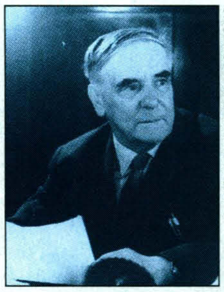
A Once-Favored Discipline Has the Furthest to Fall

MOSCOW AND ST. PETERSBURG—The town of Protvino, 100 kilometers south of Moscow, can rightly be called a science city. Directly or indirectly, nearly every one of its 40,000 residents is involved in supporting the few thousand physicists and engineers who work at the Institute of High Energy Physics (IHEP), one of Russia's main centers for accelerator physics. But in a few years' time, this science city could be a ghost town: The new machine that IHEP was counting on to keep it in the international top rank of high-energy physics centers lies unfinished due to lack of funds, and researchers despair that it will ever be completed. "Five years ago we had enough money for everything," says Yuri Ryabov, IHEP's scientific secretary. "Now we have no money for anything."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Proud heritage. Founding father Abram Ioffe *(top center)* and his students, Nobelists Peter Kapitza (*top left*) and Lev Landau *(left)*, and bomb-maker Igor Kurchatov *(above)*.

The situation at Protvino typifies what has happened to Russian physics since the fall of the Soviet Union. Among the sciences, physics was the favorite child of the Communist authorities, growing fat on the back of the frantic program to build an atomic bomb during and after World War II. Institutes swelled to enormous sizes, each employing thousands of people and maintaining huge workshops to make equipment to order, with no thought to the cost. But the bigger they come, the harder they fall, and as science funding has plummeted, Russia's physics juggernaut has ground to a virtual standstill. At many institutes, half-built devices lie rusting, probably never to be completed. Existing facilities rarely run because of the crippling cost of electricity. Technicians and young researchers are fleeing to industry or to the West. "The situation is terrible," says Vitaly Kaftanov, vice director of the Institute of Theoretical and Experimental Physics (ITEP) in Moscow. "If the economy doesn't improve, we have no chance of survival."

As in other disciplines, researchers are trying as best they can to work by traveling abroad, forging international collaborations, and applying to Western aid bodies for grants. In the first round of George Soros' International Science Foundation's (ISF) long-term research awards, for instance, physicists won 36% of the grants, the most of any discipline. But the sums are small compared to the luxurious funding to which Russian physicists were accustomed. And the senior Russian physicists consulted by *Science* have little response to this crisis beyond asking the government for more money and looking back with nostalgia to the past.

That golden past began shortly after the Bolshevik revolution, with the founding of the Leningrad Physico-Technical Institute by solid-state researcher Abram Ioffe in 1918. What later came to be called the Ioffe Institute is viewed as the cradle of Russian physics, and many famous names have worked within its walls: Theorist Lev Landau and condensed-matter researcher Peter Kapitza—Nobelists in 1962 and 1976 respectively—both started their careers at the Institute, as did Igor Kurchatov, head of the Soviet atomic bomb project.

Bomb boost. The reputations of Soviet physicists grew during the 1920s and '30s, when many spent time in the West. Kapitza, for instance, worked for 13 years at Ernest Rutherford's lab in Cambridge before being forced to stay in Moscow after returning to visit relatives in 1934. But it was the crash effort to make an atomic bomb that sparked the discipline's huge expansion.

The bomb project spawned a host of new institutes in the 1940s, including the Kurchatov Institute of Atomic Energy in Moscow and ITEP. The physicists proved their worth by exploding the Soviet Union's first atomic bomb in 1949, followed by its first hydrogen bomb in 1953. After that, says Alexander Rumyantsev, director of research and development at the Kurchatov Institute, bomb making moved to closed cities in deepest Russia, leaving these new institutes free to do civilian work. "[Weapons production] was an important stimulation to physics," says Alexander Andreev, director of the Kapitza Institute of Physical Problems in Moscow. In many cases, physicists formerly employed on the bomb program worked on civilian applications of nuclear technology. But backed by generous funding from the Soviet authorities, they also started delving into fundamental science, particularly in the fast-developing field of high-energy physics.

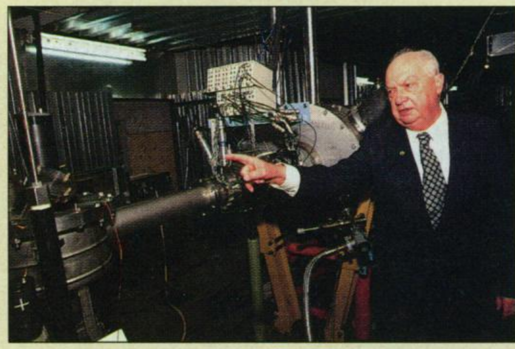
Indeed, Russian physicists often possessed the world's most powerful accelerators, such as the 480-million-electron-volt Synchrocyclotron commissioned at Dubna in 1949, and IHEP's 70-giga-electron-volt synchrotron at Protvino, commissioned in 1968. "It was an exciting time," says IHEP's Ryabov. And other areas of physics thrived on the general Soviet enthusiasm for the subject, including laser, solid-state, and semiconductor physics—all of which had potential military spin-offs.

Many institutes grew to enormous sizes: At the end of the 1980s, the Kurchatov Institute had 10,000 staff, ITEP had 3300, and the Ioffe Institute, 2700. It is the inflated size of such institutes, however, that is one of the main reasons physics is now facing a particularly tough time. As government funds have shrunk over the past 2 years, the institutes have devoted a larger and larger percentage of their resources to salaries. Yuri Gordeev, deputy director of the Ioffe Institute, says that between 1990 and 1993 the proportion of the institute's budget spent on salaries rose from 18% to 76%, while spending on equipment and materials sank from 47% to just 3%. The cradle of Russian physics last year celebrated its 75th birthday, but it was not a happy event. "We have spent 73 years developing and 2 years decaying and dying," Gordeev says.

The Kapitza Institute's Andreev blames the growth of overstaffed institutes on the inflexible approach to scientific careers in the Soviet Union: Scientists tended to stick in the same field for their whole working lives. If a new field appeared, a new laboratory, staffed with young researchers, would be set up to investigate it, and if it grew large enough, the laboratory would become an institute itself. The Ioffe Institute spawned 15 other institutes in this way, including the St. Petersburg Nuclear Physics Institute (PNPI)

The Dubna Effect

DUBNA—The Joint Institute for Nuclear Research (JINR), a huge physics center that dominates this small town 130 kilometers north of Moscow, is an island in more ways than one. Cut off from the surrounding countryside by three waterways—the Volga and Dubna rivers and the Moscow canal—it was also an island of international cooperation in the days when most of Soviet science was isolated from the rest of the world. And now it is one of the few patches of firm ground in the sea of decay that pervades Russian physics. "The position is pretty good there; they're still doing good work," says heavy-ion researcher Ron Lougheed of Lawrence Livermore National Laboratory, who is collaborating with JINR researchers to look for predicted stable isotopes among the heaviest elements of the periodic table (*Science*, 3 December 1993, p. 1515).


GEORGE DE KEERLE/SYGMA

High hopes. Alexander Baldin and the Nuclotron.

Although its budget, like those of all fundamental science institutes, has been severely cut, JINR is exploiting its position as an international institute to spread its costs among its member states—mostly former Eastern-bloc countries and ex-Soviet independent republics—and making the most of its long-standing contacts with the West. It seems to be working: The institute is abuzz with activity and it even boasts some new facilities. "The situation is satisfactory," says JINR director Vladimir Kadyshevsky. "It is a calm, stable center."

JINR was founded as an international center in 1956, as the Soviet bloc's reaction to the creation of the European Laboratory for Particle Physics (CERN) in Western Europe. A year later, JINR commissioned a new collider, the 10-giga-electron-volt Synchrophasotron, which is still in use today. The institute branched into other areas, such as nuclear structure research and neutron studies, and soon began forging links further afield than the Soviet Union's satellite states—with CERN in the 1960s and with groups in France and the United States in the 1970s.

The crumbling of the Soviet Union presented a major threat, however, because former Communist states were no longer bound to JINR by a common cause. "Political glue held JINR together," admits vice director Alexey Sissakian. Fortunately, however, when JINR's members reviewed their involvement, most decided that the center's scientific status justified continued membership; only Hungary pulled out, although it still maintains some collaborations. Nine of the independent republics created by the breakup of the Soviet Union joined as new members, and with old stalwarts like Cuba, North Korea, and Vietnam all keeping the faith, JINR now has 18 member countries.

One of JINR's most valuable sponsors, however, is not even a member. When the Berlin Wall came down, the membership of East Germany automatically lapsed. But the united Germany was keen to maintain the link and now has observer status. More importantly, Germany's research ministry is now providing $1.2 million a year under an agreement that runs to the end of 1996. "Germany has provided an example of [East-West] collaboration," says Kadyshevsky.

As yet, no other Western country has followed Germany's lead. But the U.S. ambassador to Russia, Thomas Pickering, visited the institute this year to discuss direct links between JINR and the Department of Energy, to act as an umbrella over the numerous collaborations with American groups. "The institute is now an interface between the West and the East," says Sissakian. To reflect this, JINR now has a number of prominent Western physicists on its advisory science panel, while its own researchers spread the message far and wide. "I've never seen so many Dubna people at meetings in the U.S.," says nuclear chemist Kenneth Hulet of Livermore.

The institute has been busy scientifically as well. A new detector called FOBOS has been built, in collaboration with Bulgaria and Germany, which tracks the reaction debris when ions accelerated by JINR's U-400 cyclotron hit a heavy-element target. And a whole new accelerator has been squeezed into a circular service tunnel underneath the aging Synchrophasotron. By recycling parts of the old machine, such as the preaccelerator line and the experimental halls, the institute could afford to build a new ring with superconducting magnets. The brainchild of Alexander Baldin, chief of JINR's high-energy lab, the Nuclotron will push nuclei up to energies of 7 GeV per nucleon to study nuclear interactions at relativistic speeds. Researchers have carried out three test runs this year and will soon start experimenting. Says Kadyshevsky: "It is symbolically important to create a new machine in these hard times."

JINR's ambitions do not end there: Its physicists want to build a new high-flux pulsed neutron reactor and a charm-tau factory, an electron-positron collider that produces charm quarks and tau neutrinos in large quantities. And while some of these facilities may turn out to be beyond JINR's resources, plans to open a small university at the institute are already nearing fruition. Using their own researchers as professors and the institute's labs for practice experiments, JINR will open the doors of the as-yet-unnamed university to 150 students from all over the world in September. Sissakian, the university's organizer, describes even wilder schemes: an art school and a festival of Russian films. Given the scene of desolation at most other Russian physics centers, some sort of magic seems to be at work at Dubna. Envious Russian physicists certainly seem to think so: They call it the "Dubna effect."

–D.C.

in Gatchina, a few dozen kilometers south of Russia's second city. There was also an element of empire building by institute directors: "Institutes would take on scientists even if there was no work for them to do," says Stanislav Belostotski of PNPI. "Half of them would end up doing nothing."

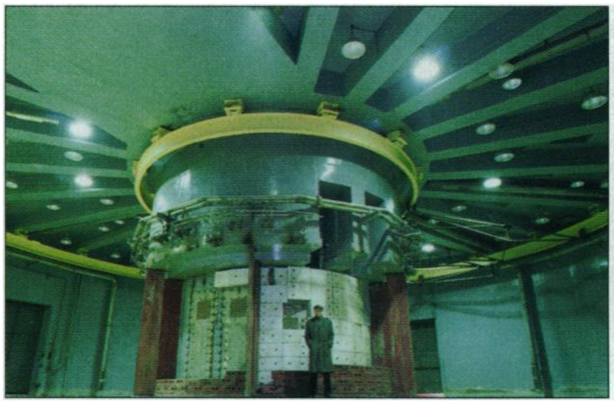
The obvious solution would be to lay people off. But after decades of guaranteed employment under Soviet rule, Russians find the idea of widespread unemployment unacceptable (*Science*, 19 November 1993, p. 1200). Nevertheless, some of the salary burden is being removed by staff defecting to industrial jobs or working abroad on contract; unfortunately, these are often the most productive researchers. The brain drain to the West is not considered a major problem, because many scientists have pledged to return if and when things improve. But other staff are more sorely missed: "The real danger," says Vladimir Kadyshevsky, director of the Joint Institute for Nuclear Research (JINR) at Dubna, "is the 'hand drain'" of highly skilled technicians to better paid jobs in industry. Because labor was cheap in the Soviet Union, institutes built up large workshops to make their equipment. But technicians have less dedication to science than do scientists: Last November, ITEP in Moscow lost its last welder to a job in industry which paid eight times more, says vice director Kaftanov. Efforts to hold on to valuable technicians, such as job-splitting between institutes and industry, are so far failing to stem the flow.

Equally disabling for many institutes is the cost of electricity, which has shot up dramatically since the government unleashed the power industry from state price control. High-energy physicists at Protvino can now only afford to run their U-70 synchrotron for two 1000-hour runs per year; in former times five runs a year were routine. "Energy is our biggest problem," says Rumyantsev of the Kurchatov Institute, which has a 3-billion-ruble ($1.7-million) debt to the power industry. "We have stopped payments for electricity because we have no funds to pay," he says. When the utility recently threatened to cut off the institute's supply, Rumyantsev and his colleagues reminded the suppliers that the institute, situated in a residential suburb of Moscow, has seven operating research reactors, and their safety could not be guaranteed without power. The supply was maintained, but with electricity costs continuing to rise, the survival of many centers may now depend on the success of Russian science minister Boris Saltykov's ability to negotiate price discounts for scientific institutes.

Dreams on hold. The most difficult thing for Russian physicists to bear, however, is being deprived of their future. Many planned projects have remained on the drawing board since the collapse of the Soviet Union, but even more tantalizing are those that were partly built when funding was abruptly cut. At PNPI in Gatchina, construction workers were 75% through building a high-flux neutron reactor to replace the institute's existing aging facility built in 1959. "When it will be completed, no one knows," says Alexey Okorokov, head of PNPI's condensed-state research division.

Perhaps the biggest tragedy is the UNK proton synchrotron at IHEP in Protvino. After its U-70 synchrotron was overtaken in the mid-1970s by more powerful machines at the Fermi National Accelerator Laboratory in the United States and at the European Laboratory for Particle Physics (CERN) in western Europe, IHEP was for a long time one of high-energy physics' also-rans. In an effort to regain its former glory, Protvino began work on the UNK machine in 1987. Its projected power was 3 tera-electron-volts, slightly more than Fermilab's Tevatron, currently the world's highest energy machine. And IHEP's Ryabov claims that the UNK's beam would have an order of magnitude greater intensity than any other accelerator, giving it a better chance of spotting the as-yet-undetected tau neutrino and rare interactions, such as those of the charm quark.

The idea was for IHEP's U-70 ring to fire protons into a 2.5-km transfer line and then into the UNK's 21-km main tunnel. In March, researchers fired the first protons into the newly completed transfer line. But for the foreseeable future, that will be the end of the protons' journey, because the main tunnel was never finished. "We have 16 km of tunnel ready for equipment, and 70% of the equipment is ready and tested," says Ryabov. Indeed, every available space in the institute's hangar-like experimental halls is filled with bright orange bending magnets, 2000 of them, each weighing several tons. Piled up on racks are focusing magnets and 20 km of vacuum tubes. But without funds to bore the last 5 km of tunnel, all this hardware will be useless. And if the tunnel is left as it is for 4 years, says Ryabov, it will decay and digging will have to start all over again.


ZAMIR USMANOV/AGENCE FRANCE PRESSE

Thwarted hopes. Research reactor at St. Petersburg Nuclear Physics Institute is 75% completed, but may never be finished.

With their own facilities unfinished or frozen by electricity prices, those Russian physicists who are managing to keep busy are mostly doing so by participating in experiments in the West. "Russian physicists are learning how to be included in the world community," says atomic theorist Nina Avdonina, who fled Russia in 1991 with her daughter and two suitcases and is now at the University of Pittsburgh. Russian researchers often pay their way in kind by supplying instruments made in their institute workshops. Many high-energy physicists from Russia have participated in experiments at CERN by supplying part of the hardware. And while they were devastated by the loss of contracts worth some $50 million for the cancelled U.S. Superconducting Super Collider, Russia has already offered to provide components worth a similar sum for CERN's planned Large Hadron Collider.

Direct Western support for research in Russia, however, is proving insufficient to support major experiments. ISF's grants, for instance, "won't pay for an additional accelerator run," says Ryabov of IHEP. Moreover, the subject of aid seems to offend physicists' pride. "Aid is not good for us. We want to produce results and don't ask for help," says Vladislav Pustovoit, deputy director of the Institute of Radio Engineering and Electronics in Moscow. Their views seem to echo the growing tide of nationalism in Russia. "Aid is not a proper way to fund science in Russia, with such scientific traditions," says JINR's Kadyshevsky. "A great country must have great science."

And although most physicists welcome the competitive funding arrangements that are being introduced in Russia as a way to promote good science and weed out the bad, they are quick to emphasize what is being lost. "[In the Soviet era] there was a real sense of community. It was easy to work with colleagues in other institutes. Samples and ideas were swapped freely because everyone was on the same salary. I'm afraid this tradition will be spoilt by grants," says Valentin Simonov, vice director of the Institute of Crystallography in Moscow.

Nostalgia for the past seems to be endemic in Russia's physics centers. The Kapitza Institute was at one time a world leader in low-temperature physics, but today, says deputy director Alexander Parshin, "everyone is going. In 2 or 3 years we will have no one." Despite this, Kapitza's house in the institute grounds is lovingly maintained. His office is kept as it was on the day he died in 1984, and in an adjoining room is a museum dedicated to his work.

Indeed, most Russian physicists seem happier tending their memories than thinking about the future. Nevertheless, Kapitza Institute director Andreev, who is also vice president of the Russian Academy of Sciences responsible for physics, predicts that Russia's strong tradition in theoretical physics will be one of the main survivors, because theorists are not tied to a particular instrument. Experimentalists, he says, will have to go back to their roots: "Russian physics started with small-scale experiments, and the same tradition still exists" in areas such as solid-state physics. He cites the case of Kapitza, who was banished to his dacha outside Moscow for 8 years after refusing to work on the atomic bomb project. "He carried out very elegant work in hydrodynamics with almost no equipment," says Andreev. Such resourcefulness will not keep tens of thousands of physicists at work, however. "The solution is far, far away," says Simonov of the Institute of Crystallography.

–Daniel Clery