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THE RUSSIAN PHYSICS ESTABLISHMENT IN CRISIS:
HISTORICAL ROOTS AND FUTURE PROSPECTS

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EXECUTIVE SUMMARY

The break-up of the Soviet Union had a direct impact on the Russian and Ukrainian physics establishments. No longer able to command the political clout, financial resources, and public support they once had, physicists and their research face an uncertain future. Economic crisis and political uncertainty threaten research programs. Staff is being dismissed or leaving of its own accord. Institutes have closed. Leading theorists have gone abroad. In particular, the big physics of space, fusion, and fission have fallen on hard times. The costs and uncertainties of conversion of the military industrial complex to civilian tasks make matters more difficult. The public has lost faith in scientists in general and physicists in particular to deliver on their promises of safe, efficacious research.

Physicists have responded to the crisis through organizational and managerial reforms and by appeals to the international community for financial and moral assistance. The reforms entail decentralized and more open decision making about research programs, hiring and firing, and access to the resources of the physics enterprise. Physicists also have banded together in a series of professional organizations intended to defend their interests before the government and a skeptical public. They have raised the spectre of Russian nuclear and chemical specialists leaving for the highest bidder in unstable third world nations to frighten western nations into underwriting research at home. Unfortunately, the reforms are threatened by the continued emphasis on the big physics of fission, fusion, and space research, and by conservative physicist administrators who are holdovers from the Soviet regime, and whose monopoly on information slows the processes of reform.
The Russian Physics Establishment in Crisis:  
Historical Roots and Future Prospects  

Paul R. Josephson

Introduction

At one time physicists commanded unquestioned authority in the USSR. Physicists were central to the efforts of Stalin, Khrushchev and Brezhnev to secure military parity with the West, and contribute to Soviet economic growth. The Communist Party apparatus endorsed a wide-ranging research program. Soviet Physicists were among world leaders in solid state, plasma, and theoretical physics. The public embraced their early successes in space and atomic energy as evidence of programs which could do no wrong.

The rapid changes in the former Soviet Union (FSU) have had a telling impact on the Russian physics establishment. Owing to ongoing political and economic crises physicists face an uncertain future. They are struggling to maintain programs and keep institutes open in spite of severe budgetary shortfalls and rampant inflation. Confusion about which bureaucracies are responsible for funding physics R and D threatens research stability. The daunting tasks of conversion of the military industrial complex (MIC) to civilian tasks makes matters worse. Growing public concern about the costs and risks associated with modern technology on the heels of the Chernobyl disaster, the failure of the Phobos 1 and 2 Mars probes, and the collapse of sections of tunnels for the UNK 3,000 GeV accelerator tunnels has seriously eroded the morale of physicists. A significant number of specialists, in particular talented theoreticians, have left the FSU for greener pastures abroad.

Physicists have responded to the crisis through organizational and managerial reforms, and by appeals to the international community for financial and moral assistance in a time of need. The reforms entail decentralized and more open decision making about research programs, hiring and firing, and access to resources of the physics enterprise. Physicists also have banded together in a series of professional organizations intended to defend their interests before the government and a skeptical public. They have raised the specter of Russian nuclear and chemical specialists leaving for the highest bidder in unstable third world
nations to frighten western nations into underwriting research at home. Unfortunately, the reforms are threatened by the continued emphasis on the big physics of fission, fusion, and space research, and by conservative physicist administrators who are holdovers from the Soviet regime, and whose monopoly on information slows decentralization.

This essay provides historical perspective on the impact of these changes on physics research in Russia. Russia has roughly 70% of the budget, and of the personnel and institutes of FSU, and a larger percentage of its physicists. Many of my comments will apply equally to Ukraine, second to Russia in terms of scientific personnel and institutes of all the republics of the FSU. Indeed, Ukrainian physics may be in a more critical state than Russian. With approximately 1/3 of its 1991 GNP connected to the MIC, 70% of R and D oriented toward military projects, and 2/3rds of its enterprises integrated solidly in organizations of the FSU so that few of them are initially capable of producing finished high technology products, Ukraine faces significant challenges in conversion to civilian tasks.

The Physics Establishment in the Postwar USSR

In the postwar years, especially after the death of Stalin, physicists assumed an almost mythic presence. They benefitted from a cult of science based on successes in nuclear weaponry, atomic power engineering, applications of radioisotopes to industry and agriculture, and space exploration. The cult of science was part of the general environment of de-Stalinization in which Soviet scientists became important actors in the political arena and reasserted control over the scientific enterprise. Scientists demanded the right to commence new research programs (including those without immediate practical application), taking advantage of a Party leadership sympathetic to the notion that successes in scientific research would contribute to the legitimacy of the Soviet regime.

The physics military enterprise expanded rapidly, as in the United States. Seemingly, no expenses were barred. The director of the atomic bomb project, I. V. Kurchatov, presided over the creation of entire closed military and scientific cities: Dubna, north of Moscow, cite of the Joint Institute of Nuclear Research, where the countries of Eastern Europe were encouraged to send their physicists; Obninsk, home of the Physics Engineering Institute where most thermal reactors were designed; the Dmitrovgrad Scientific Research Institute
Institute of Atomic Reactors, a center of breeder research; Fort Shevchenko, on the Mangyslak peninsula in the Caspian Sea, home of the BN-350 breeder reactor, which desalinates 120,000 cubic meters of water daily, primarily for the local petrochemical industry; and myriad MIC facilities such as Troitsk, Chernogolovka, Zhukovskii, Arzamas-16, Tomsk-7, and so on.

There was little public awareness of Kurchatov until he spoke the 20th Party Congress in 1956. This congress is known primarily for Khrushchev's secret speech which condemned the excesses of Stalinism. Kurchatov's speech was brazen scientific fantasy. He spoke about the creation of an army of atomic scientists, engineers and designers ready to commercialize nuclear power within five years and build "powerful atomic apparatuses for transportation purposes." Kurchatov concluded by mentioning the newly founded and promising program in controlled thermonuclear synthesis (fusion), based on the work of I. E. Tamm and A. D. Sakharov. At the next Party Congress in 1959, Kurchatov focused almost exclusively on the promise of fusion. He acknowledged some technical problems, but like most Soviet plasma physicists he promised early solutions. No longer a secret of Stalinist xenophobia, physics in general and nuclear power in particular had entered the public and international domains where they served as symbols of national achievement, the omniscient power of scientists and engineers, and the legitimacy of the Communist Party.

Owing to the absence of public scrutiny, encouraged by the winds of the cult of science, and confident of their infallibility, physicists joined with engineers on programs with reflected growing technological hubris. These include a "project plowshares" to develop thermonuclear devices for geological engineering with over 120 known applications, atomic powered engines of various sorts including a nuclear airplane like the American ANP, a series of satellites with nuclear reactor power sources, and such floating atomic power stations as the "Arbus," a 1,500 kilowatt reactor for use in the Far North, Siberia, and Far East, built in the early 1960s, and later a 6,000 kw model to provide electricity for oil and gas exploration in the arctic circle.

Those within the scientific establishment who suggested circumspection risked professional ostracism. Many who spoke out lost their positions. The physics community produced a number of leading dissidents: Yuri Orlov and Andrei Sakharov to name two.
Even Sakharov, while critical of Soviet international, legal, and human rights policies, never lost faith in its physicists. He proposed building underground nuclear power stations as a hedge against accidents or terrorism.

The Peaceful Atomic Dominates Physics Research

Until Gorbachev came to power, indeed to this day, big physics programs in high energy, space and nuclear research dominated Soviet programs. In high energy physics, physicists were determined to keep pace with the United States. In what Dr. Helen Caldicott has referred to as "missile envy," the Russians and Americans strived to build larger and larger particle accelerators. The result was the rapid construction of the Joint Institute for Nuclear Physics in Dubna where the physicist V. I. Veksler supervised the building of a 10 BeV synchrophasotron by 1957; the Institute of Nuclear Physics in Akademgorodok in Siberia where, by 1964, Gersh Budker raced physicists at the Stanford Linear Accelerator to bring a colliding beam accelerator on line; and the Institute of High Energy Physics in Serpukhov, where scientists hope some day to finish the 3,000 GeV "UNK" facility. In space, the Soviets became world leaders in numbers of launches, manned missions, and a series of other firsts.

The civilian nuclear power generation program commenced with a vitality exceeded only in the United States and France. The goal was rapid serial production of reactors in standardized form using prefabricated components. The difference between engineers and physicists became blurred. Physicist-engineers built reactors without containment vessels. They studied how far concrete could be watered down and still be safe for use in nuclear power stations. They designed the Chernobyl-type RBMK reactor to produce plutonium whose physical parameters are generally regarded as unacceptable in the West. The motivating force for the RBMK was no mean physicist. He was Anatoli Petrovich Aleksandrov, later director of the Kurchatov Institute for Atomic Energy and President of the Soviet Academy of Sciences. They built a factory on the Volga river, called "Atommash," to produce eight 1,000 megawatt reactors annually.

Soviet plasma specialists tied their efforts to the development of tokamaks and several alternative fusion reactors. They initially predicted rapid success. Budgetary support
matched their enthusiasm. By the late 1970s, however, they became much more circumspect about the prospects for commercialization. National budgets grew tighter because of military expenditures and a burgeoning fission reactor power program. When the fusion program fell on hard times in the late Brezhnev period, researchers at the Kurchatov Institute proposed to build a fission-fusion hybrid tokamak to meet military interests of producing plutonium. At Politburo plenums in June 1983 and July 1984 party leaders spared fusion from complete budget cuts. However, just as in the United States, the fusion R and D allocations were cut by fifty percent.

The Gorbachev Reforms and Physics

Salvation came from Mikhail Gorbachev who wanted to see greater Soviet participation in the international scientific community. At the Geneva Summit in 1985, to demonstrate "perestroika" in foreign policy, Gorbachev proposed that the United States and USSR undertake joint fusion research, in part through ITER. ITER, the international thermonuclear experimental reactor project which involves the European Community, Japan, Russia and the U. S., was a pet of Evgenii Velikhov's. Velikhov, a plasma specialist, Vice President of the Academy, currently director of the Kurchatov Institute, and early on one of Gorbachev's unofficial science advisors, gained the latter's ear on ITER.

Gorbachev introduced the reforms of glasnost and perestroika in the FSU. Initially, this had an almost universally positive impact on the scientific enterprise where the reforms led to decentralization of administration and funding of research; democratization of management; an end to centralized control of information and foreign contacts; the devolution of policy making from central government bodies to institutes, and professional associations; and increased public access to the policy process.

In the Stalin, Khrushchev, and Brezhnev eras, prestigious Communist Party and scientific "bosses" made most decisions behind closed doors. They dominated scientific life on the basis of personal connections. They appointed institute and laboratory directors. Conservative administrators came to dominate entire fields of research. Independent experts were seldom consulted. The rare occasions where decisions were publicly opposed such as the effort to save Lake Baikal or derail the plans to divert Siberian river water to Central Asia serve to prove the rule. Whole fields of research were closed to study. In the most
notorious case, the quack biologist Trofim Lysenko gained political favor for nearly three decades and forced genetics underground. (Kurchatov had accumulated so much authority that he was able to create within his institute a department of radiobiology to support genetics research before Lysenko's fall in 1965.) The plate tectonic theory of continental drift was opposed. On the positive side, there was considerable stability through large block funding from various governmental organizations which spared researchers the need to re-apply annually for grants.

Now laboratory directors are elected, as are most institute directors, with pro forma approval by the presidium of the Russian Academy of Sciences. Ad hoc committees and professional associations have begun to exert an influence on the policy process. The proliferation of bodies with access to the policy process should engender open discussion over the direction of research and competition for scarce resources, most likely through peer review, in which the "best" projects are more likely to win out. Russian officials and physicists who share these sentiments see the rise of market relations as part and parcel of ongoing processes of democratization and decentralization.

Recently, however, decentralization and democratization have slowed down as the same physicists who held leading positions in the Soviet regime continue to occupy managerial posts in institutes and scientific societies. These physicists often belonged to the Communist Party (which was outlawed after the aborted August 1991 coup), but now declare themselves "progressives" and "professionals" in the new Russia. They retain authority because of connections dating to the old regime. Granted, many of these individuals are first rate scholars, and most have the interests of the survival of their institutes and programs at heart. But they also have a monopoly on information and funding which interferes with the ability of younger physicists to commence new programs or participate in the international scientific community. In every institute I visited, physicists told me that program announcements, requests for proposals, and calls-for-papers rarely make their way from the directors' offices to bulletin boards in the corridors where any one can read them.

Part of the problem here is a generational one. In 1987 the Soviet Academy of Sciences announced that laboratory, institute and academy department directors would have to retire by the age of 65. The goal was to inject new blood into "the top-heavy age
structure of the Soviet scientific community." Over half of the academy's 250 full members were over seventy years old. Yet even with early retirements a vast majority of institute directors have been retained, and the Russian Academy is only somewhat younger. (Physicists account for one-sixth of Academy membership, and five of its eleven vice presidents.)

In the Ukrainian Academy of Science, the situation is worse. In elections this spring virtually all of the leading personnel were re-elected. Most of these officials were communist party members, including the 74-year-old metallurgical specialist B. E. Paton, who has served as President since 1962. Many young people have abandoned the sciences for graduate school in history, economics, or business, or have entered business outright rather than fight entrenched scientific bureaucrats.

More critical, the dissolution of the Soviet regime and the deepening economic and political crisis have left scientists without an anchor. Funding has been cut, research programs canceled. Newly-created bureaucracies are powerless and money-less to help. Even the most simple equipment cannot be purchased owing to the absence of hard currency. Rampant inflation is a major enemy. There is barely enough money to pay salaries, none for research. Scientists know too well the impact of inflation. A friend who works in one of the leading physics institutes in Russia complained to me, "I know a lady with a German shepherd. The dog earns 12,000 rubles a month to guard a car park. I earn 8,000." In comparison with other sectors of the economy, R and D lags in wages behind industry, civil engineering, transport, and "business." The life, medical, and biological sciences are the hardest hit. But the physical sciences keenly feel the current crisis.

The Kurchatov Institute for Atomic Energy (now called the "Russian Scientific Center") would appear to have significant advantages in weathering the storm. Its directors maintain valuable long-term ties with the West, in particular through ITER. The Kurchatov institute also has high visibility owing to the fact that it was home to the Soviet atomic bomb project and nuclear energy industry. But its library, a real national treasure, has had to cancel hundreds of foreign subscriptions which it can no longer afford. Staffers believe the government "has no understanding of the situation." The long-delayed T-15 tokamak fusion reactor with superconducting magnets now sits idly. There is no nitrogen, no spare parts,
staff has gone abroad. Physicists fret that an irrational, uneducated public will impinge upon the institute’s vital research program in nuclear physics.⁴

Dmitrii Riutov, head of the fusion program at the Siberia-based Institute of Nuclear Physics, spends much of his time searching down sources of support as old bureaucracies give way to new ones and sources of money dry up. The newly formed Ministry of Science of President Yeltsin’s government is still working out responsibilities, priorities, and budget with a staff consisting largely of holdovers from the former regime. Similarly, high energy physicists at the Ukrainian Physico-technical Institute in Kharkov sit in the control room of the linear accelerator facility watching television, and waiting for the Ukrainian government to agree on a budget for fundamental research so that they can buy electricity to run experiments. The story is the same throughout Russia and Ukraine.

Some physicists see the new political situation in Russia -- and the break up of the institutional momentum which characterized Soviet research and development -- as an opportunity to float new projects. A number of Russian physicists criticize the massive accelerators at Dubna and Serpukhov as "the most expensive scientific failures."⁵ However, most of the new projects are cut from the same cloth of big physics. For instance, Vladimir Orlov, one of the heads of the Russian breeder reactor program, touts new work on "inherently safe" breeder reactors. Vasilii Vladimirskii, head of the Institute of Experimental and Theoretical Physics in Moscow, is pushing to resurrect a heavy-water, gas-cooled reactor which was first proposed in 1946 but was pushed aside by the RBMK reactor. Physicists at the All-Union Research Institute of Experimental Physics (Arzamas-16) where Khariton, Tamm, and Sakharov worked on the hydrogen bomb, are designing underground nuclear power plants. In Ukraine, in an effort to achieve big power status, physicists strive to accelerate the space effort.⁶

The Professionalization of Physicists

Contributing to the process of democratization is the proliferation of groups of scientists independent of the government, what would be called "professionalization" in the West. In the early 1930s, virtually all Soviet professional organizations of architects, lawyers, engineers, biologists, physicists were outlawed or subjugated to party organs. The
The resurrected Russian Physics Society was organized in 1988. It is centered in Moscow; physics societies also were formed in Estonia, Latvia, Belorussia, Lithuania, and currently in Ukraine. Physics society members intend to bring scientists, engineers, teachers and students together to preserve fundamental research in the face of pressure for economic accountability to society; determine priorities between big science (accelerators, reactors, space) and little science; revitalize higher education and publication; establish standards of professional ethics and social responsibility; and combat mysticism, occultism, and astrology.

In a speech at the founding meeting of the society in November 1989, Sergei Kapitsa, son of Nobel prize-winner Peter Kapitsa, called for the USSR's 400,000 physicists to take a leading role "in the rebirth of our country and the perestroika of society." He urged them to clean their own house through a discussion of moral and ethical standards, a task for which, he admitted, physicists were poorly prepared. The legacy of Stalinism and Brezhnevism had left them tied to military interests, and closed-minded concerning dissent and whistle-blowing. After rapid early growth, membership has stabilized at a few thousand.

The Nuclear Society, also founded in 1989, which is based at the Kurchatov Institute, shares the goals of the Physics Society. The Nuclear Society has grown rapidly to several thousand members with chapters in the far-flung cities of the military-industrial complex, from St. Petersburg to the Urals and Siberia. The society promotes international contacts. Its membership seeks interaction between scientists and the public as a way to form public opinion and raise confidence in nuclear power. In the tradition of the 1920s when the Party
set out to teach Russia to read, nuclear physicists use a press center and a film series entitled "Liquidate Illiteracy About Nuclear Power Stations." Perhaps trying to show the nurturing side of technology, they have established a "Women and Nuclear Energy Committee" since "A woman, as nobody else, is able to carry to people treating nuclear power with distrust truthful scientifically substantiated information on siting and operation...our knowledge, experience and at last woman's charm could play their positive role [not my translation]." 9 Yet a series of technology assessment commissions to evaluate the safety of nuclear installations near Rostov, Gorky, and Cheliabinsk showed both total public mistrust of scientists, and scientists' failure to understand how an open assessment program might help recast the image of physicists in a positive light.

The Public and Russian Physicists

In the USSR, as is well known, the public was systematically excluded from participating in decisions about where to build atomic power stations, what pesticides to use, in a word, excluded from contributing to the answer to the question, "How safe is safe enough?" The media rarely reported any technological disaster. The citizen was accustomed to thinking that urban life -- and technology in general -- was safe. Now, not a day passes without exploration of some other man-made disaster. From a nuclear power industry in critical health, and spectacular space failures, to daily press reports of newly discovered toxic waste dumps and the violation of moral and ethical principles of human safety in the name of national security, the public has growing awareness of the potential social costs of unregulated science and technology. The public questions massive expenditures on technologies which it perceives to be of limited immediate social utility. The public has adopted a NIMBY (Not-In-My-Backyard) approach to technological development.

"Radiophobia" is rampant, encouraged by journalistic reports in popular weeklies and literary journals. Poets condemn atomic energy as symbolic of the general lack of concern for the environment in large-scale development projects typical for the Soviet Union. The coverage includes: reports on the sale of food tainted with cesium; expose's on the Chernobyl disaster, bureaucratic mismanagement of the clean-up and reclamation, the continued suffering of the Chernobyl victims, and confusion over dosages, rates, and
exposure; and articles on the continued problems in the industry such as those in the United States at Hanford, Washington, Savannah, Georgia, and Fernald, Ohio, in Semipalatinsk, Atomgrad on the Yenisei River, and elsewhere. Children are deeply troubled by the Chernobyl tragedy. Drawings of atomic power stations by French and Soviet schoolchildren reveal the extent of the problem: for the French child, the station sits in a pastoral setting, the sun shines overhead, and the workers, dressed in normal clothes, all smile. For the Soviet child, menacing, dark clouds hang over the atomic energy station, workers wear hardhats and stand sullenly at attention, and rockets with nuclear warheads ring the station.

The public no longer silently endorses research in high energy, nuclear or space research. They mistrust the experts whom they believe prepared environmental impact statements at the behest of the government. Several citizens' organizations have garnered broad support, like the disarmament organization Nevada-Semipalatinsk, which was formed to protest the unexpected venting of radioactive gas after an underground test in Kazakhstan, and effectively forced the government to adopt a moratorium on all future testing. Others include dozens of "green" organizations. These may be nascent counterparts to the public interest groups in the U. S. which are concerned with science and technology like Common Cause, the Center for Auto Safety, and many others. All this has had a direct impact on physicists' work.

A short drive from the Kremlin, a short walk from a subway station, seven reactors operate in the Kurchatov Institute. They include the F-1, the first Soviet reactor which has operated virtually without break since scientists first achieved a chain reaction on December 25, 1946. A handful of scientific commissions over the past five years have concluded that the reactors are safe. But the city and district councils have pressed to shut the reactors down, and move them out of the city for disposal. This would effectively slow civilian nuclear power engineering for a decade while new facilities were built elsewhere.¹⁰

Physicists at the Institute of Nuclear Physics in Gatchina south of St. Petersburg have also had to curtail their research. For years they tried to gain approval on a new experimental reactor, the 100 megawatt "PIK" to replace the obsolete VVR-M light water reactor built in 1959. But they faced opposition from the local authorities and citizens which they could not comprehend. After all, the site for the institute was selected outside of
Leningrad city limits precisely to enable the Leningrad Physico-technical Institute to expand research in the areas of nuclear fission and high energy physics. LIAF also employs a large number of local residents. Moscow’s Institute of Theoretical and Experimental Physics’s only heavy water reactor was closed down and dismantled after Chernobyl owing to the fear of local residents. But arguments of safety and the promise of jobs have fallen on deaf ears.

The whole space program has fallen in disrepute, egged on by disparaging reports in the Russian press. Open discussion of past failures, poor performance, technological backwardness, present costs, launch delays and future fantasies have generated mistrust. Some officials and space researchers are trying to prolong the life of certain programs in the hope that successes will give the Yeltsin government legitimacy as it did Khrushchev and Brezhnev, or perhaps that the United States will notice and join firmly with Russia in the race to Mars. But most officials and the public call for a moratorium to manned flight and a focus on programs with undoubted benefit: communications, weather forecasting, and navigation satellites. The budget for space research has been slashed over seventy percent, clearly inadequate to support researchers in hundreds of institutes. Future Russian efforts in "big" science and technology require international participation.

First the Iron Curtain, Now the Green One

Russian scientists were prevented from becoming full members of the international community by policies, official and unspoken, dating to the Stalin years. They were largely restricted from travelling abroad for conferences or sabbaticals, welcoming foreign scholars, purchasing equipment or even publishing in western journals. Communist Party membership was often a prerequisite to foreign travel. Frequently, attendees at conferences were individuals members whose loyalty to the regime was being rewarded. Officialdom ignored invitations of western scientists to their Soviet counterparts. Entire Soviet delegations arrived at international conferences with none of the invitees in tow. The same problem held for travel in the other direction; many a western scientist was denied a visa to the USSR for arbitrary and capricious reasons.¹¹

There was some hope after Kurchatov’s visit in 1956 to the British nuclear facility at Harwell that international contact between western and Soviet physicists would become
normalized. Soviet and American scientists next discussed plasma physics face to face at the Third International Congress on Phenomena in Ionized Gases, held in Venice, in 1957. By the following year at the Second Conference on the Peaceful Uses of Atomic Energy in Geneva in 1958, American and Soviet theoreticians and experimentalists gathered, compared results, and developed working relations. For more than thirty-five years, the countries cooperated in various fields of research. But the relationship was subject to the vagaries of political winds blowing in Washington and Moscow. Trusting high-level exchanges gave way to small, periodic ones, especially after the Soviet invasion of Afghanistan. Human rights issues played a critical and important role in shaping the face of exchanges. The race "to be first" in science and technology also plagued relations until the collapse of the USSR.

All of this changed markedly under Gorbachev. The reforms initiated during perestroika contributed to a new international self-image for Soviet scientists. From leading government officials and scientists on down they rejected "go-it-alone" ideological pronouncements about the superiority of Soviet science. They admitted the intellectual poverty of the effort to police scientific exchanges to control dissent. They recognized the need to participate in the international arena through individual, institutional, and bilateral agreements.

The internationalization of Russian science is promoted by the renewal of east-west scientific technological exchanges in such fields as nuclear safety after a ten-year hiatus. Other governments and professional associations have followed suit. Russian participation in such organizations as the International Atomic Energy Agency has been normalized. There are also such ad hoc arrangements as the Department of Energy and General Dynamics $90,000 initiative to support over one hundred Kurchatov Institute scientists working on magnetic fusion, although DOE officials seem dissatisfied with this mission.

In high energy physics, physicists travel to CERN, the SSC, to Germany, England, and Japan. The initiative of well-connected Russian scientists is crucial. Academicians Aleksandr Skriniskii of the Institute of Nuclear Physics in Akademgorodok and Lev Okun of the Institute of Experimental and Theoretical Physics in Moscow and their research teams are closing agreements with scientists at the Stanford Linear Accelerator Laboratory (SLAC) and the SSC in Texas to provide both personnel and equipment for high energy physics research.
in the U. S. Scholars at CERN have also discussed providing tens of millions of dollars for their Russian colleagues.

In the commercial realm as well, various agreements have resulted from Russia’s embrace of "the market." They run the gamut from the fire sale of high technology (for instance, the Topaz space reactor) to mineral exploration, from joint ventures to turn-key plants to basic research. The U. S. government has also announced plans to purchase up to 500 tons of enriched uranium for reactor fueling. There are now over 300 commercial agreements with Academy of Science institutes. Many are working poorly because of constantly changing tax laws, zealous officials who want their cut, and a general lack of experience. Said one official, "We’re always tardy in the creation of the legal basis for the normal operation of the Academy."

Efforts to preserve international contacts have encountered the challenges of economic decay, political crisis, and even civil war in Armenia, Georgia, and Azerbaidzhan. Rampant inflation and shortages of hard currency preclude purchasing western scientific journals and supplies, sending faxes, or repairing machinery and equipment. Only e-mail is reliable. Since the summer of 1991, Aeroflot ticket prices have grown from 2,000 to 150,000 rubles, exceeding average annual scientific salaries ten-fold. It is easier to get visas than to buy tickets. Aeroflot maintains the fiction that it is fully booked eight to nine months in advance, while its planes fly half empty. Travel between FSU states is no easier. Scientists speak without blinking of the need for the infusion of billions of rubles and tens of millions of dollars. They see such cooperative agreements in fusion as ITER and joint space shots as vital to the health of science.

As demonstrated by the recent stranding of a Russian astronaut in space, however, the U. S. would be straddled with huge bills from cooperation in space with Russia, a high price for unquestionably talented manpower and powerful rockets. Recent management changes at NASA, costs estimated at hundreds of billions of dollars, and the scientific uncertainties of the Mars mission suggest that policy makers should be wary of embracing Russian overtures in space -- or any other field -- without complete prior agreement of the two parties on costs and contributions.
A clearing house of information on public and private ventures, perhaps within the National Science Foundation or National Academy of Sciences, should be maintained to ensure a systematic approach to cooperation with Russian scientists. This will assist private foundations and professional associations such as the American Institute of Physics who wish to maintain strong contacts with the Russian scientific community to use their limited resources more efficiently.

Brain Drain

Crisis and internationalization have led to brain drain of top scientists in many fields, in particular mathematics and theoretical physics. It is difficult to get a reasonable estimate of the numbers of scientists who have emigrated since no official body gathers data systematically. It is known, however, that scientists with advanced degrees left the Ukrainian Academy of Sciences (1% of total) in 1990-1992, three-eighths of whom were physicists. At the St. Petersburg Physico-Technical Institute alone 100 leading scientists are abroad on long-term contracts. The reasons are clear: a month's earnings in the west guarantees financial security at home for a year. Some Russian officials say that 5,000 specialists have found employment abroad. Others say many more have left, but have accepted temporary positions with soft money and will return soon.

Rather than signaling the death knell of Russian science, this is a sign of health since the international transit of scientists is a central component of modern research. Western firms have taken advantage of this situation, hiring talented researchers in such fields as fusion, space, artificial intelligence and genome research at low cost. Several benefits derive immediately from brain drain. Most Russian scientists maintain close contacts with their colleagues at home, seeing to it that they get some work -- and hard currency. Still others recognize that there is a limit to the number of scientists who can be absorbed and that this limit has already been reached, and this appears closer to the truth. Indeed, the drain has slowed, limited by the inability of most scientists to buy tickets and the receiving side to pay.

Internal brain drain is more serious. The real danger is that scientists will leave Russian science for "business" endeavors within the country. Indeed, many scientific research institutes have laid off or fired workers. Others have gone months at a time without
paying salaries. Some scientists have quit showing up at work, others have formed their own
firms. Only the strongest physics institutes may survive. Between 1989 and 1990 alone, the
number of scientists engaged in research in Moscow, the center of Russia science, dropped
one-eighth. Russian and Ukrainian officials estimate that eight to ten percent of scientific
personnel are currently quitting their institutes annually. The best universities in Moscow,
Leningrad, and Novosibirsk are having trouble filling their science departments. Young
people want to make it in business; science holds no promise for them. This suggests the
possibility of a shortfall of scientific personnel in future decades.

Another side of this manpower picture is the fact that Soviet science was inefficient,
and that some down-sizing is required. The USSR turned out great numbers of scientists, in
particular engineers and physicists, in the 1950s and 1960s, often of a narrow profile,
without devoting enough attention to quality. The emphasis on physical, material, and
technological sciences was detrimental to biology, psychology, and sociology. Since it was
cheaper to produce scientists than equipment, a huge gap resulted between personnel, on the
one hand, and outdated machinery and equipment, instrumentation, and computerization, on
the other hand, which persists to this day.

Military Conversion and Western Anxiety

There is yet one more side to the internationalization of Russian science which clouds
the picture. Many western observers are concerned that Russian physicists with weapons
knowledge will contribute to nuclear, rocket, and chemical proliferation in have-not third
world nations. Tens of thousands of scientists have lost jobs and dozens of military research
cities have closed or sharply curtailed their work. According to officials in the Russian
Ministry of Science, roughly half of Soviet R and D expenditures went to the military.
Today it is on the order of twenty-five percent and falling.14

The West responded to the specter of military brain drain with the founding of Inter-
national Science and Technology Centers in Moscow and Kiev (with affiliate centers
approved for Belorus and Kazakhstan) to employ specialists with critical weapons knowledge,
at a cost of $70 million to date (with $35 million from the U. S.). One U. S. official told
me, "It's hard enough to get science on any one's agenda. The international centers are only
a first step. They are working and there will be spillovers." Another U. S. official believes the international centers have been "non-trivial" in generating other initiatives to help Russian scientists, but have been largely ineffective in achieving the established goals.

In fact, the international centers hinder the recovery of the Russian physics establishment. They prolong the Russian emphasis on large scale technologies, when smaller projects may be more cost effective and capable of generating more employment. They maintain the physics profile of Russian science when biomedical and environmental sciences are in greater need. They exclude younger physicists from access to resources. They encourage Russian officials to use similar scare tactics in the future to get western attention and money. Within the Russian physics community itself, there is controversy. Dr. Oleg Filatov, Russian home team leader for ITER said that "ITER money is disappearing before our very eyes. When we try to get international center funding, we are told that 50% of any funds must be for closed -- Arzamas or Cheliabinsk -- personnel. Why should I do the work for them? What is more, the bureaucracy to apply is formidable." 15

There are a number of reasons why the center simply will not achieve the desired end of keeping nuclear specialists in Russia. First, the policies of the Ministry of Science which have opened the borders to international market relations make it likely that scientists from all sectors will find employment abroad. Russian scientists now travel freely within the limits of their finances. Indeed, as a result of brain drain, scientists with military know-how, some from Academy institutes, others from military enterprises, are already abroad looking for employment.

Second, the study of technology transfer has shown that such international regimes as the Non-Proliferation Treaty and U. N. nuclear safeguards are far more effective in controlling critical technologies than this center ever could be. The goal should be to prevent the flow of critical technologies. 16 Greater danger comes from the continued willingness of third parties such as China, France, Germany, Israel, and the United States itself, to sell weapons and technologies to nations such as Iraq striving to develop nuclear and chemical weapons.

The recent decision of the Soros foundation to provide $100 million to individuals, not institutions in Russia to support fundamental research, libraries, international telecom-
munications like e-mail, and short-term travel grants is a sign of the vacuum that exists in western policy. Tens of thousands of fundamental researchers have been left to fend for themselves with uncertain government support, while producers of weapons of mass destruction are being rewarded for their past efforts.17

Prospects for the 1990s:
A New Profile for Physics Research?

The Russian physics establishment faces a wide range of financial, political and public relations problems. Physicists must make a series of difficult choices. Which programs merit continued support? Which institutes should be closed? How many scientists can be let go without long term damage to ongoing research? Which government bureaucracies will fund physics R and D, and at what level? Can those physicists whose research efforts were limited by the technological momentum and political favoritism of the Brezhnev era find a government or public willing to commit resources? The uncertainties involved in the solution of these issues seem overwhelming.

Many observers, inside and outside of the country, believe Russia's scientific limits have been reached, that its productivity and efficiency are now declining. The question is what to save. Democratization and decentralization of scientific institutions and policy making will ensure competition in a free market place of ideas, overcoming decades of domination of entire fields of research by one individual or institute, in some cases with disastrous results. Decentralization and democratization are likely to lead to a more rational balance between social and scientific interests and potentials, and challenge the past assumptions of the scientific and political elite that science and technology, everywhere and always, are capable of solving problems of economic and social development.

The ongoing changes will lead both to some down-sizing of the Russian research enterprise and to greater emphasis on the biological sciences, overcoming decades of emphasis on big physics, materials science, and technology. The creation of numerous professional associations and nascent public interest groups gives credence to the belief that these processes are moving ahead, albeit in fits and starts. In any event, there will be
displacement and controversy. An open, decentralized process is more likely to ensure a fair answer than when the process is closed.

As overwhelming as these problems are, there is reason for hope. First, Russian physicists are an increasingly active participant in the international arena. Many already work jointly with their western colleagues, providing necessary income for their home institutes. The increasing cost of modern research has made many western governments open to sharing its cost. The low cost of high quality Russian scientific labor appears to be enough to overcome even the most persistent cold war fears. This is not to say that the path to cooperation is a smooth one. Western firms and bureaucracies have found it extremely frustrating to deal with Russian physicists in an ever-changing environment. So uncertain is the state of affairs in Russia today that these organizations have canceled more than a few agreements since they were getting little return for their investment.

Yet the Russian physics establishment is first-rate in a number of fields according to international standards. If physicists can weather this period of national crisis, their research programs will be in an adequate position to take advantage of government and public support at the turn of this century.
ENDNOTES

1. Paul Josephson is the author of *Physics and Politics in Revolutionary Russia* (1991). He is working on a history of the Soviet atomic age. He has visited Russia and Ukraine eight times since 1985. This essay is based on work in Soviet archives, interviews with over sixty scientists, and a reading of Russian language national, regional, local and institutional newspapers and journals. Paul Josephson teaches at Sarah Lawrence College, Bronxville, NY 10708.

2. XX S"ezd KPSS. Stenograficheskii otchet, (Moscow: Politizdat, 1956), I: 595-600. For a discussion of some of these fantastic, futuristic projects, a number of which the United States also pursued, see Iu. N. Sushkov, *Atomnaia energiia i aviatsiia* (Moscow: Znanie, 1958), and A. P. Ermakov and A. G. Syrman, *Atomnaia energiia i transport* (Moscow, 1963).


8. Sergei Kapitsa, Speech at Organizational Meeting of Physics Society of USSR, Moscow, November 17, 1989.


15. Interview with Dr. Oleg Filatov, Efremov NIIEFA, St. Petersburg, January 12, 1993.

16. Among the many fine studies of these issues, see Thane Gustafson, Selling the Russians the Rope? (Santa Monica: Rand, 1982), and Bruce Parrott, ed., Trade, Technology, and Soviet-American Relations (Bloomington: Indiana University Press, 1985).