scientific value as the flight might have had. Because helium has less lifting capacity than hydrogen, half the scientific equipment that was supposed be aboard had to be dumped. As would become evident three decades later, the debate over manned-versus-unmanned exploration of the high frontier was far from over.

False Prophets

"Great Expectations: Why Technology Predictions Go Awry" by Herb Brody, in *Technology Review* (July 1991), Building W59, MIT, Cambridge, Mass. 02139.

It was the bright world of tomorrow. Solar cells and nuclear fusion were to provide pollution-free electricity, automobiles were to run on batteries, factories were to rely extensively on robots, and videotex terminals were to be important fixtures in American homes. But the technological future envisioned just a few years ago has failed to arrive, notes Brody, a senior editor of *Technology Review*. Innovations like nuclear fusion "seem, as always, to be at least a decade from practicality."

That's the way it usually goes with experts' technological forecasts, Brody says. And the result, he adds, is not just red faces but misspent scientific careers and misallocated money for research.

Why are the much-publicized predictions so often wrong? Several factors are involved, according to Brody. One is conflicts of interest. "Interested parties include not only the companies that stand to make money from a technology but also scientists whose funding grows and wanes with the level of public excitement." Researchers working on nuclear fusion, for instance, "have kept up a steady barrage of 'breakthrough' reports since the mid-1970s."

Consulting firms such as Dataquest and Business Communications, which analyze the business potential of emerging technologies, feed the bonfires of optimism. "Over the past decade," Brody writes, "outfits like these have foretold billion-dollar markets for artificial intelligence, videotex, and virtually every other new technology that laboratories have reported." Part of the problem is that the market researchers survey the wrong people: the new technology's vendors. Surveying potential buyers would make for more realistic projections, but also would be much more expensive.

The news media, of course, are ever willing to give hype a hand. Once published, the forecasts of "the experts" take on a life of their own.

False optimism about new technologies is also encouraged by underestimating the potential of old ones. "Theoretically, it's been possible for the past 25 years for computers to eliminate photographic film," says Du Pont executive Alexander MacLachlan. But thanks to continuing chemical refinements, he notes, silver-halide film has remained in the center of the picture.

"Any truly revolutionary technology defies easy prediction," Brody says. Computer designers in the mid-1970s still aimed to build ever larger behemoths. Few appreciated the value of personal machines. In fact, Brody says, from IBM's study then of what computer users said they wanted, the firm "reportedly concluded . . . that PCs would appeal only to a small group of hobbyists."

A Plague Of Scientists?

"Do We Need More Ph.D.'s, or Is Fewer Really Better?" by Constance Holden, in *Science* (Mar. 1, 1991), American Assoc. for the Advancement of Science, 1333 H St. N.W., Washington, D.C. 20005.

Some specialists are worried that the United States is producing too few scientists, but not Georgia State University economist Paula Stephan. She thinks there already are far too many of them, reports Holden, a *Science* writer.

There has indeed been a huge growth in the number of Ph.D. scientists during the past half-century. In 1940, there were 320 doctoral scientists and engineers for every one million Americans over the age of 22; by 1966, the total had reached 778, and now it stands at 2,000. This vast increase in quantity, Stephan maintains, has resulted in a discernible decrease in quality.

"The average quality of people going into science in the '70s and early '80s," Stephan claims, "was not as high as in the '50s and '60s in terms of motivation, ability, and interest in science." In the 1970s, according to studies by Stephan and Sharon G. Levin of the University of Missouri, recent Ph.D.'s in particle physics were producing, over a two-year period, an average of nine fewer articles than their predecessors in the 1950s did.

The quality of an individual scientist's work suffers when he does not have adequate resources, stimulating colleagues, and due recognition, she argues. These are available at top-level research institutions and national laboratories, but most new science positions have been created elsewhere. A physicist's chance of being at one of those "right places" plummeted from 50 percent in 1963 to 17 percent in 1973.

The large number of scientists, asserts Stephan, also has encouraged intense competition among them, with the result being not only an inordinate amount of time spent chasing research grants but a general avoidance of research that could be important but may well not pan out.

Further contributing to the putative decline in the quality of scientists, Stephan contends, has been the shift by increasing numbers of very bright students, starting in the early 1970s, away from scientific careers and toward the more lucrative fields of business, law, and medicine.

Critics of Stephan's argument are not in short supply, Holden found. "The young assistant professors I've seen are more capable and more brilliant than ever in the past," asserts Richard Atkinson, chancellor of the University of California, San Diego. Critics say that more Ph.D. scientists are required to sustain the U.S. economy's technological edge. Unless "we're just going to change the whole society we're living in," Atkinson says, we need to have more scientists.

RESOURCES & ENVIRONMENT

Going To Market For Cleaner Air?

"Incentive-Based Regulation: A New Era from an Old Idea?" by Robert W. Hahn and Robert N. Stavins, in *Ecology Law Quarterly* (Vol. 18, No. 1, 1991), Boalt Hall School of Law, Univ. of Calif., Berkeley, Calif. 94720.

For more than two decades, economists have been pushing the idea of market-based environmental regulation. In recent years, Congress and others involved in making policy have started to listen. When the Clean Air Act was overhauled last year, for example, Congress and the Bush administration included a "tradeable permit" system for controlling acid rain. Under this scheme, companies are permitted to generate certain levels of sulfur dioxide; if they keep their emissions below those levels, they can then sell their surplus permits to other firms. This gives companies economic incentives to keep their emissions down.

In the past, Congress and the Environmental Protection Agency (EPA) have favored the "command-and-control" approach to environmental protection, compelling firms to use certain pollution-control equipment or to meet certain emission standards.

That sort of regulatory approach may work to control pollution, say Hahn, a resident scholar at the American Enterprise Institute, and Stavins, a Harvard professor of public policy, but the method is inef-