

Detecting the Soviet Bomb: Joe-1 in a Rain Barrel

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DETECTING THE SOVIET BOMB: JOE-1 IN A RAIN BARREL

In April 1947, a former Wall Street banker, Admiral Lewis Strauss, became a member of the newly established Atomic Energy Commission. At the time, both General Leslie Groves and J. Robert Oppenheimer believed that the Soviets were still a decade away from nuclear success; Naval Intelligence estimated the earliest date for a Soviet nuclear weapon as 1952, five years hence. Nevertheless, just one week after Strauss's appointment, he asked Secretary of Defense James E. Forrestal if any measures had been taken for the long-range detection (LRD) of a hypothetical Soviet atomic bomb test, and the one-time banker was surprised by the answer: No. Although he had little scientific knowledge of atomic weapons effects, Strauss felt intuitively that the military could and should have such a detection capability. He therefore pressed his deep concern to the military. The Office of Naval Research responded immediately.

Putting the pieces in place

Roger Revelle, then on military duty at ONR, carried the LRD problem to the scientific leadership of the Naval Research Laboratory. Three approaches to detection were considered: sonic, seismic and radiological. The first two were not considered promising, and so the NRL scientists focused on radiological detection. The experts needed for such an effort existed in NRL's nucleonics division, rocket sonde branch and physical optics division, with leadership by Montgomery Johnson, Ernst Krause and Herbert Friedman respectively.

All of NRL's resources were made available for the LRD effort in the spring of 1947. Several pieces of apparatus for detecting, collecting and measuring airborne radioactive debris were quickly assembled at NRL, and

The Soviet Union made no announcement after its first atomic bomb test in 1949—but the US did. This is the hitherto untold story of how the secret was extracted from rainwater.

Herbert Friedman, Luther B. Lockhart and
Irving H. Blifford

arrangements were made for deploying them in the field in anticipation of the Sandstone tests, to take place at Eniwetok in the Marshall Islands in April and May 1948.

At NRL, Eugene Ram-skill had special expertise in developing advanced filter papers for protection against chemical-warfare agents; blowers forced air through these filter papers

to collect airborne particles. (See figure 1a.) Irving Blifford designed an integrated system in which the radioactivity on the filter paper was both measured continuously and recorded as the debris built up.

For direct gamma radioactivity measurements of fission products in the air, Johnson preferred tethered balloons that held Geiger counter bundles aloft at 20 000 feet. (See figure 1b.)

The most sensitive gamma-ray detector was a nest of seven large counters connected so that every pairwise connection was in anti-coincidence, which greatly reduced the background counts from cosmic-ray particles. Each counter was a cylinder 24 inches long and 2 inches in diameter, made of a chrome-iron-stainless steel alloy, sealed with soft glass end caps. Amperex Corporation supplied the steel shells that were filled with chlorine-neon gas at NRL. The electronics package—power supply, pulse-count scaler, anti-coincidence circuit and recorder—was built at NRL. These counters exhibited essentially no drift in operating characteristics. Blifford procured enough parts to assemble 100 of these units at NRL and shipped them out to collaborators in the field.

Prior to the Sandstone tests, some 75 units were in routine operation—at universities and naval stations in the continental US, and at various government installations scattered north-south from Panama to the Aleutian Islands and eastward to Bermuda. Several well-known physicists maintained security by operating the instruments in their own homes. For instance, H. Victor Neher of Caltech wrestled a 400-pound unit into his attic and the editor of *The Physical Review*, John Tate, had one in his backyard. The most reliable equipment, however, was that tended by military personnel who paid close attention to the instrument operations.

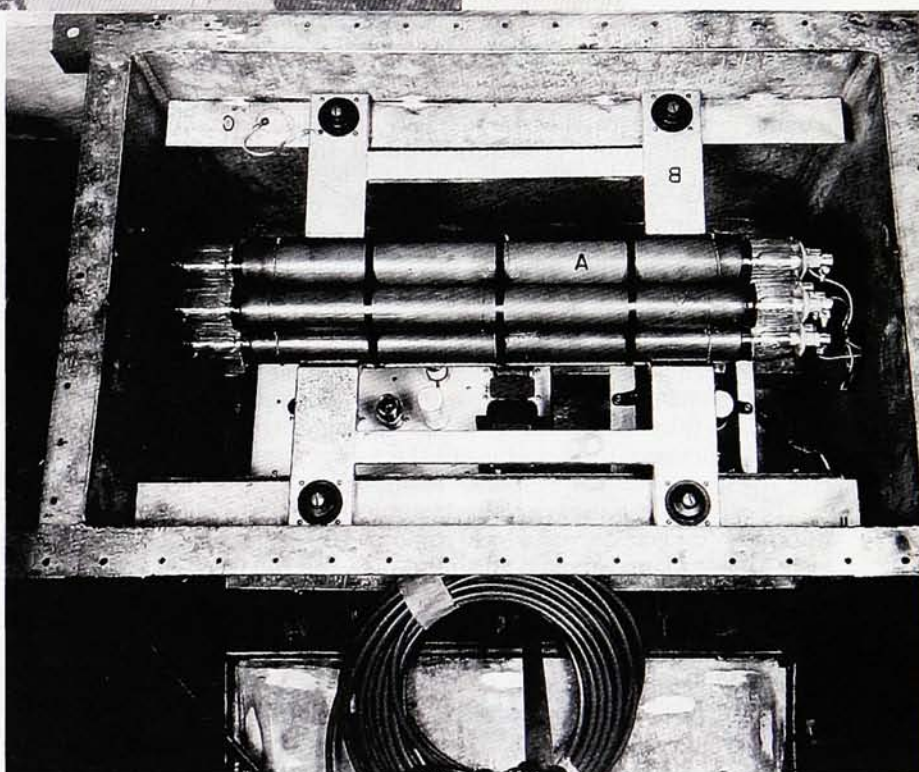
After the Sandstone tests, filter paper collectors on the NRL dock on the Potomac River in Washington, DC, obtained positive responses at roughly the same time as the balloon-borne Geiger counters at NRL's Chesapeake Bay Annex and the gamma-ray detectors on the roof of NRL's optics building responded. However, many of the

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EQUIPMENT FOR DETECTING RADIOACTIVITY.

a: A large filter paper is being clamped to a blower capable of pushing 40 cubic feet of air per minute through the paper, trapping any radioactive debris. After collecting for one day, the paper was placed under an array of mica-window counters in a lead castle. Such devices, of various sizes, were used at ground stations at NRL. b: A bundle of 7 Geiger counters used pulse-height discrimination to count individual gamma rays while rejecting background counts from cosmic rays. 'B' and 'C' in the figure label circuit mounts. Smaller and lighter weight bundles were held aloft by tethered balloons. FIGURE 1



field units were at unfavorable locations and gave only marginal detections, because of the prevailing winds. By September 1948, we decided to use only the gamma-ray detectors at Naval stations. With 20/20 hindsight, had the entire system remained in operation, most if not all of the US stations would have detected the first Soviet test, and the role of atmospheric dynamics in carrying the clouds of fission products around the world might have been clearly revealed.

The Air Force in charge

Although quickly mobilized in the spring of 1947, NRL did not act in isolation. The Air Force program started more slowly. On 16 September 1947, General Eisenhower, the chief of staff, assigned the overall responsibility for detecting atomic-bomb explosions to the Army Air Force's

General Hoyt Vandenberg. Two days later the Army Air Force became the US Air Force. In December 1947, the Air Force Office of Atomic Tests (AFOAT-1) was established, and it had primary responsibility for assessing and archiving data collected by all participants in LRD programs. In February 1948, the newly established Tracerlab Inc became the principal contractor to AFOAT-1 for analyzing any fission products recovered from nuclear tests.

Three B-29 squadrons, which provided very-long-range weather reconnaissance over tracks that included Japan, Alaska and the North Pole, were fitted with filter paper scoops. On 29 October 1948 the joint armed forces' Research and Development Board formally approved the Air Force's plan for routine monitoring flights over the expected northern tracks of radioactive debris from any Soviet nuclear test.

In the ensuing years of the LRD effort, NRL transmitted all of its technical information to AFOAT-1 and offered technical consultation. It was, however, primarily a one-way path of communication, overburdened by excessive security restrictions, compartmentalization, and need-to-know requirements.

Project Rainbarrel

In early 1948, when an operating prototype of the large gamma-ray detector was placed on the roof of the optics division building at NRL, we observed an increase in ambient gamma-ray activity when it rained. When we placed a 2-inch-deep tray over the case of counters, the count of natural radioactivity rose markedly as the tray filled with rainwater. Here then was the key to sensitive monitoring!

Now was the time to coopt the talents of our neighbors, the chemists. Friedman contacted Peter King in NRL's chemistry division and posed the questions: How could fine particulate radioactivity be concentrated and removed from rainwater? How much concentration was possible? King dispatched Luther Lockhart to investigate the water-purification procedure used at the Dalecarlia Reservoir in Washington, DC. Lockhart learned that by dumping 0.2 gram of aluminum sulphate per gallon of water into the reservoir to produce aluminum flocculent, the suspended silt and organic matter would precipitate to the bottom where it was easily removable for chemical treatment. King believed that radioactive material could be similarly precipitated, and estimated that a concentration of seven orders of magnitude was feasible. If his chemists could carry out the separation of fission products, Friedman's physicists would build the counting instruments to measure the activities of the products and their half lives.

Shortly after Sandstone, Lockhart looked for suitable rainwater collections, in which radioactivity from those tests was still preserved. In June 1948, he followed a suggestion that the Virgin Islands were a likely candidate because the islanders relied entirely on rainwater collected in concrete cisterns. Lockhart indeed found some cisterns with suitably old rainwater. The water was treated in a 500-gallon truck used for decontaminating chemical warfare agents. The flocculent settled overnight and then the clear water was siphoned off. More rainwater was added and the process was repeated until 2500 gallons had been treated, from which 5 gallons of settled floc was returned for analysis. Back at NRL, the rare-earth isotopes yttrium-91, cerium-141 and cerium-144 were chemically separated. Subsequent analysis confirmed that the ratios were in the correct proportions to be fallout from the Sandstone test. A report of this work was prepared by Lockhart and Blifford, immediately classified Top Secret, locked up, and Blifford and Lockhart were not permitted to see it because they lacked that level of clearance.

Before long, however, they obtained their clearances and were given access to their own work.

Samples were needed from more areas of the Pacific around the US test sites at Bikini and Eniwetok in the mid-Pacific, as well as those regions of North America covered by prevailing winds out of the USSR. King drafted a young chemist, Jack Kane, for this work and sent him to Shemya, the last island in the Aleutian chain, to sample pond water. From there he proceeded to Kodiak, Alaska, and repeated the collection ritual. No fission products were recovered, showing that no Soviet air burst had occurred for several years. This was July 1948.

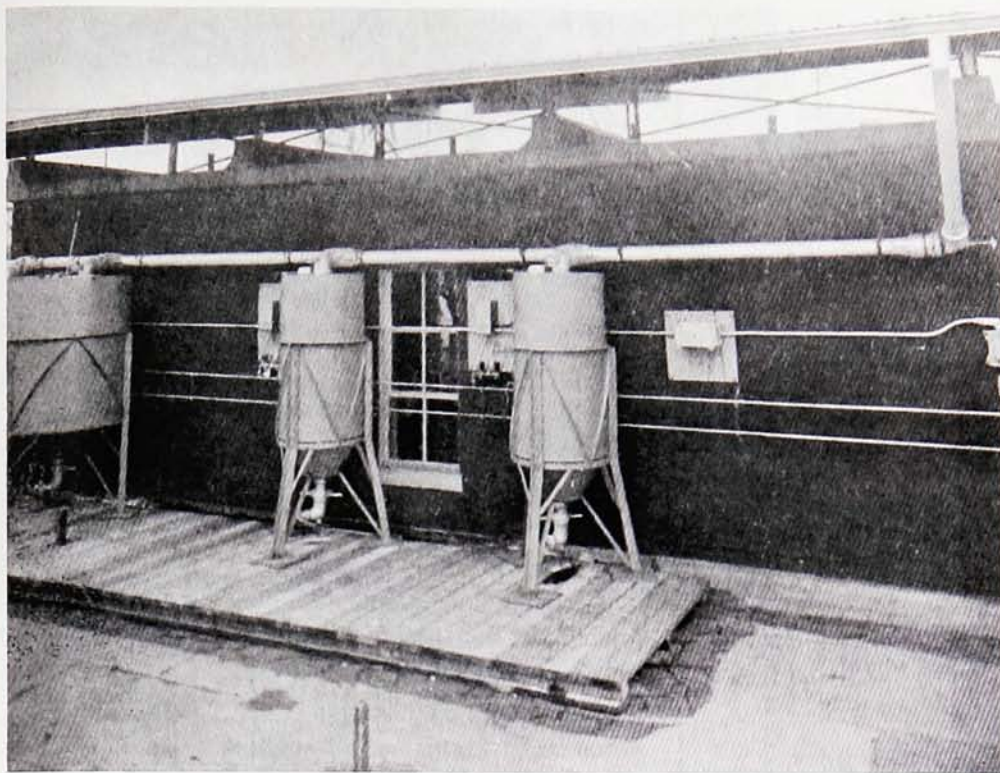
Kane then flew to the Truk islands, where we expected him to find high activity from our own tests. In the hills of Moen (site of a WWII Japanese Naval base) he discovered an abandoned swimming pool that the Japanese had used and he flocked the water that it still held. In addition, he pulled away some mossy growth from the edge of the pool, stuffed it in an empty paint can, and carried it back to NRL along with his floc samples. The water was indeed radioactive, but the vegetation was found to be especially hot.

Time was not just marching on; it was running. We felt the urgent need to decide on the elements of a detection system and to establish an appropriate number of monitoring stations. The first requirement was for a large-area collecting surface. King commandeered the chemistry division's janitorial crew, provided them with new brushes and asked them to wash and scrub their roof. In the water collected from the first rain after the scrubbing, the chemists found high levels of fission activity. In fact, the roof had absorbed radioactive material from our earlier tests in the Pacific, and the material slowly leached out with every rain. Clearly, we would need clean roofs to make definitive analyses. Several corrugated aluminum roofs, a thousand square feet each, were purchased and deployed in Washington, DC, and Kodiak. Rainfall ran off the roof, down new aluminum gutters, and into a several-hundred-gallon tank. Our large banks of gamma-ray detectors and continuously monitored filter papers attached to pumps nicely complemented the rain-collection equipment. By April 1949, we were ready for a Soviet test. The rain-tank operators had instructions to floc the water any time the filter papers showed anomalous activity.

From April to August 1949, there was no fission activity in samples received from Kodiak. We had confidence in our detection capability, and settled in to wait—however long it took. Our program was now dubbed "Project Rainbarrel." Some tensions were beginning to develop between us and the Air Force. Our budget request for establishing a Rainbarrel network was \$80 000; AFOAT-1 wanted \$32 million to fly filter-paper scoops on B-29 aircraft. The rain-collection method was criticized as being too dependent on rain falling over one of our stations. (As it turned out, in all the following history of the project we never failed to get rain when it was needed.)

Seeing Joe-1

In mid-August 1949, we received an alert from William Urry, technical director of AFOAT-1, but we got no bomb debris in our detection system. It was a false alarm. The first real Soviet nuclear bomb—called "Joe-1" in the US,



RAINWATER COLLECTION
system. Rain washes large amounts of radioactive fallout from the air, so collecting the water also collects isotopes. This 500-gallon system used a 1000-square-foot roof of corrugated aluminum to send rainwater into one of three storage tanks. **FIGURE 2**

and "RDS-1" in the USSR—exploded on 29 August. We picked up positive readings on our air monitor at NRL on 10 September and sampled the next rain on 13 September. At Kodiak, the sensitive gamma-ray detector gave a strong signal during the rainfall-dependent periods 6–12 and 13–17 September. Rain samples there were collected, flocced and the floc shipped to NRL by special aircraft flights. The Air Force also sent us some filter paper, from a scoop on a B-29 flying from Japan to Alaska, and requested that NRL analyze it for fission products. The counting rate was only a few counts per minute, which wasn't worth diverting our chemists from analysis of the very hot samples that they were working with. Our results were quickly reported on 22 September 1949, in Top Secret Restricted Data NRL Report 3536, "Collection and Identification of Fission Products of Foreign Origin" by P. King and H. Friedman. To quote from the abstract:

Positive radioactive evidence of a recent explosion of an A-bomb has been accumulated by NRL fission product detection stations at Kodiak, Alaska and in Washington, DC during the period from 9 September to 20 September. The date of fission, deduced from activity ratios of fission isotopes, is probably not earlier than 24 August. Extremely hot samples extracted from the fallout of fission products at Kodiak have yielded tens of thousands of counts per minute of the major fission product isotopes.

The day after our report, 23 September 1949, President Truman announced the Soviet test.

The hot samples from Kodiak suggested that measurable amounts of Pu-239 could be separated. Chemist Richard Baus, working with Lockhart, separated out a plutonium fraction with about 10 alpha counts per minute. That sample was given to Maurice Shapiro of NRL's Cosmic Ray Laboratory, where a highly developed capability was available for measuring particle tracks in thick photographic emulsion stacks. Shapiro determined that the lengths of alpha particle tracks from the Joe-1 sample were consistent with plutonium.

The identification of Joe-1 as a plutonium bomb im-

mediately became one of the most closely guarded secrets of the surveillance program. A related anecdote is of interest:

In October 1949, NRL hosted a symposium on Geiger counters, one of a series of "Radiac" discussions initiated by the instruments branch of the AEC. It is safe to assume that none of the participants, other than the members of the NRL bomb-detection team and one physicist from Tracerlab, knew anything about Joe-1. On the evening of 28 October, at a hotel banquet to celebrate the symposium, the guest of honor and dinner speaker was AEC Commissioner Sumner Pike. In the most casual way, he spilled our knowledge that Joe-1 was a plutonium bomb. Incredibly, in spite of the public circumstances, the presence of press representatives, and even the presence of Willard Libby—who was intent on perfecting low-energy beta counters for his work on radiocarbon dating—the story did not leak. Apparently, Pike's offhand remark failed to register with the "outsiders," although those of us "in the know" had our hearts in our throats. The evidence that Joe-1 was a plutonium bomb remained classified Top Secret for more than a dozen years.

Aftermath

NRL maintained Rainbarrel stations through the Soviet tests of Joe-2, Joe-3 and Joe-4, as well as many US tests in the Pacific and in Nevada. Before we decided to phase out the operation, we tested it to the limit of practicality—with a surface of 10 000 square feet, almost 1/4 acre, with several 1000-gallon collecting tanks to which different portions of the rain showers could be diverted. (See figure 2.) Apart from the bomb detections, much atmospheric science was accomplished up to and through the period of the International Geophysical Year (1957–58).

*Note: A complete, unclassified account of the Air Force/Tracerlab story of the detection of Joe-1 is contained in the book *Spying Without Spies* by Charles A. Ziegler and David Jacobson (Praeger Press, 1995). See the article by German Goncharov, beginning on page 44, for an engaging account of Soviet activities leading up to and following Joe-1.* ■