

SCIENCE AND SCIENTISTS FOR A NUCLEAR-WEAPON-FREE WORLD

Soviet scientists persuaded the USSR's political leadership to downplay work on missile defenses during the 1970s and 1980s. Current cooperative research by Soviet and US scientists is laying the foundation for the elimination, with verification, of offensive weaponry.

Evgeny P. Velikhov

The scientific communities of the USSR and the US have been active both in developing new weapons and in attempting to curb the arms race, or at least in trying to prevent it from leading to the ultimate catastrophe. Scientists on the two sides have worked sometimes independently and sometimes with a degree of interaction, direct or indirect.

As stockpiles of arms were built up, the real or imaginary successes of one side provoked the other side and often were used—sometimes for want of better arguments—to justify development of new weapons systems. But a dialogue among scientists seeking to comprehend the situation and to stop the slide down to a catastrophe has never ceased.

Naturally, in years of political stagnation, it could only be hoped that the dialogue among scientists would see better days. But even during the worst years of the cold war, the dialogue had a considerable impact on public opinion, providing it with a scientific basis. During the last few years of accelerating political developments, the dialogue has had great difficulty keeping pace with events.

From our perspective on the Soviet side, we must begin by giving due credit to Soviet science and scientists for responding effectively to the challenge from a most powerful rival who started far ahead. Soviet science provided the means of ending the US nuclear monopoly, which we considered potentially fatal to us, and of establishing strategic parity. Thus, as we see it, Soviet science helped pave the way for a policy of bilateral nuclear disarmament.

Now the question is, What can science do to make the world free of nuclear weapons by the start of the third mil-

lenium? There are only 12 years to go, and the idea of disarmament still encounters powerful opposition.

Soviet ABM debate

Once again, the issue of missile defenses is being spiritedly debated. Soviet scientists have had a long, active involvement in discussions of this issue.

Even at an early stage of the debate, in the late 1960s, the idea emerged of using lasers or charged-particle beams to hit warheads as they approach their targets. It was obvious from the outset, however, that the undertaking was almost certainly futile: Compact reentry vehicles, specially designed to withstand the high temperatures of reentry from space, are hard to locate and lock on to for enough time to administer fatal doses of energy. The propagation of beams of the required power through the atmosphere is itself a great problem.

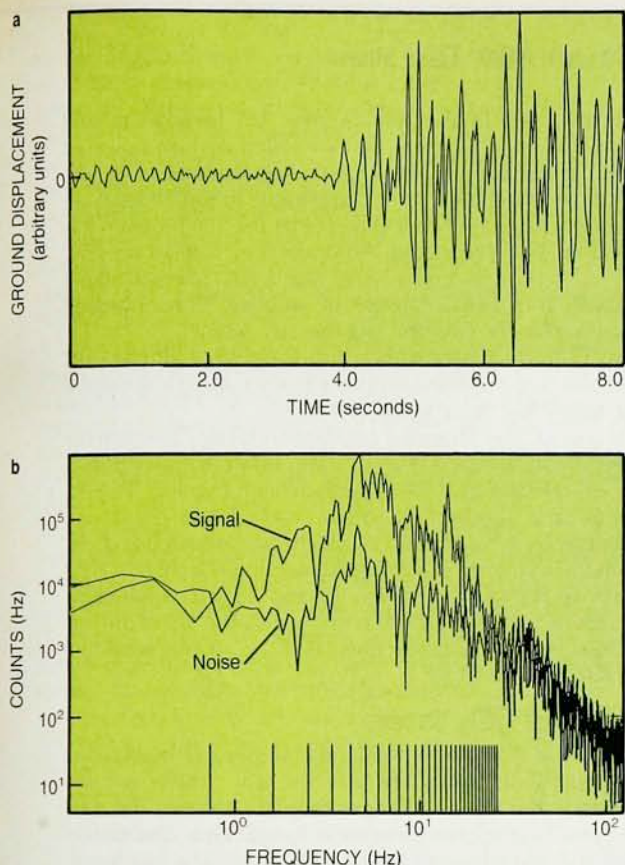
The main opposition to Soviet beam weapons proponents came from Academician Lev Artsimovich, who was the leader of the Soviet magnetic fusion program. Work was launched on directed-energy weaponry, but soon the difficulties proved insurmountable. At the insistence of Academician Yuli Khariton, deputy director of the Kurchatov Institute's nuclear weapons program, an honest and principled critique was written and handed over to the government, which decided to stop the program around the time the antiballistic-missile treaty was concluded in 1972.

Today, a reminder of that work is the collection of empty structures on the testing ground near Lake Balkhash—the so-called Sary Shagan site—which US officials and other Americans often enquire about (see the box on pages 34 and 35).

Another reminder of the interest in directed-energy weaponry at that time is the amendment to the 1972 ABM Treaty allowing the testing of ground-based missile-defense systems based on "other physical principles." The United States finally agreed to the amendment because of corresponding work in its labs on directed-energy weapons.

In the early 1970s, enthusiasm about space technolo-

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Results from nuclear explosive monitoring program conducted by the Natural Resources Defense Council and the Soviet Academy of Sciences. **a:** Recording of the vertical component of ground motion caused by a 10-ton chemical explosion at a distance of 650 km from the USSR's Kazakhstan test site. **b:** Spectra of 4 seconds of signal and noise from the same 10-ton chemical explosion. Spectra are uncorrected for system response. The vertical lines on the frequency scale at the bottom indicate (equally spaced) frequency samples in the spectral range where the signal-to-noise ratio is greater than unity. This band is from about 0.7 to 28 Hz.

gy gave rise to a Soviet version of the "Star Wars" concept. The idea of space-based neutral-particle-beam weapons was first proposed in 1969 by Academician Gersh Budker, a leading designer of colliding-beam accelerators. But this proposal was defeated within the Soviet Academy of Sciences by criticism from Artsimovich and Academician Boris Konstantinov. This debate vaccinated Soviet scientific opinion against the infectious ideas associated with directed-energy weaponry and prepared the way for the discussion that followed President Reagan's March 1983 Star Wars speech.

Second vaccination

Around 1980, well before Reagan's Strategic Defense Initiative, the idea of effective missile defenses received fresh impetus in the USSR from a proposal by Academician V. N. Chalomey, a designer of booster rockets for the Soviet missile and space programs and vice president for pure physics in the Soviet Academy of Sciences. Chalomey proposed the creation of a space-based defense using interceptor missiles, a concept very similar to the US first-phase scheme that the Reagan Administration proposed during its last year.

Chalomey made his proposal directly to General Secretary Leonid Brezhnev, and therefore the discussion proceeded in a very tense atmosphere at a very high level. A review commission was set up under the chairmanship of Vitali Shabanov, who was deputy minister of defense. Owing to the principled stand of a number of scientists and military experts, the heated debate resulted in a correct decision: The proposal was turned down.

Just imagine what would have happened had we agreed to begin work on the system. Apart from the fantastic expenditures, we would have given an excellent trump card to the Reagan Administration and to US cold warriors. We now most certainly would have a host of

costly and potentially dangerous weapons up in space, yielding no greater mutual security, and their removal would be very difficult.

The second "vaccination" occasioned by the Chalomey proposal enabled us to respond to Reagan's speech very rapidly and energetically. Less than a month after the speech, the members of the Soviet Academy of Sciences held a discussion of the Strategic Defense Initiative at the academy. This discussion was not an easy one—because of secrecy restrictions and the absence of a government position on the matter, we could not express all the arguments. But the resulting document was good, and I would subscribe to it even today. The report was published as a book in 1986,¹ and it was cited by US Star Wars opponents during the Congressional debate on SDI.

Influenced to some extent by the recommendations of Soviet scientists and by the opinion of the world scientific community, the Soviet leadership formulated the idea of "asymmetric" but effective responses to possible US space-based defenses. This was a level-headed decision, and I am sure that it helped sober US public opinion and ease the way for decisions by Congress to limit the SDI budget and protect the integrity of the ABM Treaty. It represented a break in the positive-feedback cycle that has sent the arms race spiraling upward.

Limiting tests

In 1983, before Reagan made his speech, we discussed with our counterparts on the Committee on Science and Arms Control of the US National Academy of Sciences the desirability of an agreement on nondeployment of weapons in outer space. Later, Soviet scientists discussed with Marshal Sergei Akhromeyev, chief of the general staff of the Soviet Armed Forces, the advisability of a Soviet unilateral moratorium on the testing and deployment of weapons in space. A draft treaty was submitted to the

Visit to a Laser Facility at the Soviet ABM Test Site

On 8 July, Evgeny Velikhov took a delegation of ten Americans on a visit to the Soviet testing facility near Sary Shagan on the western shore of Lake Balkhash in Kazakhstan. Sary Shagan is the USSR's main test center for air defense and antiballistic missile defense. The members of the delegation were Congressmen Robert Carr, Jim Olin and John Spratt; reporters Bill Keller of The New York Times and Jeffrey Smith of The Washington Post; Chris Paine, an arms control aide to Senator Edward Kennedy; John Adams, Thomas Cochran and Jacob Sherr of the Natural Resources Defense Council, which organized the delegation; and physicist Frank von Hippel of Princeton University. Von Hippel's report on the visit follows:

The 1985 joint report of the departments of Defense and State, "Soviet Strategic Defense Programs," showed an artist's rendering of the Sary Shagan facility with a powerful laser beam shining vertically from it (see the diagram below). The caption stated that "the directed-energy R&D site at Sary Shagan proving ground includes ground-based lasers that could be used in an antisatellite role today and possibly a ballistic missile defense role in the future." The 1984 and 1985 editions of the DOD report "Soviet Military Power" showed the same rendering with similar statements.

Unfortunately, the final confirmation of the Sary Shagan visit only occurred after the NRDC group had arrived in the USSR, and there were no US laser experts along. And because most of the day was spent in transit by air and bus, the actual site visit only lasted about three hours. But members of the group were able to make videotapes and to take over 100 photos of the equipment at the facility, and these have been examined by US government and independent experts. US intelligence experts have confirmed, from the external photos of the facility, that it is indeed the one represented in the DOD publications.

The big surprise for both the delegation and for most of

those involved in the debate over US antisatellite and missile-defense policy was that we found no high-powered lasers. Judging from the DOD's representations of the facility, we expected a laser comparable to the 2-megawatt deuterium fluoride chemical laser that the SDI program has built at the US White Sands ABM test site. Instead we saw:

▷ A set of 19 pulsed ruby lasers with a total average output of about 100 watts, capable of emitting 30-nanosecond pulses at 10 Hz (see the photograph below).

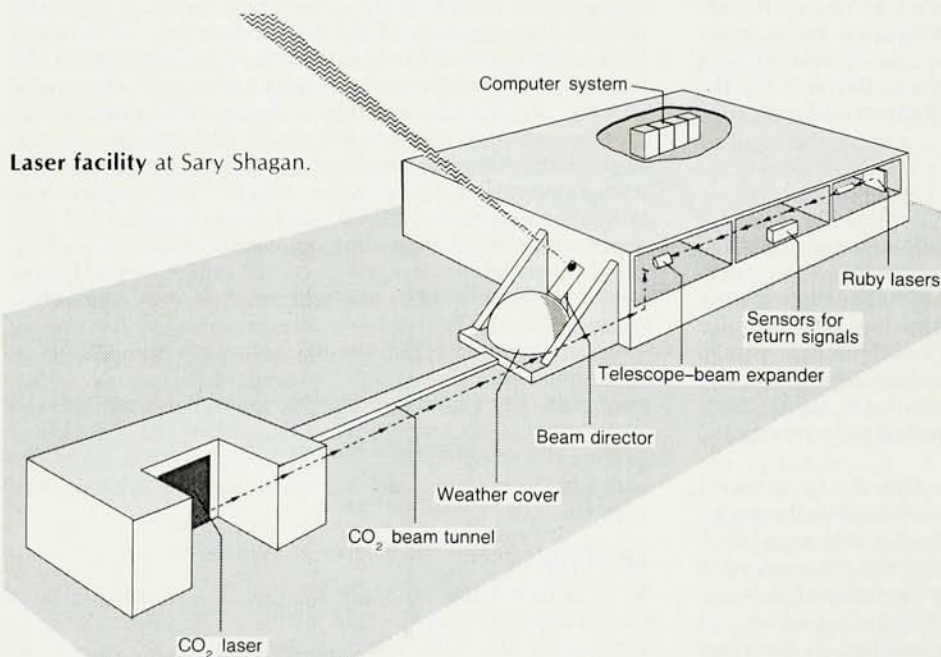
▷ A CO₂ pulsed laser with a stated power of 20 kilowatts (with only 5–10% of this output actually making it through a long beam line to a beam director).

Of course, Sary Shagan is not the only facility at which the Soviet Union conducts research with lasers that may potentially be relevant to a Soviet antisatellite program. Indeed, even at Sary Shagan, CIA analysts told us after our return, there may be a "facility B" at which laser research is done, and there is a facility in the mountains above Dushanbe, near the Soviet-Afghanistan border, that has excited considerable speculation. These facilities are now near the top of the lists of those in the US urging the USSR on to more military *glasnost*.

Ruby and CO₂ lasers

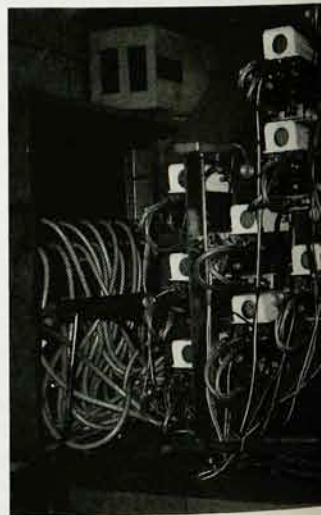
The figure at the bottom of this page shows a representation of the parts of the facility that we saw. There are two buildings. The large building at the right contains the ruby lasers and has the beam director at its near end. The smaller building at the left contains the CO₂ laser. The low tunnel structure connecting the two carries the CO₂ laser beam to the basement of the large building, where it is deflected upward and then to the beam director along the same beam line as the ruby laser beam.

We followed the ruby laser beam line from the laser room to the beam director. In between is a sensor room,



Laser facility at Sary Shagan.

Ruby-laser array at Sary Shagan, showing 19 pulsed lasers. (Photo by Thomas B. Cochran, Natural Resources Defense Council.)



where the return signals are detected, and a combined beam expander and telescope. This device is simply a reflector telescope. When it is acting as a beam expander, the ruby-laser beam enters from behind through a hole in the center of the primary mirror, is reflected from the secondary mirror back onto the front of the primary mirror and then goes to the beam director. In this process, the beam is expanded to a diameter of about 1 meter. When the return signals come from the beam director, the process works in reverse and the photons are concentrated into a small beam that passes through the primary mirror to the sensor room behind it.

The 45°, 30-cm-diameter mirror that sits in the expanded beam (shown to the left of the telescope's secondary mirror in the figure at the bottom of this page) serves to redirect the vertical CO₂ laser beam coming up from the basement to the same beam director. This 45° mirror, which provided the only possible route to the beam director from any hidden laser, was uncooled and appeared to be gold plated like the primary mirror. Polished gold has a reflectivity of about 99% from the 10.6-micron CO₂ wavelength down to the red end of the visible. When the beam director is uncovered, outside air (and dust) flows directly into the telescope. (A particle of dust on a mirror would be heated to high temperature by a high-power laser beam and would burn through the mirror's reflective coating.)

The CO₂ laser is closed-cycle, with the gas being pre-ionized by a 250-kV pulsed electron beam and the excitation energy provided by a lower-voltage electric discharge. The

general dimensions of this laser are similar to those of a 25-kW laser sold commercially by United Technologies Industrial Lasers.

Apparent significance

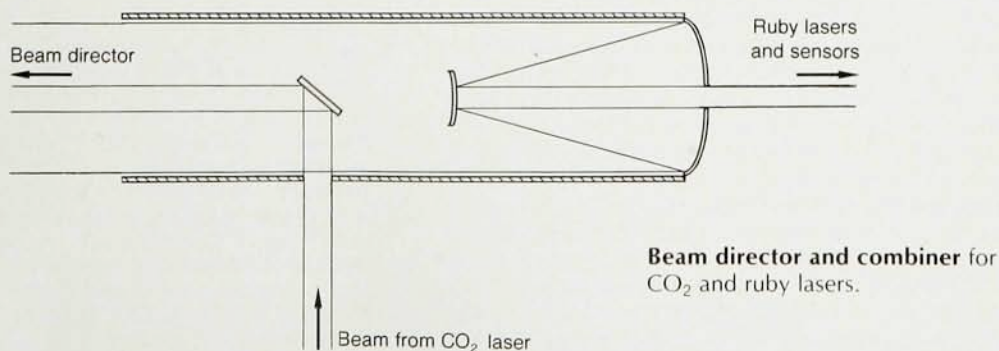
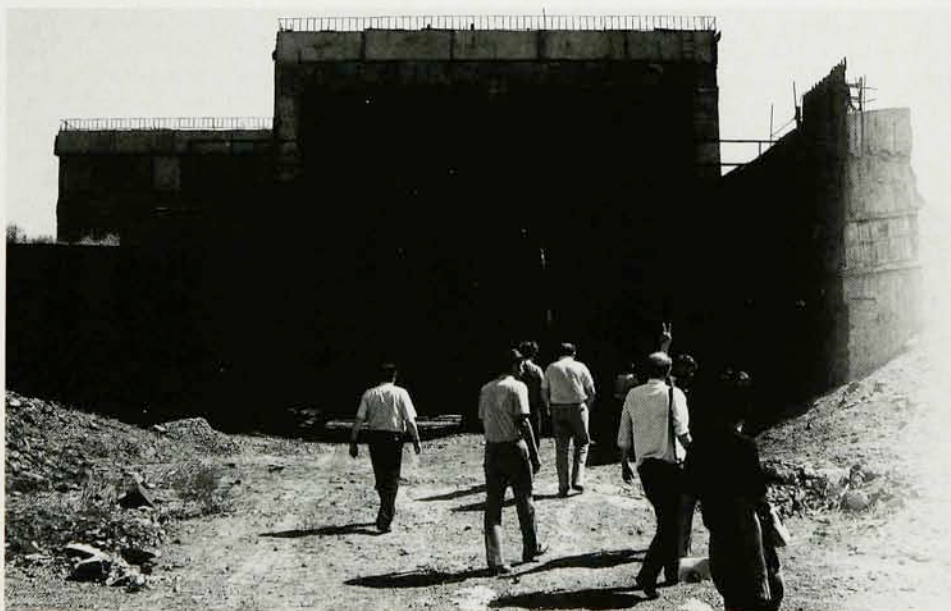
According to the engineers at the facility, it is used several times a week to track and range aircraft. A few attempts have been made to track a low-flying satellite equipped with a retroreflector—the last time in August 1988—but stable tracking was not achieved.

Clearly the Sary Shagan facility would *not* be useful as an antisatellite installation. Even a diffraction-limited 20-kW CO₂ laser beam with an initial diameter of 0.3 meters would have an intensity at orbital altitude much less than that of sunlight.

About a kilometer away from the laser facility described above, the delegation visited a huge empty room, most of which is underground. (See the photograph below.) This structure, which appeared to be about 70 meters long, 30 meters wide and 10 meters high, has very heavy walls and doors. We were told that one idea for the energy source for the high-powered laser, which was to have been installed in this room, was to create intense bursts of electromagnetic energy by imploding magnetic coils with conventional explosives. A very heavy, low wall that lies adjacent to the underground room was meant to protect its roof from the blast of such explosions.

—FRANK VON HIPPEL

Abandoned vault,
originally intended for
tests of a high-powered
laser. (Photo by
Congressman Robert
Carr.)



United Nations by Andrei Gromyko. In August 1983, the Soviet Union declared a unilateral moratorium on weapons testing in space, which remains in force to this day. Although the treaty and the moratorium were both rejected by the Reagan Administration, the US Congress responded by withholding funds for the testing of anti-satellite weapons against targets in space beginning in 1985, and last year the Pentagon abandoned development of the ASAT interceptor that was to have been deployed on F-15 fighter aircraft. [This year, however, the three US military services requested funds for development of more advanced systems, after Congress lifted its ban on tests in space—see *PHYSICS TODAY*, April 1989, page 59.]

In the spring of 1983, we also discussed with the NAS committee the advisability of signing a comprehensive nuclear weapons test-ban treaty. At the time, the main argument against such a treaty was the alleged difficulty of verification. We began discussing this problem with US scientists in 1986, during a unilateral Soviet moratorium on underground testing. Our hope was that the moratorium would help change US and world opinion about the sincerity of Soviet nuclear disarmament proposals.

In May 1986, we reached an agreement with the Natural Resources Defense Council, an independent organization in the United States that works primarily on environmental and arms control matters, providing for seismic-monitoring experiments around the Soviet nuclear test site in Kazakhstan and at the US test site in Nevada (see *PHYSICS TODAY*, November 1987, page 83, July 1986, page 63, and August 1986, page 57). The necessary permits were requested from the two governments. We on the Soviet side were so sure about our government's positive response that the US scientists were allowed to begin monitoring a week before final permission was received, and the first seismogram was obtained in July. The work was organized with unprecedented speed—in part because, on the US side, it was financed from private funds and the usual red tape was reduced to a minimum.

It took the Reagan Administration two years to allow similar on-site monitoring in Nevada. Permission was obtained only after Defense Secretary Caspar Weinberger and DOD Assistant Secretary Richard Perle resigned and the talks on ending tests resumed. This project has demonstrated² that the signal of a 10-ton chemical explosion can be reliably detected against the background seismic noise at a distance of 650 km in the USSR and at 300 km in the United States. (See the figure on page 33.)

Since 1986, the US House of Representatives has passed an annual amendment that would cut off funding for US underground tests with yields over 1 kiloton if the Soviet Union halts such tests. The Soviet government has declared that if such a limitation is adopted, it will observe it too. Regrettably, the US Senate has not agreed to this amendment.

The US government has come up with a number of other arguments against the complete cessation of tests and speaks of the need to continue testing to ensure the reliability of US nuclear warheads. But as has been stated by a number of Soviet and US scientists, among them some scientists at the Lawrence Livermore National Laboratory, reliability can be checked without actually exploding high-yield nuclear weapons.³

Among the real reasons for the resistance to a ban is a desire on the part of the US to continue the development of new types of weapons, above all the so-called third-generation weapons such as hydrogen-bomb-pumped x-ray lasers and optimized warheads for new weapons systems. It is exactly the potentially destabilizing impact of these new weapons that motivates our interest in a test ban.

Another area of cooperative activities between Soviet

and US scientists is a joint project on the verification of future arms control agreements, which was organized by the Committee of Soviet Scientists for Peace and Against the Nuclear Threat and by the Federation of American Scientists. One problem being studied in this project is the detection of nuclear weapons in space-launch payloads, ships or submarines. The scientists are investigating the limits of techniques involving the detection of warheads by their gamma and neutron emissions. Naturally, in the case of space-launch payloads, it would be much easier to inspect a payload at the launch site than when it is already in space.

The Soviet government has proposed to the US government that such work, including experiments at launch sites and on board ships, be conducted on a government-to-government basis. So far, the official response has been negative. Therefore we have decided to carry out such experiments on a nongovernmental basis in the hope that governmental organizations will join us when the political situation is ripe. The verification measures in the treaty on the elimination of intermediate- and shorter-range missiles are important steps in this direction.

Strategic arms reduction

The strategic arms reduction talks have imparted urgency to the question of verifying the destruction of nuclear warheads and assuring that their fissile materials are used only for safeguarded, nonweapons purposes. The joint CSS-FAS project includes work on this problem and on the verification of an agreement to end the production of fissile materials for weapons, for which the problems in the US and Soviet materials-production complexes have opened a window of opportunity.

Moving toward a nuclear-weapon-free world also requires study of intermediate states, in which destabilizing situations might prompt a renewed arms race. As part of a project to explore the route to a nuclear-weapon-free world, the CSS has issued a report on the stability of the strategic balance if nuclear arsenals were reduced to just 5% of current levels. The report shows that conditions can be found under which the balance will be stable at such low levels. Unfortunately, however, this transition requires the development of a new single-warhead missile such as the proposed US Midgetman, which calls for a hardened carrier, or the Soviet SS-25. This problem should be discussed between the US and Soviet governments now, because open discussion of military plans will increase mutual trust.

We are just setting off on a road leading away from an irrational world that is irresponsible to past and future generations toward a world based on reason and mutual security. The political process has started, and scientists must mobilize to provide the necessary scientific and technological backing for the journey.

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