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plans to order new computers that are large and sophisticated enough for automated air traffic control to replace the outdated computers it now has in air traffic control centers.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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or the inability to reach the desired field strength was the major stumbling block in the recent past. The problem now is that even exceptionally good model superconducting magnets still need about 2 years of intense R & D prior to production. It follows that the first magnets based on an alternative design would not start rolling off the production line until fiscal 1984, and Isabelle would not be complete until 1988—some 2 years behind the current schedule and 4 years behind the optimistic schedule posted when Isabelle was first conceived. Inflation and added research costs would push up the price, some estimates reaching $600 million. "There has been a technical turnaround," says Nicholas Samios, deputy director of high energy physics at Brookhaven, who, after the latest round of management shake-ups in June, became head of the Isabelle project. "The ability of the magnet makers to deliver has gone up enormously in the past year. But questions still arise because of increasing costs and the expanded time scale."

Delays are especially worrisome because European physicists may soon skim off the easiest discoveries in Isabelle's energy range. Physicists at CERN in Geneva, Switzerland, have just switched on an innovative machine that is first in the world to break into the energy range where one of the most elusive and long-sought theoretical particles, the intermediate vector boson, is thought to exist (*Science*, 10 July, p. 191). Known as a proton-antiproton colliding beam storage ring (CERN $p\bar{p}$ in the figure on page 850), the machine was not even envisioned when plans for Isabelle first emerged in 1974. Yet opening up this energy range was clearly in the minds of Isabelle's designers. In a 1978 conceptual design report for Isabelle,* the search for weak vector bosons was listed as the premier goal.

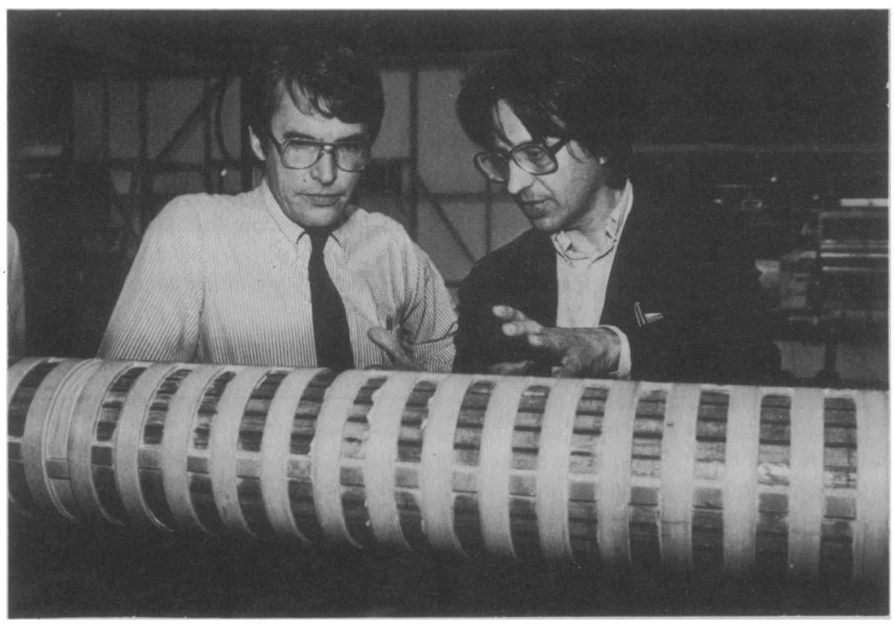
In a last-ditch attempt to decrease costs and put Isabelle back on schedule, designers at Brookhaven are now considering the importation of superconducting magnets under production at a rival lab halfway across the country—Fermilab in Illinois. The Fermilab magnets (at 4.2 teslas) are not as strong as Isabelle's and have had problems in the past, but they are now workable and are being installed in the next-generation Fermilab machine, the Tevatron. By the fall of 1982, the magnet factory at Fermilab will be free, and finished magnets could be shipped to Long Island and installed in Isabelle's empty tunnel. A successful hybridization would mean that Isabelle could start doing physics sometime in 1986. A price would have to be paid for this 2-year speedup, however. Since Fermilab magnets are built to different specifications, the energy of Isabelle would drop from 800 to 700 billion electron volts (GeV), and the luminosity, perhaps the most critical factor of all, would fall, ending up about 100 times lower than planned. (In a hopeful best-case scenario, luminosities of 10^{32} might be achieved, a drop by a factor of 10.) Luminosity is a measure of how often particles whirling about an accelerator collide and thereby provide events for experimentalists to study. Luminosity can determine whether a physicist waits minutes instead of weeks to gather significant data. Since a loss of luminosity is so critical, it is envisioned that the hybridized Isabelle, after being switched on in 1986, would have her luminosity boosted up to original design goals. This would entail the building of a special booster accelerator ring (of about 100 GeV) that would be finished in 1988. The booster ring itself would be a multimillion-dollar construction project.

The technical feasibility of this so-called phased approach, especially the second phase, is not yet known. The design is currently under intense scrutiny at Brookhaven, and, according to DOE officials, Samios has until 1 September to submit a report on whether the phased approach can extricate Isabelle from her technical problems.

An advertised attraction of the phased approach is that it would allow the breaking apart of particles other than protons. As currently designed, Isabelle is a proton-proton colliding storage ring. One ring of superconducting magnets that pushes protons to nearly the speed of light is interlaced at six points with a second ring. Proton collisions take place where the beams cross. With the phased approach, the 100 or so GeV booster ring would allow the introduction of electrons, so that proton-electron collisions could be studied. "I think the physics of the phased approach would be very interesting," says Samuel Ting, a Nobel laureate from MIT who was one of six physicists to visit Brookhaven in June in order to evaluate Isabelle's problems and potential for DOE. However, some physicists contend that the introduction of the subject of electrons into the Isabelle debate is an evasive shift of tactics. "The thing approved by everyone was a high luminosity proton-proton machine," says Malcomb Derrick, a member of HEPAP who works at the Argonne National Laboratory. "But the physics has passed that by. Proton-antiproton colliders are starting to come on. One thing to do is build something different, like an electron-proton collider. But that wasn't approved. A Machiavellian way of looking at this is saying they are trying to build an electron-proton machine while pretending it's a proton machine."

In addition to technical questions, the phased approach raises a host of political and budgetary issues. Though initially

(*Continued on page 850*)



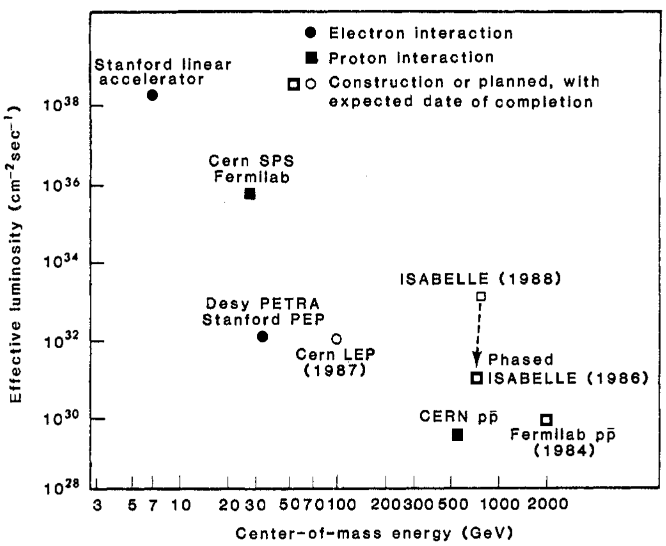
In search of a workable magnet

During a visit to Brookhaven, presidential science adviser George A. Keyworth looks on as Isabelle project head Nicholas Samios explains some of the problems with Isabelle's magnets.

**Isabelle: A 400 × 400 GeV Proton-Proton Colliding Beam Facility* (Brookhaven National Laboratory, Long Island, N.Y., January 1978).

(*Continued from page 847*)
less expensive than the original design, the phased approach in the end might cost more, although Samios does not yet have exact figures. Another question is the international competition. An electron-proton Isabelle might be scooped by a similar European machine, called HERA, that is now in the planning stages (*Science*, 31 July, p. 530). There is also the question, as one physicist put it, of the "monumental psychological barriers" that will have to be surmounted if Brookhaven is to install superconducting magnets made by its arch rival, Fermilab. Further, broad political questions are raised by the drop in luminosity. The phased Isabelle for the initial 2 years would have a luminosity close to that of the next generation Fermilab machine, a proton-antiproton collider, which is scheduled for completion in 1984. One reason funds were simultaneously dished out to construct both these proton machines was because Isabelle would be so much more luminous. "The real competition when Isabelle is running at low luminosity is Fermilab," says Burton Richter, a Nobel laureate and physicist at the Stanford Linear Accelerator Center. "If Isabelle is going to go, it has to go because it can get such high luminosity that it can search for really rare and exotic processes."

Moreover, the Europeans are about to scoop much of the physics available at low luminosities. The proton-antiproton collider at CERN may not be able to search out "rare and exotic" events, but it will—if the particles exist—find bosons. "For a while the Europeans are going to steal the glamour," says Richter, who is promoting a next-generation machine he feels will help the United States catch up to the Europeans.



The international race among particle accelerators. Colliding beam machines (everything below 10^{34}) have difficulty maintaining high rates of collision, or luminosity, because the beams racing around an accelerator are so diffuse. Isabelle's forte was to have been the possession of a luminosity higher than that of any other colliding beam machine.

Because of the mediocre potential of a phased Isabelle, a hope often expressed is that technical progress in achieving the original design goals will be so great that the project will be blessed with a "budgetary miracle," as one physicist put it.

If construction of Isabelle continues, and such a heavenly act does not materialize, the consequences will be grim, at least according to the report issued in May by HEPAP.† To accomodate Isabelle's demands for dollars, HEPAP says at least three other U.S. high energy physics programs will face the ax. These might include the Alternating Gradient Synchrotron at Brookhaven, the fixed-target program at the Stanford Linear Accelerator, and the yet-to-be-completed proton-antiproton collider at Fermilab. Over a 4-year period, it would be necessary to draw $150 million out of current operations, according to HEPAP. Even if Isabelle were scrapped, the report says "one can contemplate a modest construction project only with some further reduction in the utilization of existing accelerators." Many accelerators currently are operating at less than half their capacity. The fiscal 1982 budget for U.S. high energy physics is $393 million a year. According to the HEPAP report, the budget level needed "to maintain a very strong and preeminent high energy physics program in the United States" is $510 million.

Such a bailout is unlikely, according to presidential adviser Keyworth. "The shotgun approach that we've used in the past just cannot be afforded anymore. We have to concentrate on areas where breakthrough is most probable. . . . I basically want to make sure we have the strongest program when we come out of this, and I certainly don't want to throw good money after bad."

What if Isabelle were terminated? Though it clearly would set physicists reeling, the shutdown would probably not mean the end of U.S. high energy physics. After all, the era of three big government-maintained labs is relatively new—an outgrowth of pork-barrel politics during the 1960's. The West Coast at that time had the nation's largest accelerator, and Brookhaven on the East Coast ran a close second. Pressure for a big lab in the Midwest grew steadily during the 1960's, midwestern physicists prodding their congressmen to the verge of success. In 1964, however, President Johnson killed the enterprise, and it was not until the early 1970's that Fermilab with its 4-mile-long circular mound appeared atop the Illinois prairie. Throughout the 1970's, the U.S. budget for high energy physics contracted, and dollars were stretched further and further. The budget squeeze did not reduce the desire for big machines, and physicists often resorted to evasive maneuvers.

After championing Isabelle for 3 years and being told to wait by the Office of Management and Budget, the physicists at Brookhaven made an end run around the Executive Branch and went straight to Congress. The legislative mandate for Isabelle was approved in 1977, the effort having been spearheaded by a New York congressman. One irony of the current situation is that the relative newcomer to the world of high energy politics, Fermilab, will probably outlast its East Coast rival, Brookhaven, as an internationally competitive lab.

What initially hurt Isabelle was the lack of planning and research on magnet designs. What is killing her is the lack of funds. Three years ago Isabelle's estimated cost was $275 million. Now it has almost doubled. The figure of $500 million is many times larger than any other in the history of U.S. particle accelerators. The most recently completed machine, PEP at Stanford, was finished in 1979 at a cost of $78 million.

The options are clear: a bailout, mediocrity, or termination. A fear expressed by many physicists is that the current mood in Washington will mitigate against any of the more optimistic scenarios. As HEPAP member Derrick put it: "Stockman according to the newspapers is trying to cut something like $40 billion out of the fiscal 1983 budget. Some fraction of that is going to come out of the controllables, of which we are part. The whole thing seems sort of obvious."

—WILLIAM J. BROAD

†*Budget Impact Study for the U.S. Department of Energy High Energy Physics Program* (DOE, Washington, D.C., May 1981).