rising defense expenditures will drain critical technological resources away from more productive economic sectors.

"The shift from energy into defense doesn't bother me from the standpoint of R & D," says Arthur Bueche, "for it will stimulate high-technology industry." Lester Thurow, professor of economics at MIT, is less certain. "If you put more dollars into defense and less into the civilian economy, that can't be a positive thing for civilian industry," he says. Moreover, Thurow argues that "military R & D is moving farther away from the civilian economy than it used to be." At one time, it was possible for Boeing to develop the 707 for military needs and then market it to commercial airlines, but most weapons development now has little commercial potential: "Nobody has yet figured out what to do with a submarine in the civilian economy," Thurow points out.

As far as international competition is concerned, it should be noted that until the late 1960's, the United States devoted a far higher share of its GNP to research and development than any of its foreign competitors. The Western industrial countries are now devoting about the same proportion as the United States, however, which means that in terms of nonmilitary R & D, they are spending at higher levels.

President Reagan's crushing victories on the budget and tax bills have thus moved the U.S. economy into relatively uncharted waters. If the Administration's assumptions about what people will do with their tax breaks is correct, then industrial R & D and technological innovation could be big winners. If not, then the whole economy will be in for some tough sledding.

—COLIN NORMAN

FAA Plans to Automate Air Traffic Control

In the future, computers will take over air traffic control decisions. Human controllers will no longer have stressful jobs.

As the United States gears up to replace striking air traffic controllers, the Federal Aviation Administration (FAA) is making plans to significantly change the nature of many air traffic controllers' jobs. In 10 years, and at a cost of $1 billion, the FAA hopes to have computerized en route air traffic control to such an extent that at least 50 percent fewer controllers will be needed and those that are needed will be computer managers. The stressful aspects of the job may, thereby, be reduced.

The FAA wants to develop a system, called Automated En Route Air Traffic Control (AERA), in which sophisticated transponders on airplanes communicate with air traffic control computers. The computers would be programmed to determine optimum flight patterns, to ensure that planes do not collide, and to clear planes along their routes. The advantages of such a system would be fuel savings, increased safety, and increased productivity. Congress has so far authorized funds for the development of AERA but the FAA has not yet requested funds for its implementation.

Aircraft today frequently fly at low altitudes, which wastes fuel, or on circuitous routes simply because there is a limit to the amount of information the mind of a human air traffic controller can handle. Because computers can keep track of more airplanes than humans can and can be programmed to design optimum flight paths for all of the planes, the automated air traffic control system should save substantial amounts of fuel. Even a 3 percent savings in fuel could translate into a 30 percent increase in airline profits, according to Edmund Koenke, deputy director of the FAA's Office of Systems Engineering Management.

In addition, an average of 1.5 air traffic controller errors occurs each day. Half of these errors are caused by lack of coordination between controllers, or by controllers' inattention, lack of communication, or poor judgment. Such errors would presumably be eliminated by AERA.

What AERA would not do is control aircraft at terminals. "No one is really talking about helping aircraft take off or land automatically or worrying about ground-to-ground collisions," says a Washington area consultant. "Terminal control is not amenable to automation in our lifetimes," he remarks.

The use of computers in air traffic control is nothing new, but computers so far have been used to aid humans in making decisions rather than to make decisions for them. For example, computers now are used to keep track of where planes are and where they are expected to be. If the computer predicts that two planes may get too close, an alarm goes off to alert the traffic controllers. Computers also monitor planes' altitudes and warn the controllers if a plane may be flying too low over a mountain range or too close to the ground. But if the computers used today fail, the controllers can continue their jobs without them. This may not be possible when computers actually make the decisions that air traffic controllers make today. Koenke explains that the computers would "handle traffic automatically and possibly differently than the human mind would. If the computer fails, the controllers can't go back to the old way."

If pilots are to depend so totally on computers, it is essential that the system be reliable. But even with the best computers and the best computer programming available, no computer is completely fail-safe. Therefore, says Koenke, there must be dependable backup strategies such as plans for adjacent computer centers to take over if one center's computers fail. The aircraft also would be provided with monitors so that, at the very least, they would not collide if the computers fail.

Despite this heavy burden of reliability, the FAA and its consultants, which include the aviation industry, are optimistic that the task is feasible. "We've never really done an automatic real-time command and control system before. But the technology is there," Koenke remarks.

The FAA has contracted with Mitre Corporation to design the software for the system. To do this, Mitre is using computer simulators. One computer acts as the airplane and is programmed with actual flight plans. Another computer is the controller and is supplied with data on other planes in the airspace, weather conditions and other pertinent data. In this way, the Mitre programmers can test

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the performance of the air traffic control computer programs.

Although Koenke thinks that AERA could go into effect in 10 years, at least one engineer who is familiar with the project thinks 10 years is a very optimistic estimate. Twenty years would be more like it, he says. "This is a very hairy system." But he does think the system is feasible and desirable.

What the air traffic controllers will think of the new system is not yet clear. The FAA has not specifically consulted the Professional Air Traffic Controllers Organization, which is the controllers' union, although it discussed the project with individual controllers and Koenke recently gave a briefing on the project at a controllers' convention. Ray Alvarez, deputy director of air traffic service at the FAA, explains that, "Not too many controllers have been exposed to AERA because this is long-range engineering." But if the FAA's plans are completed, controllers will have to be retrained and the selection criteria for new controllers will have to be changed. "We will be more computer-oriented in our selection," says Alvarez. "The people we have now are used to making quick decisions. They get bored sitting around." However, when computers make the critical decisions, sitting around will be a large part of the job.

Both Alvarez and Koenke stress that the FAA has no intention of laying off controllers when the computerized system comes in. Instead, the agency will be able to avoid hiring thousands of controllers it would have needed to handle the projected 40 to 50 percent increase in air traffic 10 years from now.

In order to prepare for AERA, the FAA plans to order new computers that are large and sophisticated enough for automated air traffic control to replace the outdated computers it now has in air traffic control centers. The agency has not yet decided which computers to order and it concedes that computer manufacturers are concerned about their liability in case one of their computers fails while being used for AERA. So far, both the Airline Pilots Association and the Air Transport Association have no official comment to make on AERA.

—GINA BARI KOLATA

Limping Accelerator May Fall to Budget Ax

Science adviser sees no bailout for U.S. particle physics program; upshot could be the ditching of Isabelle, a half-built accelerator that has already consumed $130 million

A turbulent mix of technical, budgetary, and political forces are conspiring to bring about the demise of Isabelle, a one-half billion dollar particle accelerator under construction at Brookhaven National Laboratory on Long Island that would be the most powerful and expensive in the history of U.S. particle physics.

After nearly a year of stepped-up research costing some $15 million, the architects of the machine still have not settled on a design for Isabelle's 1100 superconducting magnets—the heart of the project. In the meantime, cost estimates have climbed from $420 to $500 million, budget cutters in the Reagan Administration have clipped $20 million from the fiscal 1982 construction budget, and a rival machine built by the Europeans has performed a brilliant end run around Isabelle.

Rising costs and schedule delays have resulted in a warning shot from a group of top U.S. physicists who advise the Department of Energy (DOE), which funds the Isabelle project. In a report that among other scenarios envisions abandoning the machine, the group said in May that Isabelle's growing appetite for dollars will "devastate" the U.S. high energy physics program unless there is a financial bailout. Whether this money will materialize is open to some doubt. The President's science adviser, who visited Brookhaven in June, recently told *Science* that it is "unrealistic" to expect such increases. "We've got a double problem," says George A. Keyworth in a revealing bit of bureaucratic understatement. "We still don't know the best way to build the accelerator, and the cost is rising very rapidly. Clearly, we have to ask ourselves in great detail what the composition of the best U.S. high energy physics program can be under realistic budget expectations."

Despite the darkening horizon, construction of Isabelle continues at breakneck pace. This spring the finishing touches were put in a 2-mile-long circular tunnel for the superconducting magnets, and construction costs have now climbed over the $100 million mark. (Total research and development costs have passed $30 million.)

If Isabelle were terminated, the empty concrete tunnel would become a monument to the most expensive technical failure in the history of U.S. science. The shutdown would also be a near-mortal blow to U.S. physicists struggling to beat their European rivals in the race to discover new subatomic particles. Says one eminent physicist, who asked not to be named: "I think the community sees the writing on the wall. There is a lot of last-minute planning going on, but Isabelle is probably as good as gone. It's a very complicated and unfortunate happening in high energy physics. I just hope the community can recover."

A decision concerning Isabelle's fate is due soon. In September, a committee of the High Energy Physics Advisory Panel (HEPAP), the top 15 physicists who advise DOE, will meet with DOE officials, Brookhaven administrators, and representatives of the National Science Foundation to try to arrive at a strategy for Isabelle and to chart a course for the future of the U.S. particle physics program. Keyworth says he is following the deliberations closely. A final decision, outlining either the choice of magnet design for Isabelle or a schedule for termination of the project, will be announced by DOE officials sometime this fall.

An ironic twist is that the magnet problems, which originally touched off Isabelle's woes, have now almost been solved (*Science*, 21 November 1980, p. 875). Model magnets built from the original design still have minor flaws, but models from alternative designs that have been the subject of an intense, year long R & D effort are starting to reach and surpass design goals in certain areas. Most importantly, the field strength of the magnets is reaching 5 teslas within a day of testing. Slowness

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