majors, only 700 proceeded to obtain doctorates. But there seems to be no shortage of newly minted science and engineering Ph.D.s., say Gibbs and Fox, in part because of a steady rise in the number of foreign students, most of whom remain in the United States to work. Since 1966, the annual production of science and engineering Ph.D.'s has soared 130 percent, while the U.S. population has increased only 35 percent. And if more Ph.D.'s were needed, universities could probably get them simply by filtering out fewer undergraduates, observes Glen S. Aikenhead, a professor in the University of Saskatchewan's College of Education.

Contrary to the perpetual warnings of the crisis-mongers, it is doubtful that schooling in science before college has much impact on U.S. economic competitiveness, the authors maintain. For the vast majority of students, they say, it "is utterly irrelevant."

In all the crisis chatter, Gibbs and Fox point out, "the question of what schools *ought* to teach about science" is often overlooked. But among science education researchers, teachers, and practicing scientists, "a consensus has begun to emerge...that schools should turn out scientifically literate citizens, not more candidates for the academic elite." Such citizens, having a broad understanding of the scientific enterprise, would be more aware of its important role in society—and perhaps more inclined to give it their generous support.

Freelancing in the Sky

"Delayed Takeoff" by Eric Scigliano, in *Technology Review* (Sept.–Oct. 1999), 201 Vassar St., W59-200, Cambridge, Mass. 02139.

The Federal Aviation Administration (FAA) set out in the mid-1990s to revolutionize air traffic control. Today, with the airways more congested and planes more prone to delay, the "free flight" revolution is on hold, reports Scigliano, a senior editor at the *Seattle Weekly*.

Widely credited to William B. Cotton, now United Airlines' Air Traffic and Flight Systems manager, the "free flight" idea is that pilots would be liberated from the rigid, circuitous routes imposed by ground-based air traffic control, choosing the quickest, most fuel-efficient paths around wind and weather. Advanced satellite, computer, and communications technologies would keep aircraft from crashing into one another.

As Cotton saw it decades ago, Scigliano explains, "Each plane would maintain two electronic surveillance zones: an inner 'protected zone' around itself, nestled in a larger 'alert zone' spreading out in front. To keep the protected zone inviolate, any overlap of alert zones would send a warning, prompting course corrections and restrictions."

The Traffic Alert and Collision Avoidance System—in which planes send out radio signals and interpret the responses from other planes—was an early step in that direction, and has been required on all U.S. passenger aircraft since 1993. After congressional hearings and a 1995 government-industry task force report, the FAA launched an ambitious project to test new avionics (on-board instruments and systems) for communications, navigation, and surveillance.

But this grand free-flight plan "crashed and burned," says Scigliano, "thanks to lack of industry (and, consequently, congressional) support." In its place, two smaller and less costly projects have arisen: pared-back avionics trials, and an effort to streamline ground-based air traffic control with better software. Traffic controllers, Scigliano notes, "are relieved that neither program threatens to eliminate their jobs."

Advocates such as Cotton say that free flight is being implemented much too slowly. The current air traffic control system is increasingly overloaded. "Again and again," writes Scigliano, "aircraft simply 'disappear' from controllers' radar screens." Even Air Force One vanished twice in 1998. To compensate for such lapses, controllers expand the distance between planes, increasing delays and congestion.

"With about 21,000 commercial flight departures each day, a number variously projected to grow by two percent to five percent a year," Scigliano writes, "air planners have moved from lamenting congestion to invoking the dreaded 'G' word": gridlock.