TITLE: Red Nautilus Under Way

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STUDIES IN INTELLIGENCE

A collection of articles on the historical, operational, doctrinal, and theoretical aspects of intelligence.

The use of scientific literature in estimating an operational date for the first Soviet nuclear submarine.

RED NAUTILUS UNDER WAY

John A. Lundin

Published information can be a prime source of intelligence even in military-technical matters like the application of nuclear technology to weapons. The analyst must recognize research described in the open literature as paralleling the development of a secret military project and extrapolate from the one to the other as judiciously as possible. Collateral information from other sources is required in the process; it provides the ties or clues which permit the correlation of seemingly unrelated items. Yet some of this information may be erroneous or misleading, and it is the analyst's job to sift out the false and reveal the true picture. A case in which the approach from the scientific literature was particularly successful was in estimating when the first Soviet nuclear submarine could be expected to begin regular operation.

Rumors, Reports, Announcements, 1954-57

After the U.S. launching of the *Nautilus*, in January 1954, a number of indications began to appear that the Soviets were also embarked on a nuclear submarine program. Some reports even had them launching their first submarine in 1955. In December 1955 the announcement that a nuclear icebreaker would be built lent plausibility to the prospect of a nuclear submarine.

In April 1956 Marshal Zhukov, then Minister of Defense, declared in a secret speech, "Our Navy . . . in the near future will be equipped with atomic engines." This was authoritative word that a naval nuclear propulsion program had been started but operational status had not been achieved. A year later the situation had apparently not changed: on 4 July 1957 Admiral S. G. Gorshkov, Commander in Chief of the Soviet Navy, said that it had no atomic submarine at that time but would in the future.

In the meantime, however, there were numerous clandestine reports that in 1954 modifications were begun at Shipyard 402 at Severodvinsk to permit construction of nuclear submarines and that in 1956 hundreds of new workers arrived at the plant. Among the welter of other conflicting reports, many implied that nuclear submarines were already in existence as early as 1956. The problem for intelligence was thus to get firm information on the Soviet program and determine when the first unit had become or would become operational.

The Atomic Energy Program to 1954

Up until the time of their first nuclear test, 29 August 1949, the Soviets had bent all their efforts toward obtaining a nuclear weapon. In 1950 they reorganized the atomic energy program and expanded it to include development of a nuclear power station as well as continued work on weapons. This expansion necessitated the training of new scientific personnel, the construction of new research facilities, and the development of a supporting nuclear industry.

In June 1954 the program bore fruit when the world's first nuclear electric power station began operation at Obninsk with a generating capacity of 5 megawatts. This achievement, which demonstrated the practicality of obtaining power from nuclear energy, had required concentrated research in an experimental reactor. The production of high-pressure steam to drive the turbogenerators of a power plant called for fuel elements which could operate at temperatures considerably higher than those in the reactors the Soviets had built for plutonium production. To develop this new type of fuel element, a research "Reactor Physical Technical" (RPT) was constructed at I. V. Kurchatov's Laboratory of Precise Measurements, now called the Institute of Atomic Energy.

The RPT began operation in April 1952 and was brought up to full power in December, when the first experimental loop, or test channel, was ready to test fuel elements for power reactors cooled and moderated by water under high pressure. Later on, about mid-1953, two additional loops were put into service, one to test structural elements for water-cooled reactors and the other to test fuel elements cooled by liquid metal. Still later, early 1954, two more loops were put into operation testing fuel elements for power reactors with air and water cooling. During this period RPT had to be shut down several times, not only to install the new loops and replace experimental fuel elements, but also to repair breakdowns of the reactor itself.

Until early 1954 research reactor facilities were thus fully tied up in work on the Obninsk power reactor fuel elements. Research on a nuclear propulsion plant, especially the reactor portion, had to be confined to theoretical considerations such as calculations in reactor physics to select the best kind of reactor for this purpose. Such theoretical studies on reactors cooled and moderated by water were conducted in 1952 and 1953 by A. P. Aleksandrov at Kurchatov's Laboratory. After the Obninsk reactor proved successful, experimental attention could turn to propulsion plant development, for the icebreaker *Lenin* and presumably the submarine.

Fellow Scientists Confer

By 1956 this history of Soviet research was known in the West from scientific papers and publications. It was known, too, that the propulsion plant being developed for the *Lenin* was to be based on a pressurized-water reactor. In April of that year a presentation by Kurchatov at Harwell showed that the Soviets had selected uranium dioxide as the fuel for this type of reactor and were well into a development program.

The next important new insights into the Soviet program came from the World Power Conference held in Belgrade in June 1957. At this conference S. A. Skvortsov presented a paper on a new pressurized-water power reactor to be constructed at Novovoronezh. His presentation showed that its over-all design parameters were already fixed. Its uranium dioxide fuel was to be enriched to a 1.5-percent content of the U-235 isotope. In a new development, zirconium was to be used as the sheath or cladding to protect the fuel from the water; the Obninsk reactor had used stainless steel.

The extent and complexity of the data indicated that the Soviets had largely completed their basic research and were now in the engineering phase of development. The Novovoronezh reactor was to be a large version of the type one would expect to see used in ship propulsion plants. This information, extrapolated over to the submarine program, meant that the major features of the propulsion plant had been developed and it was probably under construction. Yet there was nothing onto which one could hang a timetable.

Finally, at the Second International Conference on the Peaceful Uses of Atomic Energy, held September 1958 in Geneva, the Soviets presented a large number of papers on the technology of the pressurized-water reactor, and these contained the key to the time factor in their development and construction of the nuclear submarine. The controlling factor was the development and testing of the fuel element.

Fuel Element R&D

First of all, the neutron spectrum (the distribution of neutron speeds) for the water-cooled and -moderated system had to be worked out. A paper by V. I. Mostovoi *et al* of the Institute of Atomic Energy reviewed the study of neutron spectra in such systems; it had been started in 1956. From these studies the optimum spacing of the core lattice was determined, so that the fuel assembly could be designed accordingly.

A paper by S. M. Feinberg *et al* described the mathematical procedures used for determining how the geometry of the uranium-water lattice, the initial content of fissionable isotopes, and the size of the core affect the quantity of power released per unit weight of fuel (the degree of fuel burnup achieved). The neutron cross sections (giving probability of interaction, for which neutron speed is critical) that he used were those worked out in early 1956. These calculations established the basic parameters for the core of a pressurized-water reactor using uranium dioxide as the fuel and zirconium as the cladding.

A paper by R. S. Ambartsumyan *et al* recounted Soviet efforts to find a commercial zirconium alloy suitable for continuous operation in water and steam at high temperatures. Specimens were tested for as long as 10,000 hours (13.5 months), but the critical results had been obtained at about 6000 hours (about 8 months). In the course of these tests continual reference was made to a paper presented by D. E. Thomas at the First International Conference on the Peaceful Uses of Atomic Energy held in September 1955. This meant that the Soviets probably began testing alloy samples in late 1955. When the decisive results were available, in mid-1956, they could then select the best alloy for the cladding and proceed with the next phase of the test program, namely in-pile tests of fuel element prototypes.

This phase was discussed in a second paper by Ambartsumyan *et al*, which completed the timetable key. It disclosed how the Soviets tested a fuel element under the conditions of the proposed *Lenin* reactor. After the first 3000 hours the test element was taken out and inspected, and the state of the jackets was very good. After 7464 hours in this loop it was shifted to a second test channel closer to the axis of the reactor, where test conditions were similar to those planned for the Novovoronezh electric power reactor. As of 1 February 1958, the prototype fuel element had been in the second loop for 3653 hours, making a total test time as of 1 February 1958 of more than 463 days.

The Time-Table

The testing of the prototype element therefore began no later than 25 October 1956. When the 3000-hour inspection in late February 1957 found it to be in good condition, the Soviets knew they had a fuel element of satisfactory reliability. About March 1957, then, they could fix its design and start manufacturing. Using U.S. experience as a guide, it was estimated that nine months would probably be required to produce the first core. January 1958 was then the earliest the core could be loaded into the submarine reactor. Another three to six months would be required before dockside trials could take place. The submarine could have begun sea trials at the earliest in late spring 1958.

Such a schedule would count on a normal rate of construction, allowing for no unexpected delays. With a newly designed submarine, however, it was supposed that problems might crop up and take time being worked out, leaving a period of uncertainty in the estimated schedule perhaps as long as a year. In that case, the first Soviet nuclear submarine would become operational by mid-1959. The chronology is summarized in the table on page 56.

Controversy and Confirmation

This conclusion, reached in the fall of 1958, was supported by information from a U.S. military editor who had visited the USSR in September. He reported rumors that the first Soviet nuclear submarine was launched in July 1958 and that it was to be commissioned—this precedes fitting out and the shakedown cruise—near the end of the year. On the other hand, a clandestine service report shortly thereafter stated flatly that the nuclear submarines were in series production in Leningrad, not Severodvinsk, and that as of January 1959 twelve were "on the way."

CHRONOLOGY

Pressurized-Water Power Reactor	Icebreaker Lenin Reactor	Postulated Submarine Reactor
1954: First atomic power station in operation. Expansion of atomic energy program.	Draft of propulsion program	Draft of propulsion program
1955:	Announcement of planned nuclear icebreaker.	
1956: Neutron spectrum study. Calculations on $Zr-UO_2$ lattice. Corrosion tests end; Core design begins. In-pile tests begin under *Lenin* conditions.	Keel laid; core design begins. Motors under construction.	Core designs begins.
1957: Design released at Belgrade Power Conference. In-pile tests for power reactor begin.	3000-hr. inspection of in-pile test for *Lenin*. 7464-hr. *Lenin* test ends. *Lenin* launched, Dec 1957.	Core construction could begin. Possible launching.
1958: In-pile tests end.	Core loading begins.	Core loading. Sea trials (sometime between spring 1958 and mid-1959).
1959: Operational.	Dockside trials. Sea trials. Operational.	Operational.

This last report found a number of partisans in the intelligence community, and there was great controversy for a time over the validity of reasoning from open scientific literature, of deriving production rate from shipyard capacity, of depending on rumors, etc. The report could possibly be interpreted to mean only that twelve nuclear submarines were planned and construction had started, but the Leningrad location could not be reconciled. (In the end, much later, it was learned that this information was deception material fed to the source by the KGB.)

In the fall of 1959 a Soviet sailor who had been stationed at the Severodvinsk Shipyard 402 reported that the first nuclear submarine was launched in spring 1958; he had seen it in June. Other information of his concerning the shipyard and naval activities was well substantiated. He implied that the submarine began operation late that year.

At about this same time a report came in of the sighting and sketching of a new submarine, Pendant No. 251, in September 1959. Records showed that this number had first been noted in July. This, right on schedule, was the nuclear submarine, now called N-class; but it took several years to confirm the fact. In 1963 the Soviets finally published an article describing the voyage of the nuclear *Leninsky Komsomol* to the North Pole, and an accompanying photograph showed an N-class submarine, No. 270, with the same features as had been seen in No. 251.

This case history illustrates that in countries that have limited resources and manpower devoted to R&D in a given technology, the scientific literature in that field reflects the progress being made in both unclassified and secret projects. We have seen a situation in which clandestine reporting informed us of the existence of a nuclear submarine program, but it was scientific discussion of developments in pressurized-water reactors that permitted a correct estimate of the initial date of operation.