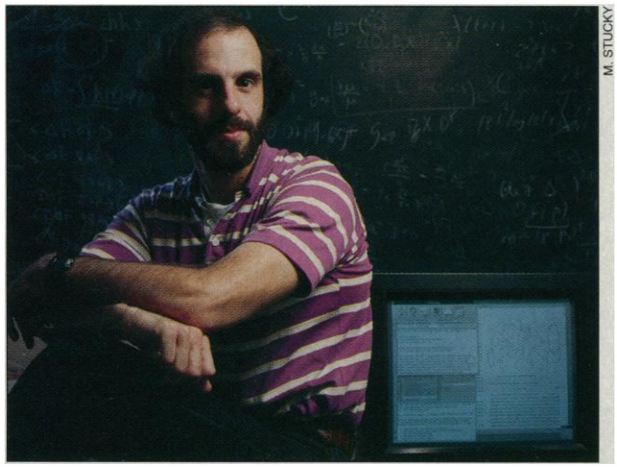
Publication by Electronic Mail Takes Physics by Storm

The American Physical Society (APS) has a vision of the future of physics publishing, in 2020 or so. "It goes like this," says APS president Burton Richter, who is also head of the Stanford Linear Accelerator Center (SLAC). "Any physicist, any place in the country, can turn on his computer and for free browse through the table of contents of any APS journal." Next, adds Richter, this browser "can select those things about which he wants to see an abstract, and then, after deciding what he might read, ask for the article itself and eventually pay for it like you pay your telephone bill."

Paul Ginsparg, a theoretical physicist at Los Alamos and a lifetime member of the APS, thinks that vision of the future looks a lot like the present. In fact, it looks a lot like hep-th@xxx.lanl.gov, which is the Internet address of an electronic bulletin board he created in August 1991. Hep-th (for high-energy physics-theory) can be accessed from almost anywhere through electronic mail. Physicists can submit preprints—unpublished papers—to hep-th, or they can scan a list of the preprints already on the system, read any abstracts that sound interesting, and then request that an entire preprint be transmitted, which takes a second or so and is free of charge.

Ginsparg began his bulletin board with a distribution list of 160 physicists, predominantly string theorists. Sixteen months later, hep-th has 2000 users. "Depending on how you define the cutting edge," says Michael Peskin, a theorist at SLAC, "you can't be on it without being in touch with Ginsparg's preprint board." As a result, hep-th has become, in Ginsparg's modest assessment, "the primary means of information [exchange] within the field." Since February 1992, Ginsparg has augmented that growth by setting up bulletin boards in eight other subdisciplines of physics (see graph on page 1248), and he has been asked to do so for a dozen more, from experimental nuclear physics to nonlinear dynamics and material science. By now, subscribers to one or more of the Los Alamos bulletin boards number more than 8000, and physicists are submitting almost 600 preprints each month.

Notice that these bulletin boards—actually "electronic preprint archive and distribution systems" rather than informal message boards—don't constitute peer-reviewed electronic journals like those being experimented with in several fields outside physics. And some scientists are skeptical of this notion of unfiltered scientific communication. Because bulletin boards lack peer review, says Benjamin Bederson, editor-in-chief of the APS, they can be considered no more than an experiment that "works beautifully in a small community of people who work in harmony with each other and who know each other's reputations."



M. STUCKY

String theorist and networker. Paul Ginsparg of Los Alamos, architect of preprint bulletin boards for physics.

But other observers have started to wonder whether bulletin boards, if they adopted an electronic system of peer review, could replace established journals in physics and perhaps some other fields. Says Louise Addis, associate head librarian at SLAC, "There's a free-floating anxiety in the academic community that this whole system of journals is going to be up-ended and destroyed by the bulletin boards." And one thing is certain: Whereas the handful of peer-reviewed electronic journals that already exist have had little or no impact on their relevant fields, Ginsparg's bulletin boards are, as Addis puts it, "taking over the world."

A preprint culture

Two factors made the physics community ripe for an electronic revolution, says Ginsparg. One is what might be called the preprint culture of physics. For keeping up with the latest developments, physicists have long relied not on journals but on preprints of articles submitted to journals. Though not peer reviewed, they are available months earlier, and the faster, more efficiently and less expensively physicists can get and distribute preprints, the better they like it. "In the dark ages," says Andy Strominger, a theorist at the University of California, Santa Barbara, "people used to publish in journals. Then came this preprint system. Copying got cheaper and everybody started mailing out copies at the same time they submitted them to journals." Ginsparg's bulletin boards, says Strominger, were the obvious next step. "Now everybody sends their papers to Ginsparg's bulletin boards."

The technology that made the bulletin boards possible was electronic mail, which physicists had been relying on as their primary means of communication since the mid-1980s. When TeX, a scientific word processing system created by Donald E. Knuth at Stanford University, became the standard in the field by 1985, physicists found they could easily send manuscripts, including mathematical formulae and graphs, back and forth over the networks to collaborators and colleagues. "The bulletin boards," says Ginsparg, "were a natural transition from the way people were already working."

Earlier attempts to set up similar databases had failed to catch on, perhaps, Ginsparg thinks, because networks weren't yet extensive enough. But by 1991, Joanne Cohn, a young string theorist then at Princeton's Institute for Advanced Study, had begun distributing electronic preprints to keep her friends and acquaintances in the field abreast of the newest developments. Eventually, her mailing list numbered almost 100.

Cohn's efforts spurred Ginsparg to conceive his system when he and Cohn were both attending a string theory workshop at the Aspen Center for Theoretical Physics in the summer of 1991. There, Ginsparg heard colleagues complain that they were afraid to take vacations for fear that, by the time they returned, their disk storage allocations would be overwhelmed by 40- to 100-page preprints flooding their mail accounts. After talking over the problem with other researchers, Ginsparg decided on a more efficient system. "I realized," he says, "that the way to do it was to just receive all the papers, store them in one central place, and then send out only the abstract. [A user] could typically determine on the basis of the abstract whether or not to read the paper."

He also did a few calculations to test the feasibility of the idea. What surprised him, he says, "was that such a system was immediately realizable, but would not have been a few years earlier. It was driven by the revolution in desktop work stations and inexpensive disk storage." Ginsparg estimated that

an average paper with figures would require 50 kilobytes of storage space. A rapid-access gigabyte disk drive, which then cost under $2,000, "could hold 20,000 papers at an average cost of 10 cents per paper."

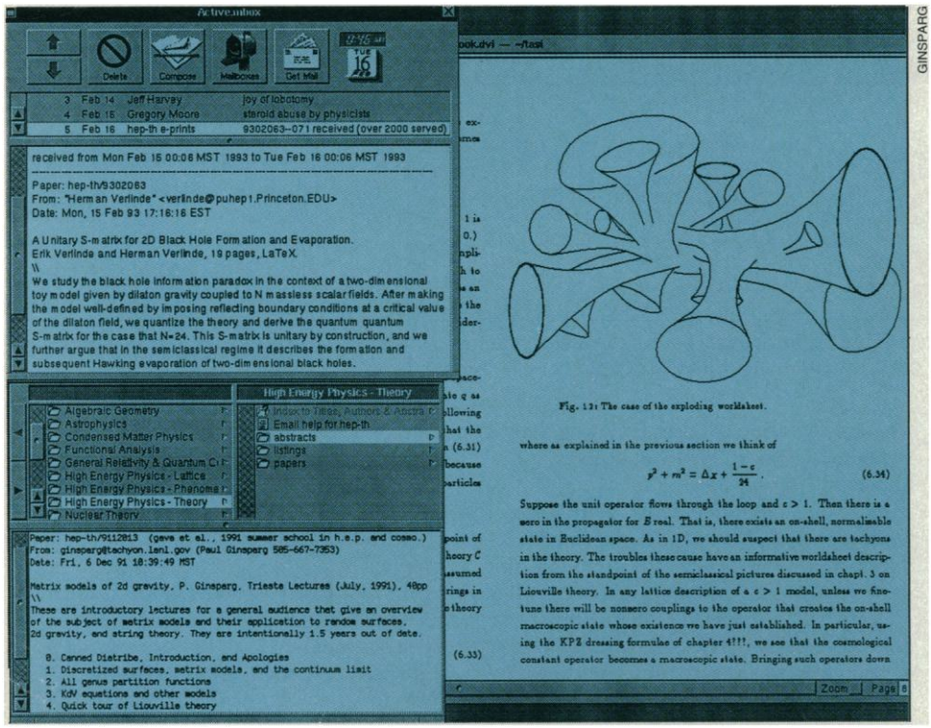
It took Ginsparg several afternoons in August 1991 to set up the system at Los Alamos. His only worry was whether or not he could automate the system: It would have to accept and process an incoming preprint, strip off the title and abstract, and then maintain a database and distribution system, "preferably with zero interference from a human being." Apparently, he succeeded. "I worry about a janitor unplugging the computer," he says, "but I don't worry about the software screwing up."

After the system went online, Ginsparg not only added new bulletin boards but also modified the system design in response to user requests. He developed an automatic archiving function that stores the papers indefinitely—"Since electronic storage doesn't cost anything," he says, "why not keep them indefinitely?" He also added search functions so that users reading a preprint can call up any other preprint it references by entering an identifying number.

Ginsparg isn't the only researcher now experimenting with bulletin boards, but the few analogous efforts have had a much slower start, perhaps because they aren't as convenient. A mathematics preprint bulletin board set up in 1990 at Yale University, for example, requires a specific piece of communications software, instead of being accessible through ordinary electronic mail. According to Katherine Branch, head of science libraries at Yale, only 80 to 100 users log on to the Yale bulletin board each month. On the other hand, says Branch, "I've spoken to physicists here at Yale who say that it is essential now to consult the Los Alamos bulletin boards. They cannot work without them."

SLAC's Peskin feels that way. He has set up his computer so that when he logs on every morning, the first thing it displays is a list of new abstracts from a bulletin board. "I read them," he says. "Very often I'll call for the manuscript itself from the bulletin board, have it in my reader, and print it out the same day." Regular users of the bulletin boards, like Peskin, say that they now value journals mainly as archives, not as sources of current information.

What's more, electronic preprints have effectively democratized high-energy physics. As Ginsparg likes to point out, his bulletin boards are now accessed by regular users on every continent except Antarctica. As a result, they bring up-to-date information to physicists in developing countries, who may not have access to good libraries. Other physicists point out that even in developed countries they open up what had been a cliquish system of preprint distribution. "The [paper] preprint system was terribly unfair," says David Mermin, a Cornell physicist who has written several editorials in *Physics Today* on the need for electronic journals. "If you're not a member of the in-group, you have to wait for the journal to come out. Now anybody who has access to a computer can receive these lists and get information." SLAC's Addis agrees. "On the surface," she says, "the bulletin boards just appear to be a much better, more even-handed way to distribute preprints and information."



What's on. A subscriber to the preprint bulletin boards can choose a physics subspecialty and look at the titles and abstracts of new submissions *(left side of screen)*, then retrieve the full text of a paper, complete with figures *(right)*.

How wide a net?

Those attractions don't guarantee that bulletin boards will make inroads into disciplines other than physics, however. In many cases, the preconditions are missing: a discipline-wide software standard for word processing and a habit of exchanging information via preprints rather than journals. Allen Bard, for instance, a University of Texas electrochemist and editor-in-chief of the *Journal of the American Chemical Society*, points out that his colleagues in electrochemistry are likely only to send out a half-dozen preprints to researchers doing closely related work. Joshua Lederberg, Nobel Prize–winning geneticist and former president of Rockefeller University, adds that in molecular biology, preprints "are not a well-honed formal mechanism."

Even within physics, the future of the preprint bulletin boards will depend on how they address some broader issues, in particular the questions of copyright and peer review. Legally, explains Ann Okerson, director of the office of scientific and academic publishing at the Association of Research Libraries, what the bulletin boards do can be considered copyright infringement, because journals own copyright to any work they accept and publish. As a result, some electronic information services, such as the *High Tc Update*, a newsletter run out of the Ames Laboratory in Iowa, and the Yale math bulletin board, list only preprint titles and authors and then direct readers to the authors themselves for the actual manuscript. In contrast, Ginsparg's system, by storing and distributing the full text of preprints, in essence competes with the publishers.

Ginsparg points out that journal publishers have already learned to look the other way at the hundreds of preprints physicists regularly distribute in advance of publication. He has worked on the assumption that the journals would view bulletin boards simply as an electronic version of the paper network. But copyright may become an issue, he concedes, if journals perceive that they're losing subscribers to his bulletin boards.

A deeper concern, at least from the users' point of view, is that the lack of peer review is opening the way to junk science—a concern known in the lingo of the bulletin boards as the noise issue. One lesson of fevered episodes like cold fusion or even the

breakthrough in high-temperature superconductors is that the quality of scholarship drops precipitously when researchers are rushing into print. And some researchers worry that electronic bulletin boards may encourage that kind of haste even in normal times. "My main concern," says one SLAC physicist, "is that people can put out preprints without any thought whatsoever. If you're mailing out 1000 preprints around the country, at least you have to give some thought to what you're going to do. But if all you have to do is push the return key, and it goes to 1000 people..."

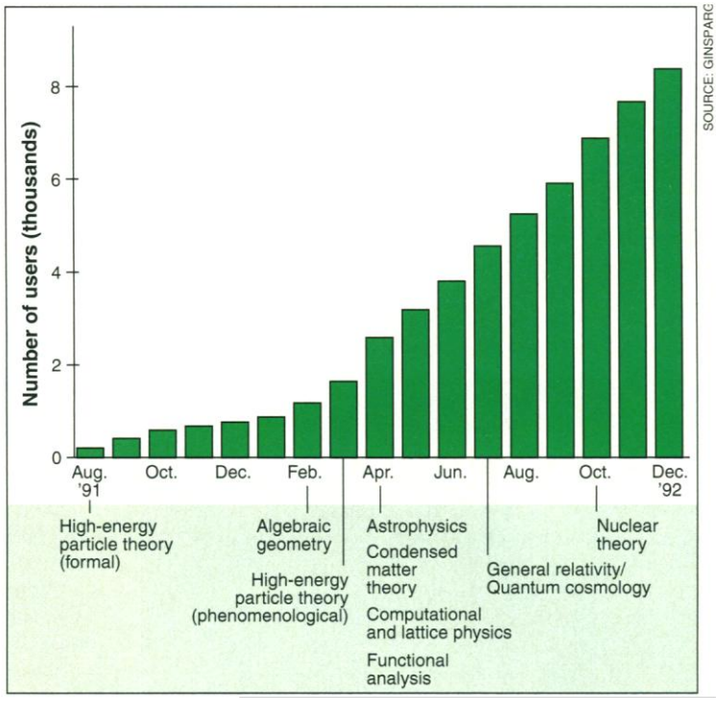
The proponents of the brave new world come back with this defense: The inevitable "noise" can be filtered out by a reviewer whose rigor you can trust—namely yourself. "It's fairly easy to tell if a paper is junk if you know the field," says Mermin. Thus, so the logic goes, researchers who repeatedly submit sloppy work to a bulletin board will find after a while that their peers are no longer bothering to pay attention.

But recognizing poor science may be easier in the theoretical fields that spawned the first bulletin boards than in experimental fields, where a reviewer has to evaluate experimental design and statistics as well as mathematical reasoning. What's more, even in physics the bulletin boards so far offer no substitute for the cachet that comes from publication in a peer-reviewed journal such as *Physical Review Letters*. Those drawbacks leave many people intrigued by bulletin boards but looking for a way to combine the technological ease and efficiency of electronic mail with the established editorial processes of the scientific journals. "In the end," Nobelist Lederberg told *Science*, "we have to marry the best elements of the two."

Ginsparg accepts this, and he has already envisioned one way of doing so: splitting the bulletin boards into multiple levels. The highest level would be populated by papers that had been rated as significant by a chosen body of reviewers. The lowest level would be open to all preprints. Mermin adds that, as a substitute for the imprimatur of a prestigious journal, the APS or some other scholarly organization "could simply rate a paper for people who want to have it rated" for purposes of tenure or grants.

From bulletin board to journal?

If the bulletin boards were to adopt this kind of filtering and reviewing, says John Franks, a Northwestern University mathematician who chairs an American Mathematical Society committee on electronic products, "it blurs the line between preprints and electronic journals." And that means that if the professional societies and publishers that produce scholarly journals don't respond quickly to the electronic opportunities, they may find that the preprint bulletin boards have already done so. "Personally, I don't think that would be particularly bad," says Franks, "but it's going to eliminate a lot of revenue for a lot of publications and societies, including the American Mathematical Society, if that happens."



Physicists tap in. As bulletin boards have been added, the total number of users has grown. A dozen more subdisciplines are in the works.

Not that publishers have been ignoring the possibilities. Elsevier Science Publishers, for example, has two electronic-publishing experiments in the works. One, called TULIP, will make the Elsevier materials science journals available in electronic form to a group of nine universities. The other, expected to start in April, will be an electronic preprint service in which articles accepted by *Nuclear Physics A* and *Nuclear Physics B* but not yet printed will be made immediately available to subscribers over the network. Such a system, says Henk van der Rijst, a deputy director at Elsevier, will shave 5 months off the time it usually takes a paper to appear in print. The APS, says Bederson, is also planning an experiment in electronic journals in conjunction with Los Alamos in which it will publish all or part of one APS journal online.

The APS hopes to ensure a readership for its electronic publication by launching it as a version of an established journal that already has prestige and visibility. Lack of both, after all, seems to be handicapping the few existing experiments in online journals, which have been launched as brand-new publications. The *On-line Journal of Current Clinical Trials (CCT)*, for instance, inaugurated last July by the American Association for the Advancement of Science and the Online Computer Library Center, has published only seven refereed research articles since then. Even after arranging to collaborate with the *Lancet* in a parallel publishing venture (*Science*, 4 September 1992, p. 1341), CCT is still not getting nearly the number of submissions that the editors hoped for. Eventually, though, CCT editor Edward Huth believes that the advantages of an electronic journal—quick publication, within 48 hours of receiving positive referee reports, and no limit to length of papers—will win over the community.

For Bederson of the APS, however, such slow starters confirm what he says is his organization's major concern about electronic publishing, even if concerns about peer review and copyright can be allayed. "It's not entirely clear that people like to read journals on the screen," he says, nor that "the screen version will ever replace the paper version for plain convenience."

Ginsparg, not surprisingly, disagrees. He not only considers the electronic journals inevitable, but he thinks that even his bulletin boards are far too conservative considering the technology available. Ginsparg foresees eventually transmitting interactive papers, in which equations can be solved and graphed by readers online, references called up and studied in window formats, and even comments from reviewers accessed by the click of a mouse. "All we've done so far," says Ginsparg, "is naively transferred the printed form to an electronic form. We haven't really gone that far beyond the century-old mentality other than to improve the distribution."

With Vice President Gore trumpeting the coming of a fiber-optic data highway and plans in the works for other new computer networks, Ginsparg adds, his bulletin boards should be viewed simply as forerunners of what will be available down the line. "Now is the time," he says, "for publishers to start developing, testing, and getting involved, so that they can be there when things really explode."

–Gary Taubes