ARMS CONTROL PHYSICS: THE NEW SOVIET CONNECTION

Informal contacts established between US and Soviet physicists during an unpromising period in relations between the superpowers have taken on new significance since Gorbachev's emergence.

Frank von Hippel

US and Soviet scientists have been holding quiet discussions on matters like missile defense since the first International Pugwash Conference on Science and World Affairs in 1957 (see PHYSICS TODAY, September, page 81). Sometimes these discussions have constituted an informal "backchannel" between the governments for consideration of possible arms control initiatives. Thus in conversations between US and Soviet scientists in 1964, US scientists argued that ABM systems would not be effective against a determined adversary and that their deployment would stimulate an offense–defense arms race; they accordingly proposed a treaty to limit ABM systems. Two high-level Soviet scientists, Lev Artsimovich (who was head of the Soviet fusion program) and Mikhail Millionshchikov (who was vice president for applied physics and mathematics of the Soviet Academy of Sciences), subsequently helped bring their government around to this position, thereby contributing to the achievement in 1972 of the ABM Treaty.[1]

When cold war tensions have been at their worst, informal contacts between US and Soviet scientists have not always been welcomed in government circles. Yet as the history of the ABM Treaty illustrates, such discussions often have provided an opportunity to investigate new, experimental ideas that government agencies have been loath to explore for fear of reducing political maneuvering room. Such informal discussions also have been convenient forums in which to go beyond the issues of the day and to develop a basis for longer-range planning.

Therefore, despite misgivings, government officials who are interested in the possibility of progress in arms control negotiations have sometimes welcomed the type of research done within the framework of private initiatives. They see independent scientists as scouts mapping out technical territory that the armies of government technical experts will be able to secure very quickly once they are permitted to move forward.

During the early 1980s, a period of renewed cold war tension, a number of US scientists began cautiously to cultivate contacts with independent-minded Soviet counterparts such as Evgeny P. Velikhov, the Soviet Academy's current vice president for applied physics and mathematics, and Roald Sagdeev, until recently the head of the Soviet Institute for Space Research. With the emergence in the mid-1980s of Mikhail Gorbachev as leader of the USSR and the advent of *glasnost*, it has been possible to experiment with more open types of exchange, including joint research programs on the technical basis for new arms control policy initiatives. At the same time, some Soviet scientists have been catapulted into positions of top advisory authority, a situation that involves some risks but also great opportunities.

As some of the Soviet scientists have taken on greater

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responsibilities, demands on their time have become voracious, limiting their availability for casual discussion. Despite their closeness to power, however, they have continued to operate with an activist style.

As a result of various fortuitous circumstances, I have been personally involved in a number of exchanges with these Soviet scientists, and my professional life has become more exciting as a result. I first met Velikhov at a meeting of the International Physicians for Social Responsibility in the summer of 1983. Earlier that year, a group of Soviet academicians had sent an open letter to the US scientific community asking whether, in light of President Reagan's "Star Wars" speech of March 1983, there had been a change in the professional consensus in the US regarding the feasibility of effective missile defenses. Only the Federation of American Scientists responded directly, and that response led to an invitation from Velikhov to visit the Soviet Union. Despite a partial boycott on bilateral scientific contacts, which the federation had joined mainly because of the Soviet government's treatment of Andrei Sakharov, the group decided to accept Velikhov's invitation. In November the federation sent a party to the USSR that included FAS President Jeremy Stone, John Pike of the FAS staff, John Holdren of the University of California (FAS vice chairman), Berkeley and myself (FAS chairman).

About this time, Velikhov also received an invitation from Senator Edward M. Kennedy to come to the United States to testify about the "nuclear winter" debate. Velikhov came with a party that included Sergei Kapitsa (Vavilov Institute of Physical Problems) and Vladimir V. Aleksandrov (Computing Center of the Academy of Sciences). While in the US Velikhov also visited Princeton and FAS headquarters in Washington, affording an opportunity for further conversations.

The Committee of Soviet Scientists

Velikhov met with the FAS and came to the Kennedy hearing as chairman of the Committee of Soviet Scientists for Peace and Against the Nuclear Threat. This committee, mostly made up of high-level members of the Soviet Academy of Sciences, was established in the spring of 1983, following Reagan's Star Wars speech. Velikhov had succeeded Artsimovich as head of the Soviet fusion program and Millionshchikov as the Soviet Academy's vice president for applied physics and mathematics.

In early 1983, Velikhov had already had discussions with Richard Garwin of IBM and others concerning the possibility of a ban on antisatellite weapons. These discussions took place in a meeting between the US National Academy's Committee on International Security and Arms Control and a counterpart group from the Soviet Academy of Sciences. The two groups had been meeting since June 1981. (Marvin Goldberger, at that time president of Caltech, was the first chairman of the US Academy's committee, and Academician N. N. Inozemtsev, director of the Institute of World Economics and International Relations, headed the Soviet Academy's group.)

These discussions helped persuade the Soviet government to declare, in August 1983, a unilateral moratorium on the testing of Soviet ASAT (antisatellite) systems. That same month the USSR introduced at the United Nations a draft ASAT treaty that owed a good deal to a model treaty that Garwin and Kurt Gottfried of Cornell had developed in cooperation with the Union of Concerned Scientists (see PHYSICS TODAY, November 1984, page 99).

Velikhov told me that the reason he decided to organize the Committee of Soviet Scientists was to educate a new generation of Soviet scientists, including himself, about nuclear arms control and to reopen the US–Soviet dialogue on strategic defense with the roles reversed. Now it would be the Soviet scientists who would try to convince the US government, with US scientists as intermediaries, that the pursuit of ballistic missile defenses would be counterproductive.

The Committee of Soviet Scientists therefore opened exchanges with scientists representing the full spectrum of US opinion on SDI—including, to the surprise of some of us, Edward Teller. (Velikhov and Teller had both attended conferences in July 1982 and July 1983 in Sicily on "how to avoid nuclear war" and "the technical basis for peace.")

As a result of such exchanges, its own studies and previous Soviet studies (see the article by Velikhov on page 32), the CSS became quite expert on the technical aspects of SDI, and a group under the leadership of Velikhov, Sagdeev and Andrei Kokoshin (at that time head of the division of military–political affairs of the Institute of US and Canadian Studies) wrote up its conclusions in a book which was printed in 1986 in both Russian and English.

The primary message of the book was that it would be feasible to neutralize space-based defenses with much less expensive countermeasures. The analyses presented were based on descriptions of proposed SDI weaponry that had been published in US publications, such as *Aviation Week and Space Technology*, and on back-of-the-envelope physics calculations—much in the style of Garwin and Hans Bethe. However, open publication of a technical discussion of possible future weapons systems was an unprecedented event in the Soviet Union and led to a number of letters from irate Soviet citizens demanding that the members of the CSS be prosecuted for revealing how the Soviet Union would neutralize the US Star Wars system. Fortunately, the Soviet government ignored these demands.

In the upshot, the direct impact of the CSS on the US debate over SDI was negligible. But the indirect impact was more important, because it helped persuade Gorbachev, who became General Secretary in early 1985, to announce that the Soviet Union would not compete with the United States in attempting to establish space-based defenses but would instead make an "asymmetric response" based on the types of countermeasures described by the Soviet scientists. This undermined the argument of American SDI proponents, who had said that if the United States did not go full speed ahead, the Soviets would deploy space-based defenses first.

In parallel with its critique of space-based defense, the Committee of Soviet Scientists also sponsored some studies on nuclear winter.[2] In part because of the limited capacities of Soviet computing facilities, these studies contributed more to the internationalization of scientific

GLORIA B. LUBKIN

Roald Sagdeev (left), a leading figure in the Committee of Soviet Scientists, and Richard Garwin of IBM, well known for his contributions to scientific research on arms control in the United States, chat while Sagdeev cooks pilaf Tatar style during a recent visit to the United States.

concern about nuclear winter than they did to the understanding of the phenomenon itself.

In-country seismic monitoring

For many years the US government had been on record as favoring a comprehensive nuclear test ban, but the Reagan Administration had backed away from this position. Gorbachev apparently hoped that world opinion would persuade the United States to join in a moratorium. In fact, although the Soviet moratorium was widely praised by advocates of arms control, the public response was far weaker than that to the 1958–61 moratorium, perhaps because moving testing underground had effectively ended the fallout that had so frightened the public.

When Gorbachev came into power in early 1985, *glasnost* and a personal relationship between Velikhov and Gorbachev gave the CSS the opportunity to undertake new ventures.

Its first new move was in direct support of Gorbachev's first arms control initiative: the Soviet unilateral moratorium on underground testing that began in August 1985.

In announcing the moratorium, Gorbachev presumably was inspired by the bilateral test moratorium of 1958–61, with which the US and Soviet governments signaled to each other and the rest of the world that they were seriously interested in ending all nuclear testing (see the box on page 43). That moratorium led to the Kennedy–Khrushchev Partial Test Ban Treaty of 1963, which ended nuclear testing in the atmosphere, in outer space and in the oceans, but not underground. Now Gorbachev wanted to complete the job by ending all underground testing of advanced nuclear weapons systems.

One of the major obstacles that had prevented Kennedy and Khrushchev from consummating a comprehensive test ban had been a claim by US weapons laboratories that the Soviets might be able to continue to develop new nuclear weapons with small underground tests, which seismic sensors beyond the borders of the USSR would be unable to distinguish from earthquakes. The 1958 International Conference of Experts sketched out a verification system involving a worldwide network of seismic stations and on-site inspections at the locations of suspicious seismic events, but in the end, the system that the US government wanted was too intrusive for the Soviets, and the underground part of the ban had to be dropped.

Meetings with Shevardnadze, scientists

In September 1985, at a meeting in Copenhagen commemorating the centennial of the birth of Niels Bohr, Velikhov suggested to me that the Soviet government might be willing to let an outside group set up a seismic monitoring system in the USSR. I was already aware that one group, Parliamentarians Global Action, was interested in establishing a monitoring system for a bilateral US–Soviet moratorium. (Founded in 1979 by British and Canadian legislators, Parliamentarians Global Action had launched a peace initiative in May 1984—now known as the Five Continent Peace Initiative—with the objective of getting the two superpowers to reopen a constructive dialogue on arms control.) During the next several months, I learned that similar proposals were being made by Jack Evernden of the US Geological Survey and Thomas Cochran, a physicist with the Natural Resources Defense Council, an independent organization that does legal and technical work on environmental, energy and arms control policy.

The Parliamentarians were proposing to establish a monitoring system under the auspices of their peace initiative. Evernden was attempting to expand a scientific seismic monitoring agreement between the US Geological Survey and the Soviet Academy to provide information toward the design of a network to monitor a 1-kiloton threshold test ban. The NRDC was proposing a nongovernmental monitoring project to provide information about tests that both the US and the USSR keep secret.

In early 1986, Cochran wrote to Reagan and Gorbachev asking permission for private groups to establish seismic stations in the two countries for joint verification research. But after learning that the NRDC proposal was unacceptable to the Soviet foreign ministry, Cochran was ready to give up. At this point Jeremy Stone of FAS suggested trying to work through the Soviet Academy instead, and he invited Cochran to attend a meeting with

Academy representatives that was to take place at Airlie House in Warrenton, Virginia, in March 1986. At that meeting, which I also attended, the idea of nongovernmental monitoring met with a favorable reception from the Soviet delegation, which was headed by Sagdeev.

In April 1986, I accompanied a delegation from Parliamentarians Global Action on a visit to Soviet Foreign Minister Edward A. Shevardnadze. The delegation urged that the Soviet Union extend its testing moratorium in the hopes that the United States might still be persuaded to join.

To a physicist unfamiliar with the rituals of diplomacy, the meeting with Shevardnadze seemed very stylized. After we had shaken hands, we sat down, and tea and cookies were brought in. Then the spokesman for the Parliamentarians made his statement, and Shevardnadze responded politely. There were one or two additional polite exchanges; then the delegation got up, shook hands with Shevardnadze and left. It was not clear to me that anything had been accomplished, and so I suggested that we meet with Velikhov.

That meeting could not have been more different. The first thing Velikhov asked was, "Do you have any good ideas?" This led to a brainstorming session, at the end of which Velikhov and I agreed to organize a workshop the following month in Moscow. I agreed to bring representatives of the Western groups that were interested in setting up seismic stations in the USSR.

After the meeting, as we drove away, one of the Parliamentarians said to me in wonder: "You scientists can talk to each other!"

May 1986 workshop

By the time the workshop on test ban verification convened in May 1986 in Moscow, there were several reasonable proposals on the table. But the monitoring system suggested by the Parliamentarians would have required the Reagan Administration to join the Soviet test moratorium, and Evernden's plan also would have required US governmental support. Under the circumstances, the idea of doing the project on a nongovernmental basis carried the day, and the NRDC was able to make an immediate commitment to the project.

The final project incorporated elements from each of the three proposals. The design of the seismic monitoring system was based on that developed by Evernden; the scientific director of the project, Charles Archambeau of the University of Colorado at Boulder, had originally been recruited by the Parliamentarians for their project; and the NRDC undertook to raise funds for the US side of the project and to administer it.

The workshop led to an agreement between the Soviet Academy and the NRDC to set up three seismic stations around the principal US and Soviet underground test sites. Less than two months later, a team of seismologists recruited by Archambeau and led by Jon Berger and James Brune of the University of California's Scripps Institution of Oceanography were taking data in Kazakhstan, 100 kilometers from the Soviet test site. Cochran was in charge of the overall US effort.

This project had a rather big political impact, probably bigger than Gorbachev's unilateral moratorium on testing, because it vividly demonstrated, before the conclusion of the treaty eliminating intermediate-range missiles in Europe, the Soviet government's willingness to accept in-country monitoring of an arms control agreement. The project also had technical merit: It provided data that would be valuable to the design of an in-country monitoring network to verify a low-threshold underground test ban treaty.

International Scientists' Forum in Moscow

A key event in the developing exchanges between Western and Soviet scientists was the International Scientists' Forum on Drastic Reductions and Final Elimination of Nuclear Weapons, which Velikhov organized with some assistance from Western scientists, including myself, and which took place in Moscow in February 1987 (see PHYSICS TODAY, April 1987, page 67).

It was at this meeting that Sakharov reemerged as a public figure in the USSR, and it was here that he argued, in public for the first time, that the USSR should stop conditioning its agreement to a new strategic arms reductions treaty on a US promise not to deploy strategic defenses. Sakharov argued that the SDI program would collapse under its own weight.

There was a workshop at the forum on the idea of clarifying the gray areas of the ABM Treaty by imposing quantitative limits on parameters such as laser brightness. This idea was subsequently taken up by both the Soviet government and by Paul Nitze, who at that time was Reagan's specially designated arms control expert in the State Department. (Strobe Talbot, *Time* magazine's chief diplomatic correspondent, credits John Pike of FAS with implanting this idea in both governments.[3])

Also at the forum, a group of West European advocates of "non-offensive defense," who had been developing their ideas for several years in a series of Pugwash workshops, had the opportunity to present to Gorbachev's advisers their arguments that the best way to stabilize and shrink the conventional-weapons confrontation in Europe would be to preferentially eliminate offensive weaponry such as tanks. Subsequently, three of the West European analysts, physicist Anders Boserup (University of Copenhagen), economist Robert Nield (Cambridge University) and philosopher Albrecht von Mueller (Max Planck Society, Starnberg), and I were invited to write a letter to Gorbachev explaining the idea of non-offensive defense and its implications for arms control efforts.[4] These inputs probably helped provide the intellectual basis for Gorbachev's decision in late 1988 to unilaterally eliminate 5000 tanks from Soviet forces in Eastern Europe (about one-half the total number there) and another 5000 from the Western USSR.

Finally, it was decided at the forum to launch three new cooperative East–West ventures:

▷ An international journal, *Science and Global Security*, to publish the results of research pertaining to arms control, disarmament and the environment

▷ A five-year Cooperative Research Project on Arms Reductions under the joint auspices of the Federation of American Scientists and the Committee of Soviet Scientists

▷ An International Foundation for the Survival and Development of Humanity.

Joint journal on science and security

Although a number of American journals, including *Scientific American* and PHYSICS TODAY, publish occasional articles on the technical basis for arms control agreements, and the APS Forum on Physics and Society has published a number of useful collections of articles, there has been no journal with the publication of such work as its primary mission. *The Bulletin of the Atomic Scientists* was for many years devoted primarily to the publication of articles by scientists concerned about the arms race on the subject, but it has been used by them primarily to reach the public and to communicate with one another about political concerns, rather than to make detailed presentations of technical work.

With the creation of *Science and Global Security*, a

Test-Ban Technical Talks of 1958

UPI/BETTMANN NEWSPHOTOS

'Molodets!'—"Bravo!" or "Fine fellow!"—Khrushchev exclaimed, greeting W. Averell Harriman the day after the conclusion of the partial test-ban treaty in 1963. Harriman struggled hard for a comprehensive ban and was a key figure in the negotiation of the partial ban.

At the end of 1957, after the USSR proposed a two- or three-year trilateral ban on nuclear weapons tests, President Eisenhower suggested, amid growing world concern about fallout from such tests, that Great Britain, the United States and the Soviet Union conduct "technical studies of the possibilities of verification and supervision." In early 1958, a panel convened by the President's science advisory committee and headed by Hans Bethe concluded that a ban could be policed and would be advantageous to the US, and in April that year Eisenhower suggested technical talks to Soviet leader Nikita Khrushchev. Khrushchev accepted, and in the summer of 1958 teams of British, American and Soviet scientists met in Geneva. This was the first instance of technical cooperation between US and Soviet scientists in furtherance of arms control objectives.

Despite cold war tensions and questions concerning the political independence and authority of the three teams, they were successful in reaching agreement on a proposed system of in-country monitoring stations. Leaders of the three nuclear weapons states thereupon agreed to diplomatic negotiations, which opened in an atmosphere of optimism at the end of October 1958. Immediately upon the beginning of the diplomatic negotiations, however, the US delegation presented new scientific evidence indicating that a larger system of in-country stations might be required. The US delegation also raised the question of whether a weapons test could be concealed ("decoupled") in a big hole. The Soviet side, whose scientific team had been operating under much tighter political supervision from the start, reacted with suspicion, finding it hard to believe that the United States would change its position in so important a matter solely on the basis of scientific findings. Both sides nevertheless declared testing moratoria, and the talks proceeded, only to break down in May 1960 with the shooting down of the U-2 piloted by Francis Gary Powers and Khrushchev's breaking up of the Paris summit conference.

Talks resumed during the Kennedy Administration, but by that time a history of unilateral test moratoria followed by frenzied testing on both sides had generated wide cynicism, and when a partial test-ban treaty finally was concluded in August 1963, it involved no mutual system of in-country verification. The accord barred testing in the atmosphere, the oceans and space by the three parties to the agreement, but not underground testing, and in the following years the US and USSR continued to conduct such tests at increasing rates.

Could a comprehensive test-ban agreement have been achieved in 1963? The two sides seemed to some to be close, in that the USSR said it would permit three in-country challenge inspections, while the US insisted on six. Even, however, if the two sides could have reached agreement on the number of stations, it would have been hard to agree on what the inspectors should do.[1]

While agreeing by and large on the positive value and precedent-setting character of the Geneva technical talks, participants and scholars have drawn from them varying conclusions about the benefits and pitfalls of joint scientific research in matters of acute political sensitivity:

▷ James R. Killian Jr, president emeritus of MIT and science adviser to Eisenhower: "While unexpressed, it seemed clear that many political officers of our government hoped fervently that the whole test-ban controversy would be resolved by scientists; the political level looked for scientific certainty to minimize the difficulty of weighing other imponderables in the decision making. In the end, a limited test ban was achieved by diplomacy aided in essential ways by scientists."[2]

▷ Charles S. Maier, Harvard University: "In hindsight, it can be seen that the new scientific resources of the President provided a two-edged blade. Eisenhower himself clearly belonged among the supporters of a test-ban treaty. . . . Nonetheless, his style of administration and careful delegation of authority constrained his own convictions. . . . This is not to argue that caution should have been abandoned, but the search for loopholes became all-consuming. Here the scientists' ingenuity hobbled the President even while it aided him. . . . The new scientific advisory panels could only multiply choices or frame them more intelligently; they could not resolve them."[3]

▷ Robert Gilpin, Princeton University: "In retrospect there can be no doubt that the Conference of Experts was unique in the annals of diplomacy. . . . [But] in the mistaken belief that one can separate the technical and political aspects of national policy, [the] American political leadership in the summer of 1958 assigned to a group of inexperienced private citizens the task of negotiating the first part of what might have been an extremely important arms control agreement. As should have been expected, the American scientists . . . fell into a number of regrettable errors. Yet, under the circumstances, it is surprising that there were no greater errors committed and that the the scientist-diplomats did as well as they did."[4]

—William Sweet

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specialized journal for just that purpose now exists. Harold Feiveson, a Princeton physicist and political scientist who now works primarily on arms control, is the US editor, and the publisher in English is Gordon and Breach Science Publishers, which has a long-standing relationship with Sagdeev and a number of the other leading members of the Committee of Soviet Scientists. We expect that the publisher in Russian will be Nauka ("Science"), the publishing house of the Soviet Academy.

The first (double) issue of *Science and Global Security* appeared in English in October 1989 and contained articles on arrangements to verify nuclear weapon dismantlement, on the verification of limits on sea-launched cruise missiles and on space-reactor arms control. Future issues will also contain articles relating to the verification of arms control agreements, including an analysis of the results of the NRDC–Soviet Academy in-country seismic verification project.

The Cooperative Research Project

The FAS–CSS cooperative research project, of which Sagdeev (who succeeded Velikhov as chairman of the CSS) and I are codirectors, has thus far focused principally on approaches to verifying limits on nuclear warheads, a ban on nuclear reactors in Earth orbit and a ban on testing ground-based lasers as antisatellite weapons. On the US side, about 20 analysts, almost all of whom are university and national laboratory physicists, have contributed. On the Soviet side, the contributors have been six physicists from Sagdeev's group at the Space Research Institute and four analysts from Kokoshin's military–political affairs group at the US–Canadian Institute. Funding for the FAS group has been provided by the W. Alton Jones Foundation, the Carnegie Corporation and an anonymous philanthropist.

The focus of our work on the verification of limits on nuclear warheads is deliberately complementary to the traditional approach of limiting ballistic missiles and nuclear weapon "launchers"—the approach followed in the 1972 strategic arms limitation agreement (SALT), the 1979 SALT II treaty, the 1988 treaty eliminating intermediate-range missiles in Europe (the so-called INF Treaty) and the current strategic arms reduction negotiations (START). In the past, nuclear warheads were beyond the reach of arms control because they are small and cannot be counted from satellites. Now, with *glasnost*, it is possible to consider agreements requiring on-site verification.

Another reason it is now important to focus on verifying limits on warheads is that nuclear arms negotiations are concentrating for the first time on *reductions*. The INF Treaty eliminated a class of land-based nuclear missiles, and the START negotiations have the objective of reducing by approximately 50% the warheads currently deployed on strategic ballistic missiles. But neither the INF Treaty, as ratified, nor the START treaty, as it is being negotiated, include procedures for eliminating the warheads being retired. These warheads and the fissile materials they contain are therefore available for other uncontrolled weapons systems or for a sudden "breakout" from the constraints of arms reductions agreements.

One of the FAS–CSS papers therefore has examined possible arrangements for verifiably eliminating warheads and placing their fissile materials under safeguards without revealing warhead designs to the other side. Another explores the problem of verifying declarations of stockpiles of warheads (deployed and nondeployed) and stockpiles of weapons-usable fissile materials in weapons or available for their manufacture.

Two other papers have examined general approaches to the problem of verifying limits on long-range, nuclear-armed, sea-launched cruise missiles—one of the major unresolved issues in the START negotiations. All of these papers appeared in the first issue of *Science and Global Security* or will appear in *Reversing the Arms Race*, a book Sagdeev and I are editing for publication in English next year by Gordon and Breach.

A major joint FAS–CSS study relating to controls on nuclear warheads examined the applicability and limitations of passive radiation detection and of radiographic techniques for detecting nuclear warheads. This paper provided the theoretical basis on the US side for the recent Velikhov–NRDC project in which the gamma rays and neutron emissions from a Soviet cruise-missile warhead were measured on a Soviet cruiser through a three-inch-thick launch tube, at short range and at distances up to 70 meters, respectively (see the box on page 45).

Other papers have explored the application of similar techniques to the verification of limits on the number of warheads carried by a ballistic missile without actual removal of the nose cone. Two overview papers considered how nuclear balance would be achieved if each side's strategic arsenal was reduced from current levels of over 10 000 warheads to 2000 warheads or less.

A number of papers have also been written relating to the desirability and verifiability of a ban on nuclear reactors in Earth orbit. One of the indirect results of this effort was the uncovering of the fact, previously kept secret by both the US and Soviet governments, that gamma and positron emissions by Soviet nuclear reactors in Earth orbit have become a major problem for gamma-ray astronomers.[5]

In May 1989 FAS and CSS launched a joint assessment of a possible method of verifying limits on the potential brightness (measured in watts per steradian) of ground-based lasers being fired into space. One method would involve measurements at a distance of a kilometer from the laser of the light scattered out of the beam by atmospheric aerosols. The lead on this project is being taken by FAS under the direction of Ron Ruby, a physicist at the University of California, Santa Cruz.

The Soviet scientists in this cooperative project have repeatedly shown their independence from official Soviet positions as the following two examples will attest.

▷ In February 1988 the CSS brought to a joint workshop in Key West a manuscript that found no technical basis for Gorbachev's statement two months earlier that the Soviet Union had created "national means for verifying the presence of nuclear weapons on various naval ships... without conducting any on-the-spot inspection on board the vessels themselves."

▷ In May 1988 Sagdeev signed a joint CSS–FAS proposal to ban nuclear reactors in Earth orbit. It quickly became clear that this statement did not reflect Soviet policy when the Soviet space-reactor community counterattacked with a *Tass* article arguing the importance of space reactors and subsequently sent a delegation to the annual US space-reactor contractor in Albuquerque with offers to sell Soviet space reactors to the US. The leader of the Soviet delegation, Academician Nikolai N. Ponomarev-Stepnoi, when asked at the meeting about Sagdeev's opposition to space reactors in Earth orbit, said that he had met with Sagdeev before leaving Moscow and that Sagdeev "told me his opinion and I told him mine. And we were both so glad that we could tell each other our own opinion in our own country finally."

The International Foundation

At the January 1987 forum, Velikhov proposed the creation of a new foundation dedicated to fostering international cooperative solutions to the arms race,

Measurements of Radiation from a Soviet Warhead

One of the main issues that have blocked movement toward a Strategic Arms Reduction Treaty concerns limitations on long-range, nuclear-armed, sea-launched cruise missiles.

The Soviet government argues that unless the multiplication of this new type of long-range nuclear weapon is restricted, an agreement limiting other types of strategic nuclear weapons could be rendered meaningless. It claims that limits on nuclear cruise missiles could be adequately verified, and it has proposed a joint US–Soviet verification experiment on nuclear warhead detection on ships.

In contrast, the US government, which is ahead in the development of both the nuclear and nonnuclear variants of these missiles, feels no urgency about achieving a limitation agreement. It argues that the manufacture, storage and deployment of the small missiles can be so inconspicuous that verification of limits would be impossible. The US Navy has made it clear that it opposes any verification arrangement that would allow Soviet officials to inspect US ships or would reveal the presence of warheads to the general public. (Because the presence of nuclear warheads is a politically sensitive issue in many ports that naval vessels visit, the Navy neither confirms nor denies the presence of nuclear warheads on its ships.)

In an attempt to break this impasse the Soviet government, on 5 July, joined with the Natural Resources Defense Council in a demonstration of warhead detection on one of its ships, the guided-missile cruiser Slava. The demonstration occurred in the Black Sea off Yalta.

The warhead was easy to detect because the cruise-missile launcher was unshielded and in an exposed location above the deck. Even so, the demonstration of military *glasnost* was important because it was the first time that either government knowingly let anyone other than its own technicians close to one of its warheads with a high-resolution gamma detector—the instrument that the NRDC group brought along.

For this experiment, Thomas Cochran of the NRDC had recruited four other physicists: Steven Fetter of the University of Maryland, the lead author of the FAS–CSS study "Detecting Nuclear Warheads"; Lee Grodzins of MIT; Harvey Lynch of Stanford; and Martin Zucker of Brookhaven.

The NRDC group used a high-purity 150-cm^3 germanium crystal scintillation detector with a resolution of about 2 keV. The detector was placed on the launcher at a location directly over the warhead designated by the Soviet team (see cover). The gamma rays had to penetrate the launcher material, which was steel about 8 cm thick.

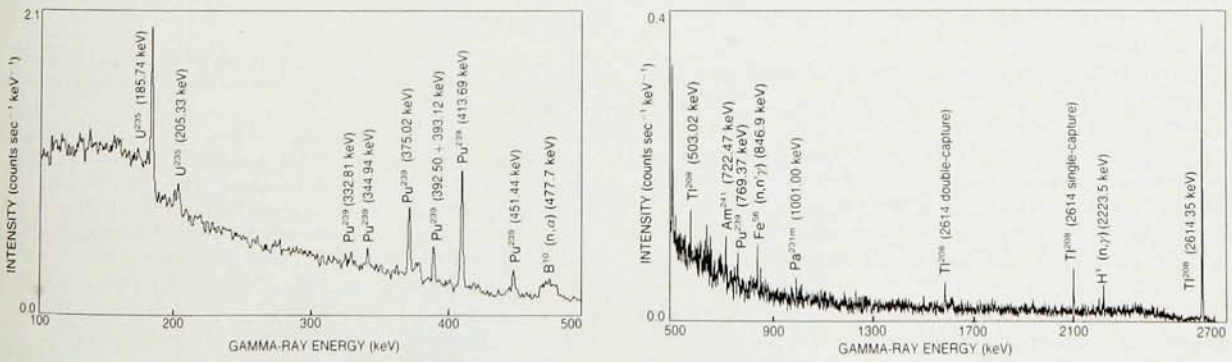
The background-subtracted gamma spectrum resulting from a total of about 20 minutes of observing time is shown in the figure below. It clearly shows peaks associated with the alpha decays of the fissile isotopes U^{235} (especially at 186 keV) and Pu^{239} (especially at 375 and 414 keV). It also shows gammas from the alpha decay of Am^{241}, itself a decay product of Pu^{241} (722 keV) and from Tl^{208}, a decay product of the artificial isotope U^{232} (especially at 2614 keV). The presence of U^{232} indicates that some of the uranium in the warhead must have been exposed to neutrons—implying that the Soviets must have recycled uranium from their production reactors for use in weapons.

The spectrum was surprising in two principal ways to the US experimenters, whose expectations were formed by calculations in the FAS–CSS report of the radiation from a number of highly simplified models of nuclear warheads. First, the number of 1001-keV gammas from the decay of U^{238} was unexpectedly low, indicating that all the uranium in the warhead is highly enriched (only about 4% U^{238}). And second, the observation of the low-energy gammas from the U^{235} decays indicates that there is virtually no heavy-metal shielding between the U^{235} and the detector, since the mean free path of these gammas is only about a millimeter in lead.

A group from the Soviet Academy's Institute of Earth Physics carried out measurements similar to those of the NRDC group on top of the launcher (with an instrument of somewhat poorer resolution), and a group from the academy's Geochemistry Institute attempted—unsuccessfully—to detect the warhead with a 0.25-m^2 array of sodium iodide counters from a landing ship passing along the side of the cruiser.

The most interesting Soviet experiment was done, however, by a group from the Kurchatov Institute's physics division, whose head, Academician Spartak Belyaev, was present. This group conducted neutron measurements from a helicopter using a set of He^3 proportional counters with a total area of 2.5 m^2. The helicopter detected statistically significant signals at distances of up to 70 meters (where the signal was about 1 neutron per second) from neutrons emitted as a result of the spontaneous fission of Pu^{240} in the warhead. The Kurchatov group apparently has worked with the Soviet Navy doing this sort of measurement before.

—Steven Fetter and
Frank von Hippel



Gamma-ray signal recorded by germanium detector placed on top of cruise-missile launcher 3.4 meters from the lid for ten minutes. Background signal from the neighboring, empty launcher has been subtracted.

environmental degradation, underdevelopment, denial of human rights and lack of education. This proposal was inspired in part by Velikhov's exposure to US foundations such as the Carnegie Corporation and the MacArthur Foundation, which had supplied prompt support for the NRDC–Soviet Academy seismic monitoring project, despite the fact that it was not greeted with universal enthusiasm within the US government. The American who played the greatest part in organizing the foundation was Jerome Wiesner, science adviser to President Kennedy and president emeritus of MIT.

In January 1988, with start-up grants from a number of US foundations and the Soviet Peace Fund, the board of directors of the International Foundation for the Survival and Development of Humanity had its first meeting in Moscow. The name of the foundation, like that of the Committee of Soviet Scientists for Peace and Against the Nuclear Threat, is somewhat awkward sounding to Western ears. But it appears to be important to declare your purpose in naming an organization in the Soviet Union.

The Soviet government has given the foundation a unique charter that permits it, "for completion of its projects, . . .to create enterprises and organizations." Thus far, the foundation has used this authority to support a Soviet human rights group sponsored by Sakharov and to create a Soviet chapter of Greenpeace under the chairmanship of Alexei Yablokov, a leading Soviet ecologist.

An assessment

Cooperative and open research on the technical basis for arms control policy initiatives by independent US and Soviet scientists is a hopeful indication that the pressures driving the arms race may be dissipating. Such cooperation would not be permitted by either country if there were not an increasing consensus that the arms race is more of a threat to both countries than we are to each other.

Of course, the cooperation has a political impact—it strengthens the basis for further cooperation. Therefore, if one thinks that strengthening cooperative relationships between the US and USSR is dangerous because it undermines the will to invest in defenses, one will not welcome these initiatives.

It is often asked whether the types of joint projects discussed here are not better left to the governments. But governments don't like to sponsor research on questions relating to policy decisions that have not been made yet. Such research may undermine objections they may later wish to make to a policy option. Thus, for example, Colonel Ed Nawrocki, an assistant to former Assistant Secretary of Defense Richard Perle in the Reagan Administration, explained their office's opposition to the NRDC–Soviet Academy seismic-monitoring project as follows:

"The NRDC's goals were totally the opposite of our own. They went into this project to prove that a comprehensive test ban treaty is verifiable. [And we'd made verification the main public objection to a comprehensive test ban because] verification is such a 'showstopper,' as Perle is fond of saying. So the government didn't go much beyond verification as a reason why we shouldn't have a CTB. And the NRDC was out to undermine the verification argument against a CTB."[6]

The NRDC–Soviet Academy project has therefore been inconvenient to those who oppose a test ban because they think it is important to continue to develop new types of nuclear weapons, forcing them to "come out of the closet" and make their arguments before a not completely sympathetic public.

At this time, the future of the Committee of Soviet Scientists is uncertain. Both of its key scientific leaders, Velikhov and Sagdeev, have been caught up in the dramatic events associated with the effort to open up the USSR and reenergize its economy. Sagdeev has emerged, with Sakharov, as the leading advocate of reform in the Soviet Academy and its institutes (see PHYSICS TODAY, January 1989, page 61).

Velikhov has become a member of the Central Committee of the Communist Party of the USSR, the chairman of the armed forces subcommittee of the Supreme Soviet's Committee on Defense and State Security and the new director of the giant Kurchatov Institute of Atomic Energy.

In the meantime the CSS has received a charter that allows it to recruit a full-time staff and establish a small "think tank" with 17 full-time researchers working on the technical basis for disarmament. Whether, with its two original leaders so distracted, the CSS will successfully make the transition from an *ad hoc* organization of high-level and talented amateurs to a group whose work is done primarily by much less senior full-time professionals remains to be seen.

The next generation

A first step to ensure that there will be a next generation of Soviet physicists working on the technical basis for Soviet policy initiatives on global problems was taken early in September when the Committee of Soviet Scientists joined with the Moscow Physico-Technical Institute to sponsor an eight-day International School on Science and World Affairs. There were 24 Soviet physics students, ranging from second-year undergraduates to research associates; nine US postdocs with physics PhDs; one US graduate student; five physics graduate students from Imperial College, London; and two physics graduate students from Beijing. The US participants all are engaged in arms control research—at universities, with public-interest groups or as Congressional fellows. The faculty of the school also was diverse and lectured on global climate as well as arms control issues.

The US postdocs came away from the school quite impressed with the Soviet students. Some had obviously done considerable independent study in preparation for the school. The MacArthur Foundation sent the message that it would entertain applications from Soviet students for its predoctoral and postdoctoral fellowships in international security. A number of US-university arms control research groups had already expressed their willingness to host Soviet postdocs embarking on careers in that area. Obviously the door is wide open for further development of the US–Soviet "connection" in arms control research.

References

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