ARGENTINA

A Once-Privileged Physics Lab Faces an Uncertain Future

BARILOCHE, ARGENTINA—Staffers at Argentina's Centro Atómico Bariloche should be resting easy. The reputation of this 500-person institute for training the country's best physicists and nurturing some of its strongest basic research is secure. And its setting could hardly be more serene. Some 1200 miles southwest of Buenos Aires, the Centro Atómico Bariloche is set beside the turquoise waters of Lake Nahuel Huapi at the foot of the Andes. Snowcapped peaks rise behind modern laboratories, alpine-style cottages, and classrooms and administration buildings built of local green stone. But all that apparent good fortune can't allay the anxieties of the 150 physicists and engineers at the institute.

One clue to their unease could be found last November just inside the administration building. Pinned to a bulletin board was a 2-week-old newspaper clipping quoting the Argentine minister of the economy on the future of scientists in his country: They might as well learn to wash dishes, he had declared. Once, that comment might not have unnerved staffers at the Centro Atómico, which has a history of surviving Argentina's political shifts practically unscathed. But it comes at a time when the institute is especially vulnerable because of the debilitated state of its patron: the National Atomic Energy Commission (CNEA).

For four decades, this powerful technocracy has controlled all of Argentina's nuclear activities, including its commercial nuclear power plants. Because the CNEA served the needs of Argentina's leaders—and incidentally provided most of the funding for the Centro Atómico—the Centro (like many of the U.S. national labs) long felt untouchable. But last October, Argentina's President Carlos Menem issued a decree initiating a reorganization of CNEA, with the goal of shrinking it and selling off the power plants to private industry. Suddenly, the Centro Atómico found itself within an agency with the same name but less than half the size of the original commission—and with a proportional diminution in autonomy.

Because CNEA is the largest supporter of physics research in Argentina, the move is sending chills through the nation's physical science research community as a whole. In the future, Argentine researchers told *Science*, funding for the Centro Atómico and other CNEA laboratories could be in the hands of politicians no more sympathetic to science than the current economy minister. And this has Alfredo Caro, the Centro Atómico's director, very worried. For now, he says, the institute's $16 million annual budget is stable, but "most of our budget in the past came from electricity produced in the power plants. ... And that's why we're worried. In the case of any [economic] instability, we know where the government will cut first. And it will be here."

To protect some of its research programs, the Centro Atómico is seeking industrial customers for its work in metallurgy, materials science, automation, and nuclear engineering—work that until recently was done in support of Argentina's nuclear-energy program. But even if enough support from industry materializes, it won't help the basic scientists who make up perhaps half the Centro Atómico's staff. They will have to convince the government that, as Caro puts it, "it's important to have experimental physics for success in industry."

At stake is a rare tradition of research and teaching. "In Argentina, it's not easy to find experimental work and people of that quality," says Ricardo Sagarzazu, a manager at INVAP, a high-technology company founded 20 years ago in Bariloche by Centro Atómico researchers. The plaudits come from outside Argentina as well. Harvard University physicist David Nelson calls the low-temperature physics group "a source of magical graduate students." Commenting on its work, he says: "It just doesn't often happen that a [developing] country has that kind of impact."

That's a reputation built up from an unlikely beginning: a fraudulent fusion power project bankrolled more than 40 years ago by Argentine President Juan Perón. Just after the end of World War II, explains physicist

CENTRO ATÓMICO BARILOCHE

Prime location. The Centro Atómico's site in Argentina's lake district kept it far from political instability in Buenos Aires.

ARGENTINA AT A GLANCE

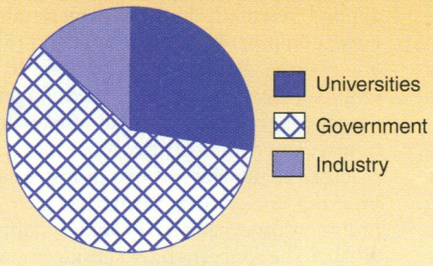
Roughly a third of government support for R&D in Argentina comes from the National Council of Scientific and Technical Research (CONICET), which funds scholarships, researchers' salaries, institutes, and grants. Caps on CONICET's budget, now about $220 million, and increasing outlays on salaries and overhead have reduced spending on grants, and for the past 2 years the agency's cash-flow problems have been so severe that grants went unfunded. CONICET is now being reformed, and the National Atomic Energy Commission, the National Commission of Space Activities, and other agencies have continued to support research.

The Big Picture

Population, 1994:	33.9 million
GDP, 1993:	$255 billion
Total R&D Spending, 1993:	$922 million
Scientists and Engineers, 1993:	13,000

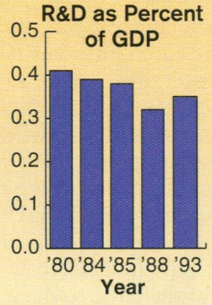
SOURCES: GDP, R&D, Scientists and Engineers: SECYT; Population: 1994 CIA World Fact Book

R&D by Performer, 1993



SOURCE: Secretariat of Science and Technology (SECYT), Argentina

R&D as Percent of GDP



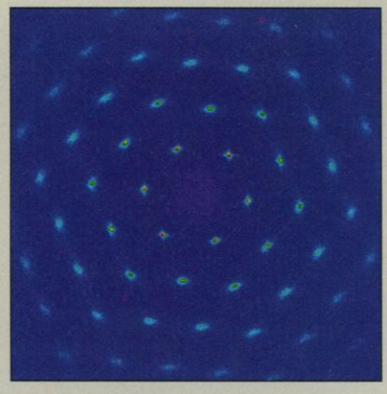
SOURCE: Secretariat of Science and Technology (SECYT), Argentina

One Bastion of Experimental Physics

It can be tough to do experimental physics in Argentina in the face of equipment shortages and political and economic turmoil. Says physicist Carlos Balseiro of the Centro Atómico Bariloche, "It's much easier to do theoretical work." But flouting that rule is a point of pride for the Centro Atómico.

Against the odds, this 500-person institute in the foothills of the Andes has built up a low-temperature physics group that superconductivity researcher David Bishop of AT&T Bell Laboratories, a longtime collaborator, considers "as good as any in the world" and groups in magnetism and atomic physics that receive high marks as well. Among the highlights of their research:

■ Francisco de la Cruz and his colleagues are trying to understand a problem that is bedeviling efforts to turn high-temperature superconductors into practical materials. When a high-temperature superconductor is exposed to a magnetic field, the field lines pierce the material in isolated "vortices." As long as the array of vortices remains fixed, as it does at low temperatures, the material remains superconducting. But as the temperature rises or the flow of current is increased, the vortices move, generating electrical resistance that destroys superconductivity.



Magnetic decoration. Microscopic iron particles reveal a superconductor's lattice of flux lines in work done at AT&T Bell Laboratories by Centro Atómico student Cristian Bolle.

De la Cruz's group in the low-temperature laboratory has been trying to understand this transformation—a prerequisite for controlling it. Among other things, they have shown that the onset of vortex motion is a true phase transition, like the melting of ice: As the lattice breaks down, the density of vortices increases, just as the density of water jumps when ice melts. Other groups had gathered indirect evidence, says Bishop, but the Bariloche group's finding is "unambiguous—it's the end of the story." And with Bishop's Bell Labs group, they showed that in certain layered superconductors, the vortices can break up into stacks of two-dimensional pancakes that wander independently through the material. Both insights may eventually help researchers develop ways to keep the lattice rigid at higher temperatures and currents.

■ One researcher trying to do just that is Leonardo Civale, another member of the low-temperature laboratory. In 1991, Civale collaborated with groups at IBM and Oak Ridge National Laboratory in Tennessee to pin the magnetic vortices in a ceramic superconductor by using high-energy ions to drill minute holes in the material (*Science*, 17 September 1993, p. 1521). Civale and his colleagues also observed hints that when these "columnar defects" are splayed at many different angles, they may be even better at snaring the vortices. He and his colleagues at the Centro Atómico and at a heavy-ion accelerator run by the Atomic Energy Commission near Buenos Aires are now trying to test that promise. They are bombarding superconductor samples with streams of ions from various angles, then measuring their ability to carry current in a magnetic field.

■ Surfaces are strange places, where the orderly crystalline array of many solids becomes ragged and the atoms, no longer surrounded by their fellows, display altered electronic properties. But examining surface properties alone, isolated from the properties of deeper layers, isn't easy. Oscar Grizzi and his colleagues at the Centro Atómico's atomic collisions division are doing so by probing surfaces with beams of ions, sent along trajectories that barely graze the surface. The glancing collisions are still violent enough to agitate the atoms, which spit out so-called Auger electrons from deep inside their electronic structure. By capturing and measuring these electrons, the Centro Atómico researchers have found they can study the properties of the topmost layer of atoms in a semiconductor—and how those properties change as, for example, the material becomes oxidized.

One factor in these successes is 40 years of stability and steady support, a rarity in Argentina (see main text). Another is the inventiveness of the scientists and their students, whom Bishop calls "the smartest kids in Argentina." Because they don't have a lot of sophisticated equipment, says Bishop, "they spend a lot of time figuring out how to get the last 10, 20, or 30% out of the equipment they do have." The result, he says, is not only good science but innovative research strategies. "Time and time again they find solutions when other people would just throw money at the problem or give up."

–T.A.

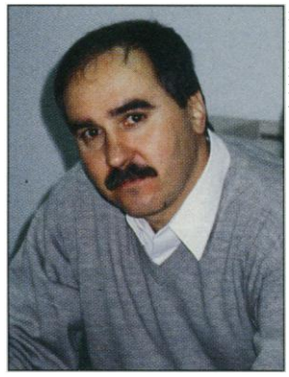
Mario Mariscotti, the president of the country's Academy of Sciences and the author of a history of atomic energy in Argentina, Perón invited an Austrian physicist named Ronald Richter to pursue his research in Argentina. Richter was convinced that he could trigger controlled thermonuclear fusion with an electric spark—call it warm fusion. In short order, Richter built a secret facility on an island in Lake Nahuel Huapi and reported generating miniature suns in the laboratory.

In 1951, however, a committee of Argentine physicists debunked Richter's work and persuaded Perón to close down the project. But the physicists made the best of Richter's legacy. They persuaded the government to support a legitimate research effort and shifted Richter's equipment from the island to a former military base on the shore of the lake, where they set up programs in atomic physics, metallurgy, and theory.

Those research programs have been going strong ever since, and in 1955 the fledgling research center took on its second major task: training Argentina's physicists. The academic program set up in that year now enrolls nearly 100 undergraduate and master's-degree students and 80 Ph.D. candidates, chosen by a nationwide exam and supported by scholarships from CNEA. Meanwhile, the scope of the basic research done at the Centro Atómico has broadened to include low-temperature physics, magnetic resonance, and neutron physics (see box).

As CNEA's own activities expanded in the 1970s from research to commercial and—some say—military uses of atomic energy, the Centro Atómico added programs of applied research, including materials science, computational modeling, and nuclear engineering. Along with CNEA's two large engineering centers, it helped Argentina develop a nuclear program unequaled in South America, with two operating power reactors, a nuclear export industry, and a uranium enrichment plant that gave nonproliferation experts fits of anxiety during the 1980s. (The concerns have subsided now that Argentina has opened its nuclear program to international safeguards.)

All along, say staffers and outsiders, the Centro Atómico was isolated from much of Argentina's political and economic turmoil. While the military government of the 1970s—the same government that "disappeared" thousands of Argentines and fought and lost the Falklands war—devastated the universities, for example, the Centro Atómico went relatively unscathed. One buffer was simply its distance from the capital. "They are out in the sticks," says superconductivity researcher David Bishop of AT&T Bell Laboratories, "and that really saved them." Another was CNEA's own privileged status. "We were lucky," says Caro, "because both military and democratic governments found different reasons to support atomic energy—as you can imagine." As a result, says Carlos Balseiro, a solid-state theorist who heads the academic programs at the Centro Atómico, "we had stability for 40 years."



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Planning for survival. Centro Atómico director Alfredo Caro.

But now the world has changed for CNEA—and for the Centro Atómico. Roberto Ornstein, CNEA's director of international relations, explains that Menem's government has already dismantled much of the Peronist legacy of state-run companies, privatizing everything from the state oil company to telephones and transportation, "and now it's time for atomic energy too." To sustain his institute's applied research programs through the transition, Caro is consciously trying to imitate the survival strategy of U.S. national laboratories by stressing the commercial promise of the materials, processes, and software developed in the Centro Atómico's laboratories.

Around the Centro Atómico, researchers list the contract work now under way: developing metal-matrix composites for components in racing-car engines, designing heat-resistant magnetic cores for electromagnetic pipe welding, and writing software that schedules the unloading of tankers at an oil terminal. The contracts topped $1 million last year, says Caro, but he acknowledges that meeting his goal of covering 30% of the Centro Atómico's annual budget—or about $5 million—through such arrangements will be difficult. "We don't have any experience in marketing," he says. Another hurdle may be what many Argentine scientists describe as their country's technological inferiority complex—a tendency to doubt that anything good could be invented at home.

The prospects for the basic research that was the Centro Atómico's original mission and still accounts for most of its international reputation are even more uncertain. The pace of research and publication has not slackened, but there's a background of gloom and gallows humor. No one can forget that from now on, the Centro Atómico's isolation and prestige will offer little protection when ill winds blow from Buenos Aires.

–Tim Appenzeller

ARGENTINA

Patagonian Dinosaurs Reveal A Cosmopolitan Cretaceous

NEUQUÉN, ARGENTINA—For 100 kilometers around this dusty provincial city in northern Patagonia, the arid uplands are broken by fossil-bearing outcrops of red and yellow rock. These striking formations are windows into a time 110 million to 75 million years ago, during the final chapter in the reign of the dinosaurs. And to a trio of young paleontologists, the rocks are offering up surprise after surprise. Their discoveries—half a dozen new dinosaurs over the past 5 years—are transforming the image of the dinosaurs that inhabited South America at a time when continental drift was carrying that landmass into ever greater isolation. "With each new specimen we have to redraw the picture," says one member of the group, Leonardo Salgado of the University of Comahue in Neuquén.

Five years ago Salgado and his colleagues Jorge Calvo in Neuquén and Rodolfo Coria, based 100 kilometers away in the small town of Plaza Huincul, expected that their work would add to the established picture of a unique fauna. Earlier discoveries, many of them by José Bonaparte of the Museum of Natural History in Buenos Aires and his students—among them Salgado, Calvo, and Coria—implied that during the Cretaceous period, from about 145 million to 65 million years ago, South America and perhaps other southern continents evolved an assemblage of dinosaurs sharply different from those of North America and Eurasia. But the newer bone strikes are blurring that north-south divide, and the mid- to late-Cretaceous scene in South America is looking increasingly cosmopolitan. "In the last 5 years, we've started to find representatives of [northern] dinosaur lineages never recorded in South America," says Coria.

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Dino-finders from Patagonia. From left to right, Rodolfo Coria, Leonardo Salgado, and Jorge Calvo.

Paleontologists elsewhere are watching with interest. "They've got a burgeoning fauna there," says Johns Hopkins University paleontologist David Weishampel, who adds that he will be eager to learn more about "who these creatures are and what their relations are." One reason for the interest, explains the University of Chicago's Paul Sereno, is that the fate of the dinosaurs in the Cretaceous is a test of how the migrations of continents affect patterns of evolution: "There's been no experiment quite like this in the history of life."

The beginnings of the experiment go back to the Jurassic period, which ended about 145 million years ago, when most continents were united in a single supercontinent called Pangaea. Dinosaurs roamed freely across the supercontinent, and the major dinosaur lineages were found throughout the world. By the end of the Jurassic, however, the supercontinent was rupturing into a northern part called Laurasia and a southern part called Gondwana. At that point, many paleontologists believe, the dinosaurs on each landmass began to go their own way. By the middle and late Cretaceous, when Gondwana and Laurasia in turn were breaking up, few reminders of their former kinship were left—or so it seemed until recently.

On the northern continents of Laurasia, the giant vegetarian sauropods of the Triassic and Jurassic periods—creatures like *Brachiosaurus* and *Diplodocus*—had died out and been replaced as plant-eaters by the ornithischians, a varied group that included the duck-billed hadrosaurs and the armored