the more traditional means of formally and informally exchanging scientific ideas and data. And these electronic vehicles are significantly altering the way in which researchers do their work. In particular, electronic communication allows the speedy posting of new findings.

In 1987, news of the discovery of the brightest supernova detected in nearly 400 years swept through astronomical circles well before it hit the front pages of newspapers. Because it was crucial to start taking data as soon as possible, rapid electronic communication allowed astronomers to begin an extensive, coordinated campaign to monitor the supernova within days of its sighting (SN: 3/7/87, p.148).

In another instance, the first suggestions that a Japanese mathematician might have proved a famous mathematical conjecture known as Fermat's last theorem appeared on an electronic bulletin board (SN: 4/9/88, p.230). Subsequent notices carried news about efforts to check the "proof" and, finally, the discovery of a serious flaw.

Many interesting results surface electronically, partly to elicit comments and partly to establish priority — if the results prove correct.

Last year's epidemic of "cold fusion" fever, when the international scientific community confronted the possibility of

forcing atoms to fuse by an electrochemical process (SN: 4/1/89, p.196), offers a striking example of the new role played by electronic communication. Researchers all over the world caught their first glimpse at the suggestive data in the form of fuzzy copies of unpublished manuscripts circulated with the help of facsimile machines. And the web of interconnected computer networks became a kind of international party line, carrying rumors, speculations and other provocative tidbits.

"Bitnet is buzzing," one scientist remarked at the furor's height.

But while the quick spread of information about a potentially revolutionary idea seems an inherently good thing, the scientific community is already concerned about how the new technologies might circumvent the generally slow process of scientific verification and publication. The term "publication by fax" already has pejorative connotations.

On a personal level, users of electronic communication systems face a number of potential hazards. Perhaps because electronic mail is so easy to use and so convenient for those in the know, the number of messages exchanged can become overwhelming. It's not unusual for a scientist to find dozens of messages awaiting his or her return after even a brief absence, and it sometimes takes a considerable amount of time to weed out the trivial from the essential.

Users also have legitimate concerns about security and privacy, especially when they use electronic mail to handle matters that ought to remain confidential, such as ratings and evaluations of research proposals. And there always lurks the danger of a computer "virus" or "worm" either destroying information or impeding communications (SN: 11/12/88, p.310).

Yet all the proposed solutions, such as password systems and the encryption of information, get in the way of communication.

"Yes, you can make secure computers and networks. Systems that outsiders can't easily break into," astronomer Clifford Stoll writes in *The Cuckoo's Egg* (Doubleday, 1989). "But they're usually difficult to use and unfriendly. And slow. And expensive. Computer communication already costs too much — adding cryptographic encoding and elaborate authentication schemes will only make it worse."

Moreover, sending electronic mail, which ought to be as simple as placing a phone call or posting a letter, is no simple matter. Messages launched into the electronic unknown have a significant chance of being inexplicably delayed or getting lost.

Even finding the correct address to which to send a message can prove burdensome, and if the address isn't exactly right, the message doesn't get through. And many researchers, for a variety of reasons, still have no links to computer networks.

John McCarthy of Stanford University comments in the December 1989 COMMUNICATIONS OF THE ACM on the frustrations of using electronic mail and the appeal of facsimile transmissions:

"Electronic mail over computer networks has been in use for almost 20 years. The widespread use of fax is more recent. However, unless e-mail is freed from dependence on the networks, I predict it will be supplanted by the telefax for most uses in spite of the fact that [electronic mail] is more advantageous.

"To become a telefax user, it is only necessary to buy a telefax machine . . . , and to publicize one's fax number. . . . Once this is done, anyone in the world can communicate with you. No complicated network addresses and no politics determine who is eligible to be on what network."

The ephemeral nature of much electronic communication poses a different set of problems — intriguing archival issues with which future historians and others wishing to track the progress of science will have to cope. Long ago, scientists often kept diaries, recorded laboratory results in notebooks, wrote letters — all on paper. Although much of this material has disappeared, enough survives to provide valuable historical and scientific details.

Electronic information faces a less certain fate. Much of it is simply erased, although a portion may end up in some form of electronic storage or get transferred to paper.

However, experience with electronic data storage is still quite limited. Who knows how long magnetic tapes will last, how long polymer coatings on optical disks will survive? Careful maintenance is essential for preserving the encoded information.

NASA's troubles with its reams of space data show how serious the problem can become. A recent report from the General Accounting Office noted that hundreds of thousands of magnetic tapes containing space science data may be rotting away because of inadequate storage, and some data may already be lost because of magnetic tape deterioration.

Moreover, NASA cannot easily identify or retrieve much of its space data. Because the tapes often lack adequate supporting documentation, researchers who want to use this material may need years of detective work to figure out what the data in hand represent. Some tapes are so old that today's computer experts do not understand how they were programmed. Others must be processed by machines so outdated that it's hard to find the machines themselves or the spare parts to keep them going.

Nevertheless, the urge to go electronic seems irresistible. Earlier this year, the National Science Foundation (NSF) and the Defense Advanced Research Projects Agency awarded $15.8 million to the Corporation for National Research Initiatives, based in Reston, Va., to lead a research effort focusing on how to operate computer networks that transmit information at rates of a billion bits per second or more. Such high-speed computer links — several hundred times faster than those now available — would enable researchers to quickly send huge amounts of data, including full-color, animated images and other complex software, from one computer to another.

In addition, the project represents an important part of an effort to develop a national research and education computer network (SN: 6/18/88, p.394).

Various groups continue exploring ways of extending and, in effect, institutionalizing the international scientific party line. A 1989 NSF workshop report exploring how to do this states: "Some of the most pressing scientific challenges facing the United States and the world can be met only through remote interaction with instruments, colleagues and data."

The report concludes: "By providing the first technological base specifically created to support collaboration independent of distance and by increasing productive access to scarce and expensive national scientific assets, the National Collaboratory will significantly increase the productivity of science and engineering, accelerate the pace of discovery and amplify the capabilities of human intellect. . .

"The goal is to build no less than a distributed intelligence, fully and seamlessly networked, with fully supported computational assistance designed to accelerate the pace and quality of discourse, and a broadening of the awareness of discovery."

That's an ambitious goal with potentially far-reaching consequences for researchers and for all the institutions that support their work.

The present, fragile system of interconnected computer networks, no matter how flawed, somehow succeeds in handling a great deal of traffic. Judging by today's rapid rate of growth in network use, it will have to handle much more in the future, with who knows what effects on scientific and mathematical research. Right now, the choice for the individual scientist seems limited to linking up or getting left behind. □