

# **The Black Sea Experiment**

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## Introduction

The Black Sea experiment refers to a set of seven experiments, conducted under the auspices of the Soviet Academy of Sciences and the Natural Resources Defense Council (NRDC), to study the utility of different radiation detectors for detecting the presence or absence of nuclear warheads on ships. The experiments took place on July 5, 1989, aboard and alongside the *Slava*, flag ship of the Soviet Black Sea Fleet, which was anchored offshore at Yalta. The *Slava* was equipped with launch tubes for 16 P-500 *Bazalt* (NATO name: SS-N-12 Sandbox) medium range (300 nautical miles) anti-ship cruise missiles with nuclear warheads. For these experiments all but one of the missiles had been removed from their launch tubes by the Soviet Navy.

## Preceding Events

In the years prior to the Black Sea experiment there were discussions among government officials and non-government experts about how to ban or limit naval nuclear weapons. More specifically the issue of long-range sea-launched cruise missiles (SLCMs) had become a contentious issue in the START negotiations. Given its range and the many platforms it was deployed on, the SLCM could be seen, at least from the Soviet perspective, as part of U.S. strategic forces. Though the U.S. and Soviet Union agreed at the December 1987 summit to conduct experiments on SLCM verification, nothing had transpired. Paul Nitze had proposed the elimination of all tactical naval weapons, including long-range cruise missiles. In July 1988, Col Gen. Nikolai Chervov had proposed eliminating all Soviet nuclear cruise missiles if the United States did the same. This was vigorously opposed by the U.S. Navy. Furthermore, critics cited the difficulties of verifying such a ban. These events set the stage for the Black Sea experiment.

Academician Evgeniy P. Velikhov and I agreed to pursue the project in the spring of 1988. For two years we had already been working closely together on other verification projects.<sup>1</sup> Velikhov's interest in arms control and his role as scientific advisor to General Secretary Mikhail Gorbachev are chronicled in David E. Hoffman's book, *The Dead Hand* (New York: Random House, 2009). I first met Velikhov in Moscow in May 1986 at a nuclear test ban workshop organized by Velikhov and Professor Frank von Hippel, of Princeton University's Woodrow Wilson School of Public and International Affairs.<sup>2</sup> A few days after the workshop Velikhov, on behalf of the Soviet Academy of Sciences, and Adrain DeWind, chairman of NRDC, signed an agreement to undertake what became known as the US-USSR Test Ban Verification Project—a joint effort to demonstrate that a nuclear test ban could be verified and thus increase support for an end to nuclear weapon testing.

In July of 1986, NRDC and the Soviet Academy established the first of three seismic stations around the Soviet nuclear test site at Semipalatinsk, jointly manned by Soviet and U.S. seismologists. The following year we demonstrated the sensitivity of these stations by setting off 10 and 20 ton chemical explosions adjacent to the test site. We invited three U.S. congressmen and reporters to witness this event. A few days later Velikhov arranged to take the delegation to tour the controversial Krasnoyarsk radar site, which at the time was partially constructed and was

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<sup>1</sup> At the time Velikhov was a vice president of the Soviet Academy of Sciences and director of the Kurchatov Institute of Atomic Energy. I was a senior scientist at NRDC.

<sup>2</sup> Frank von Hippel was also co-director of the Nuclear Policy Alternatives Program of the Center for Energy and Environmental Studies at Princeton University and was chairman of the Federation of American Scientists Fund, the research arm of FAS.

in violation of the Anti-Ballistic Missile (ABM) Treaty. In April 1988, we established three seismic stations around the Nevada Test Site and arranged a similar demonstration using three ten-ton chemical explosions more than 100 kilometers distant.<sup>3</sup> Following this demonstration while flying back to the east coast, Velikhov and I discussed what sort of joint project we might do next. We agreed to examine experimentally the utility of radiation detectors to verify the presence or absence of nuclear weapons on surface ships.

A year earlier, in 1987, the Federation of American Scientists (FAS) and the Committee of Soviet Scientists for Global Security (CSS) began cooperation on a number of research studies on potential technical support for new arms control agreements.<sup>4</sup> One of the studies undertaken by the joint FAS-CSS group was to estimate the range at which nuclear warheads could be detected under various scenarios. Earlier Velikhov had repeated a claim made by Academician Valeri L. Barsukov, director of the Soviet Academy's V.I. Vernadsky Institute of Geochemistry and Analytical Chemistry, that radiation detectors could detect nuclear warheads at kilometer distances. Academician Roald Z. Sagdeev, director of the Space Research Institute and head of the CSS group, was motivated to show that Barsukov's claim was wrong. Frank von Hippel, head of the FAS group, sought to show that the first Bush Administration was wrong when it claimed in Intermediate-Range Nuclear Forces (INF) Treaty ratification hearings that warhead dismantlement could not be verified.<sup>5</sup> The FAS-CSS study group estimated that, in the absence of additional shielding, passive gamma and neutron detectors could detect nuclear warheads at a distance of tens of meters, and if subjected to neutron irradiation shielded warheads could also be detected at similar distances.<sup>6</sup> Velikhov's interest in pursuing the Black Sea Experiment may have been influenced by disagreements among Soviet academicians over the limitations of radiation detectors.

In the following months I set out to identify and purchase the best portable radiation detector equipment commercially available and to assemble a team of scientists to operate it. In a call to Moscow I recall informing Velikhov that I was about to purchase \$70,000 worth of intrinsic germanium gamma-ray spectrometers, and I needed his assurance that we would be able to use the equipment with a real nuclear warhead. He gave me his assurance.

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<sup>3</sup> Sandra Blakeslee, "Method to Verify Arms Ban is Tested by U.S. and Soviet," *New York Times*, April 30, 1988, p. A6.

<sup>4</sup> The FAS studies were led on the American side by Professor Frank von Hippel and on the Soviet side by Academician Roald Z. Sagdeev, director of the Space Research Institute. Other U.S. participants in these studies included Thomas B. Cochran, Alex De Volpi, Steve Fetter, William Higginbotham, Marvin Miller, Robert Mosley, Christopher Paine, R. Prilutsky, Jeremy Stone, Theodor Taylor, Valerie Thomas and David Wright. Other Soviet participants included Academician Spartak Belyaev, General Vladimir Belous (ret.), V. A. Frolov, Andrei Kokoshin, Victor Kravetz, Valentin Lebedev, Alexei Mitrophanov, Academician Karl K. Rebane, Stanislav Ridinov, S.N. Rodionov, and Alexander Sanin, FAS-CSS project studies were compiled in the book, *Reversing the Arms Race: How to Achieve and Verify Deep Reductions in the Nuclear Arsenals*, Frank von Hippel and Roald Z. Sagdeev, eds. (Gordon and Breach Science Publishers [now owned by Taylor and Francis] 1990). The book has sections on "Verifying Reductions of Nuclear Warheads," "Verifying Limits on Nuclear-armed Cruise Missiles" and "The Technical Basis for Warhead Detection," and includes reprints of Black Sea experiments.

<sup>5</sup> During the Clinton Administration, the U.S. government concluded that warhead dismantlement could be verified after all and initiated U.S.-Russian lab-to-lab projects on the subject.

<sup>6</sup> Fetter, S, Frolov, V. A., Miller, M., Mozley, R., Prilutsky, O.F., Rodionov, S.N., Sagdeev, R.Z., "Detecting Nuclear Warheads," *Science and Global Security*, 1 (3-4):225-253, 1990.

As preparations advanced on April 6, 1989, a message was relayed to us from one of our Soviet colleagues at the O.Y. Schmidt Institute of Physics of the Earth, that “the naval verification project had been approved;” that “we would have a ship on the Black Sea with missiles for an experiment between mid-May and mid-June.”<sup>7</sup> A few years after the Black Sea Experiment Frank von Hippel was told by Academician Yuli B. Khariton, the director of Arzamas-16, one of the Soviet nuclear weapon design laboratories, that Gorbachev had ordered the warhead to be made available for the experiment despite Khariton's strenuous objections.<sup>8</sup>

When we arrived in Yalta on July 4, the day before the experiment, we were taken to a hospital ship docked in the harbor, where we were quartered, briefed and entertained. We met the large group of Soviet scientists that Velikhov had assembled, comprised of more than two dozen scientists from the Kurchatov Institute of Atomic Energy, the Institute of Physics of the Earth, the Institute of Geochemistry and Analytical Chemistry, and the Ministry of Medium Machine Building.

In addition to the scientific teams there were a number of observers present on the *Slava* that day and on the hospital ship where we stayed the evening before. These observers included Deputy Minister of Foreign Affairs and chief Soviet arms negotiator Victor P. Karpov, Vice-Admiral Gennady Zolotukhin, Deputy Commander in Chief, Soviet Navy, Dr. Mikhail Gerasev, of the Institute of USA and Canada, three U.S. congressmen, (John M. Spratt, Jr. (D-South Carolina), Robert Carr (D-Michigan) and Jim Olin (D-Virginia)), Christopher E. Paine, aide to Senator Edward Kennedy, Thomas S. Kahn, legislative counsel to Rep. Spratt, several reporters, including Bill Keller of the *New York Times* and Jeffrey Smith of *The Washington Post*, three NRDC staff (John Adams, Jacob Scherr and Robert S. Norris), Professor Frank von Hippel, Dr. Valerie Thomas, of the Center for Energy and Environmental Studies at Princeton University, Dr. Barry Blechman, of Defense Forecasts, George Lewis, of Stanford University and William M. Arkin, of the Institute for Policy Studies. The KGB was also well represented.

The evening before the experiments the American participants met with Ambassador Karpov and senior Soviet officials for informal discussions, including proposals for the removal of tactical nuclear weapons on ships.

Later that evening I learned that the recording time using our germanium detector would be restricted to 10 minutes. Previously, I did not have the foresight to ask Velikhov how long we would be allowed to take measurements.

### **The Black Seas Experiments**

Of the seven experiments, one by the NRDC team and a second by the Kurchatov Institute were of special significance. Three others were of lesser importance because the gamma-energy resolution of detectors was less than that of the American germanium detector. Two other Soviet experiments failed to detect the nuclear warhead at all.

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<sup>7</sup> This was a message from Vladimir Ratushny of the Institute of Physics of the Earth, via Dr. Jonathan Berger of the Scripps Institution of Oceanography, who was heading NRDC's seismic field team on the NRDC/Soviet Academy of Sciences test ban verification project.

<sup>8</sup> Frank von Hippel, private communication.

**The NRDC Experiment.** To carry out the U.S. experiment I recruited a five-member scientific team. Team members included Steve Fetter, of the University of Maryland, Lee Grodzins, at Massachusetts Institute of Technology, Harvey L. Lynch, of the Stanford Linear Accelerator Center, Martin S. Zucker, of Brookhaven National Laboratory, and myself. The original concept was to have two experimental teams. I had purchased duplicate portable 35 percent efficient high purity germanium detectors from Princeton Gamma-Tech (Model IGC 3520) and two portable 4,096 channel analyzers from Davidson Company (Model 2056-B MPCA). It was good that we brought duplicate systems because in setting up and testing them on the hospital ship the day before we were to go out to the *Slava*, we discovered that one of the germanium detectors had not survived the trip from the United States to Yalta.

In what was unprecedented at the time, and even today, the Soviet government permitted U.S. scientists to measure radiation from an operational warhead using a portable germanium gamma spectrometer. Using the germanium detector the U.S. team took three measurements at about 70 centimeters from the center of the warhead. Although we were told that we could record measurements for only 10 minutes, and a KGB officer stood over us to enforce this limit, Fetter and I inserted a couple of setup and calibration periods before we started our “official counting period.” In all we collected data directly above the warhead for about 24 minutes.

The technical analysis of the NRDC team’s gamma measurements can be found in Steve Fetter, Thomas B. Cochran, Lee Grodzins, Harvey L. Lynch, and Martin S. Zucker, “Gamma-Ray Measurements of a Soviet Cruise-Missile Warhead,” *Science*, vol. 248 (May 18, 1990): pp. 828-834. We of course already knew that warheads could be hidden by shielding, and that due to the small detector volume of high resolution germanium detectors, our detector had to be within a meter of so of the unshielded warhead to identify its presence.

We concluded from our subsequent analysis of the data that passive radiation detectors, even those with high energy resolution, would not reveal sensitive weapon design information if measurements are constrained to a few locations and counting time was less than one hour, since in our view there would be insufficient data in the gamma spectrum to deduce a design *ab initio*. This conclusion was subsequently disputed by the Russian weapon laboratories. By starting with a library of U.S. warhead designs, scientists at the Lawrence Livermore Laboratory conducted a so-called “forward analysis” approach to determine warhead design parameters that best fit the Black Sea gamma-ray spectrum. The Chinese subsequently may have done the same. I was told that the Livermore scientists concluded that the warhead was a two-stage “oralloy burner,” an interesting conclusion but not one that would harm Soviet national security.

**The Kurchatov Institute Experiment.** The Kurchatov helicopter-based neutron measurements were most intriguing to me. Russian scientists from the Kurchatov Institute used large helium-3 neutron detectors mounted in two separate Soviet helicopters that flew past the *Slava* at close range detecting emissions from plutonium in the warhead.<sup>9</sup> Staying about 50 to 100 meters from the *Slava*, the helicopters would take about one and a half minutes to traverse the length of the 186.4 meter (612-foot) cruiser. These helicopter systems detected the warhead-pit plutonium at distance of about 70 meters, and were said to be capable of detecting warheads at distances

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<sup>9</sup> The Kurchatov Institute of Atomic Energy team was led by Dr. Valentin I. Lebedev.

between 100 and 150 meters. The technical analysis of this experiment can be found in S.T. Belyaev, V.I. Lebedev, B.A. Obinyakov, M.V. Zemlyakov, V.A. Ryazantsev, V.M. Armashov, and S.A. Voshchinin, “The Black Sea Experiment: The Use of Helicopter-Borne Neutron Detectors to Detect Nuclear Warheads in the USSR-US Black Sea Experiment,” *Science and Global Security*, 1 (3-4), 328-333, 1990; reprinted in the journal’s 20th anniversary issue: 17:186-193, 2009.

Some months later when visiting the Kurchatov Institute I was told that these helicopter-based systems were used to spy on American ships, and that they could count, within plus or minus one, unshielded warheads on deck-mounted systems, and could even see nuclear bombs stored below deck in aircraft carriers, but could not count the number. I was shown photographs of American sailors on a U.S. warship taken at close range.

**Other Experiments.** The Russian lithium-drifted germanium detector system and two Russian portable sodium iodide detectors had a lower energy resolution than the U.S. germanium detector and therefore did not provide added value to the U.S. germanium detector measurements.<sup>10</sup>

The Soviet Academy’s Schmidt Institute of Physics of the Earth used a large truck-based sodium-iodide detector system.<sup>11</sup> The truck was parked on the deck of a transport vessel that steamed alongside the *Slava*. After examining their results the American team concluded that the system had detected the *Slava* but not the warhead—being unable to detect the warhead above the background from the radioactivity in the steel of the ship.

The Soviet Academy’s Vernadsky Institute of Geochemistry and Analytical Chemistry brought a truck mounted sodium-iodide gamma-ray telescope. It remained on shore. A few days earlier the telescope was driven alongside the *Slava* when it was in port at Sevastopol. We were informed that it could identify the location of the warhead at a distance of 40 feet. It failed to detect the warhead when the *Slava* was anchored considerably further out to sea as was the case when we were in Yalta.

### **Follow Up**

The American and Soviet scientists met in Moscow on July 7, 1989, and in Washington, D.C. on December 1, 1989, to discuss the results and to exchange information from the detectors and the data collected by them. Scientists from both countries agreed that the Black Sea experiments had successfully demonstrated the ability of a variety of techniques—especially high-resolution portable gamma-ray detectors and helicopter-based neutron detectors—to identify the presence and location of a nuclear-armed SS-N-12 as it is normally deployed. The group also identified several weaknesses of passive radiation detectors. Shielded warheads, warheads stored near nuclear reactors, or warheads not containing uranium-232 or plutonium-240 would be exceedingly difficult if not impossible to detect using these techniques.

Shortly after returning to the United States I met with Chairman of the Joint Chiefs of Staff General Colin L. Powell at a reception at the Soviet embassy in Washington, D.C. I informed

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<sup>10</sup> Lee Grodzins of the U.S. team members also brought his own portable sodium-iodide detector as a backup. It also did not add value to the U.S. germanium detector measurements.

<sup>11</sup> The Schmidt Institute of Physics of the Earth experimental team was lead by Dr. Viktor Lapshin.

General Powell that based on our private conversations with Ambassador Karpov, I thought the Soviets would be prepared to remove tactical nuclear warheads from surface ships and store them on shore if the United States did the same. I followed up our conversation with a November 8, 1989 letter to General Powell. In a December 11, 1989 letter, General Powell in reply, raised three issues in arguing against the proposal:

- (a) storing the tactical nuclear weapons ashore is not consistent with the operating procedures of our naval forces;
- (b) loading such weapons in a period of rising tensions could send an unintended and possibly exaggerated signal to observers; and
- (c) since an effective verification regime has not been found, the U.S. has continued to endorse a nonbinding declaratory approach until an effective verification regime can be found.

Less than two years later, on September 27, 1991 President George W. Bush unilaterally pledged to substantially reduce the deployment of U.S. tactical weapons. Among other steps President Bush announced that U.S. naval tactical weapons, including Tomahawk sea-launched cruise missiles, would be removed from surface ships and placed in “central storage areas” in the United States. The following week, on October 5, 1991, General Secretary Gorbachev made a similar unilateral pledge. Among other steps Gorbachev said tactical nuclear weapons will be removed from surface ships and attack and cruise missile submarines. Some will be destroyed. Gorbachev also challenged the United States to agree to destroy all naval nuclear weapons. Over the next two years or so the unilateral pledges were implemented on both sides.

After a struggle among civilian DOD and other Administration officials regarding the deterrence value of SLCMs, the Obama Administration, in its 2010 Nuclear Posture Review, accepted the recommendation of the U.S. Navy to eliminate them from the stockpile. On the Russian side, SLCMs have not been deployed for 20 years but some may still be kept available for deployment.

All of these steps were accomplished without a formal treaty or a joint verification regime. Of course we would have been better served had the United States and the Soviet Union/Russia agreed to mutually verify the reductions, storage and dismantlement of their respective nuclear arsenals, since the earlier such actions are taken, the greater confidence each side will have in subsequent declarations of the other side’s warhead and fissile material inventories.

### **Conclusion**

Not surprisingly, the Black Sea Experiment confirmed the results of the FAS-CSS study regarding limitations of passive radiation detectors for verifying the presence or absence of nuclear weapons, including the limited range of passive radiation detectors for detecting nuclear weapons. These experimental results reduced some of the uncertainties in the earlier FAS-CSS theoretical studies. The NRDC germanium detector experiment provided the only unclassified gamma-ray spectrum of a nuclear warhead, which can be used in future verification studies. This experiment also confirmed the presence of thallium-208, a decay product of uranium-232, indicating the uranium had been recovered from production reactor fuel before being enriched to HEU. Both the NRDC portable germanium detector, which detects gammas but not neutrons, and Kurchatov Institute’s helicopter-borne helium-3 detectors, which detect neutrons but not

gammas, confirmed the presence of plutonium. The range of detection of the helium-3 detectors was substantially greater than that of the portable gamma-ray detectors.

The more significant result of the Black Sea experiment was not in the physics, but something Velikhov and I already understood from our earlier collaborative efforts. It is difficult to get policy makers to pay attention to what you have to say no matter how thoughtful or scholarly your report or publication may be. But if you perform a demonstration; putting scientists in the field, and invite the press and dignitaries to witness the event, the demonstration is likely to have a far greater political impact. Moreover, one should not underestimate the value of NGO and lab-to-lab collaborative projects that demonstrate adversaries can work together to improve the relationship.

Three Russians were essential to the demonstrations in the 1980s: Soviet leader General Secretary Mikhail Gorbachev, who wanted to end the Cold War and the nuclear arms race, Academician Evgeniy Velikhov, who was a bold scientist—a risk-taker—who had the ear of Gorbachev, and the scientist-team leaders reporting to Velikhov who managed the day-to-day staffing and logistical issues. For the test ban verification work the day-to-day management was provided by Dr. Mikhail Gokhberg, of the Institute of Physics of the Earth and for the Black Sea experiments it was Dr. Albert Mokerov, a retired Soviet submarine officer then working for the Soviet Academy of Sciences. In the years since the Black Sea Experiment, unfortunately we have not seen the same level of arms control leadership that we saw in the late-1980s although even here historians are likely to conclude that had more creativity and initiative been shown by U.S. leaders during the period of the USSR's breakup and the early years of the Russian Federation, much more nuclear disarmament could have been accomplished. Furthermore, senior scientists who are politically engaged and bold are a rare commodity.