CONFERENCES AND SYMPOSIA

PACS numbers: **01.65.+g**, 89.20.Dd

The Academy of Sciences and implementation of the Atomic Project in the USSR
(on the 75th anniversary of the Atomic industry)

R I Il'kaev, L D Ryabev

DOI: https://doi.org/10.3367/UFNe.2020.12.038931

Abstract. The article is based on the report delivered at the scientific session of the General meeting of the Department of Physical Sciences of the Russian Academy of Sciences, "75 years of the Atomic industry. Contribution of the Academy of Sciences," which was held on December 7, 2020. The participation of the USSR Academy of Sciences in the implementation of the Atomic project is presented, examples of the support provided by the Academy of Sciences to the development of atomic and thermonuclear weapons in the USSR through research and engineering solutions and the personal involvement of researchers are given, and the prominent role of scientists from the USSR Academy of Sciences in the creation of the USSR's nuclear shield is highlighted. The need for active cooperation between specialists from the Russian Academy of Sciences and Rosatom nowadays is stressed.

Keywords: history of the Soviet Atomic Project, contribution of the USSR Academy of Sciences to the Atomic Project

After the meeting of the leaders of the USSR, the USA, and Great Britain on July 24, 1945, at which the USA officially disclosed information about the creation of an atomic bomb, the USSR's leadership almost immediately made a decision to implement in the USSR an Atomic Project of its own.

On July 24, 1945, in Potsdam, US President Truman informed Stalin that the United States "now has weapons of extraordinary destructive power."

The existence of an atomic project in the United States was reported to Stalin at the beginning of 1942, and he ordered the commencement of uranium-related work in the USSR.

The Potsdam meeting took place even before Hiroshima was bombed by a uranium charge, which consisted of two pieces fired at each other, and Nagasaki by a plutonium charge with a spherical implosion.

However, studies related to uranium had begun in the USSR much earlier, and these activities, which also have a rich history, are marked by famous scientific and engineering achievements.

R I Il'kaev [(1)], **L D Ryabev** [(2)]
Russian Federal Nuclear Center–All-Russian Research Institute of Experimental Physics,
prosp. Mira 37, 607190 Sarov, Nizhny Novgorod region, Russian Federation
E-mail: [(1)]ilkaev@vniief.ru, [(2)]LMKondratenkova@rosatom.ru

Received 12 February 2021
Uspekhi Fizicheskikh Nauk **192** (5) 528 – 536 (2022)
Translated by M Zh Shmatikov

Leaders of the UK, US, and USSR (left to right): Winston Churchill, Harry Truman, and Joseph Stalin (July 1945, Potsdam).

The outstanding achievements of the Atomic Project, which were based on the solid foundation for the development of physics in the USSR laid in the 1920s–1930s, were due to the high level of Soviet research, including:

- development of the theory of the atomic nucleus;
- discovery of nuclear isomers and spontaneous fission of uranium;
- construction of Europe's first cyclotron;
- holding of five all-union and international conferences on nuclear physics;
- creation of the Commission on the Atomic Nucleus of the USSR Academy of Sciences;
- creation of a network of physical and physical/engineering institutes in many cities of the USSR;
- development of the physics of explosive detonation processes.

Soviet physicists before WWII were working at a number of first-class scientific centers located in Moscow, Leningrad, and Kharkov, and achieved outstanding results. By that time, the following institutions had been founded:

- in 1918, the X-ray and Radiological Institute,
- in 1922, the Radium Institute,
- in 1923, the Leningrad Institute of Physics and Technology (LFTI),
- in 1928, the Kharkov Institute of Physics and Technology,
- in 1931, the Institute of Chemical Physics and the Institute of Rare Metals,
- in 1932, the Lebedev Physical Institute,
- in 1934, the Institute of Physical Problems,
- in 1938, the Commission on the Atomic Nucleus at the USSR Academy of Sciences;

A B Ioffe, one of the organizers of physical studies in the USSR, with his students A I Alikhanov and I V Kurchatov in an LFTI laboratory (1935).

• and in 1940, the Commission on Uranium Problems was organized (which included N N Semyonov, I V Kurchatov, and Yu B Khariton) [1].

A F Ioffe foresaw in 1940 who would become the scientific and engineering leaders of the Soviet Atomic Project. In his memo to the Presidium of the USSR Academy of Sciences dated August 24, 1940, he noted that "the possibility of the engineering employment of uranium energy cannot be ruled out at the present state of our knowledge.... The leading specialists who should be involved are, first of all:

I V Kurchatov and his collaborators Flerov and Petrzhak (LFTI), Zel'dovich and Khariton (LIHF1).... The overall guidance of the issue should be assigned to I V Kurchatov as the best expert in the area, who exhibited outstanding organizational skills during the construction of the cyclotron."

The country's leadership set the main tasks of the Academy of Sciences for that period.

DECREE OF THE STATE DEFENSE COMMITTEE no. 2352ss of September 28, 1942.

On the organization of work on uranium

The USSR Academy of Sciences (*Academician Ioffe*) *is instructed to resume studies of the feasibility of using atomic energy by fissioning the uranium nucleus and submit to the State Defense Committee by April 1, 1943 a report on the possibility of creating a uranium bomb or uranium fuel.*

To this end:

1. The Presidium of the USSR Academy of Sciences should:

a) *arrange at the Academy of Sciences a special laboratory for studying the atomic nucleus*;

b) *by January 1, 1943, at the Institute of Radiology, design and develop a facility for thermodiffusive separation of uranium-235*;

c) *by March 1, 1943, at the Institute of Radiology and the Institute of Physics and Technology, produce, using the centrifugation and thermal diffusion methods, uranium-235 in the amount required for physical studies and, by April 1, 1943, at the atomic-nucleus laboratory, explore the feasibility of fissioning uranium-235 nuclei.*

2. The Academy of Sciences of the Ukrainian SSR (*Academician Bogomolets*) *should organize under the guidance of Prof. Lange the development of a project of a laboratory facility for the separation of uranium-235 by centrifugation and, by October 20, 1942, submit a technical project to the Kazan Hammer and Sickle plant of the People's Commissariat of Heavy Engineering.*

One of the organizers of physical studies in the USSR was A F Ioffe (1880–1960). His participation in the implementation of the Atomic Project should be specially noted. Abram Fedorovich Ioffe was the founder and director of the Leningrad Institute of Physics and Engineering (LFTI), which became a base for the development in the USSR of a network of institutes of physics and engineering (including the Institute of Chemical Physics and the Kharkov Institute of Physics and Technology) and deployment of research in various areas of physics. An academician beginning in 1920, he was an active participant in the first stages of the Atomic Project, a member of the engineering council of the Special Committee, and a Hero of Socialist Labor (1955).

Related to his school were a number of prominent leaders in research and engineering in the Atomic Project: A P Aleksandrov, A I Alikhanov, L A Artsimovich, I V Kurchatov, I K Kikoin, B P Konstantinov, A I Leipunskii, N N Semyonov, and Yu B Khariton [2].

Yu B Khariton writes about A F Ioffe: "Abram Fedorovich believed that physics is almighty.... He scattered a lot of ideas around him.... Ioffe had a deep understanding that nuclear physics is the section of physics which cannot but yield a [practical] result."

On February 11, 1943, the State Defense Committee (GKO) issued a decree On the Start of Practical Activities for the Creation of an Atomic Bomb. V M Molotov, GKO's deputy chairman, was in charge of the overall management of the project; he, in turn, appointed I V Kurchatov head of the Atomic Project.

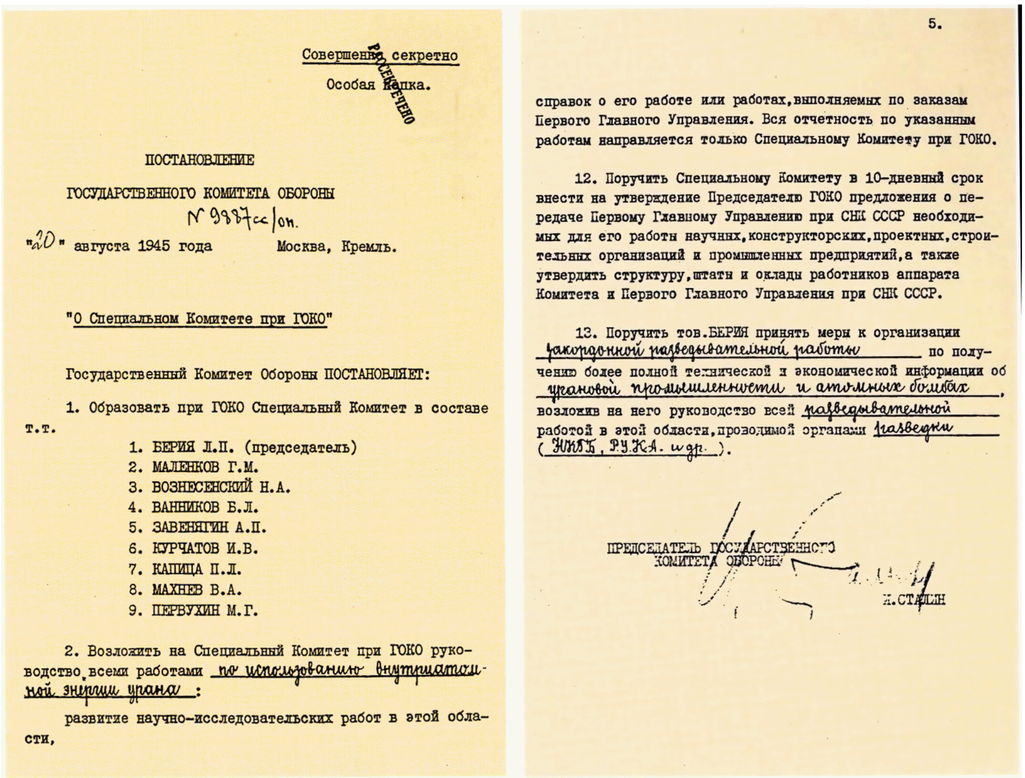
On April 12, 1943, Academician A A Baikov, vice-president of the USSR Academy of Sciences, ordered the creation of Laboratory No. 2 of the USSR Academy of Sciences. I V Kurchatov was appointed the head of the laboratory.

On August 20, 1945, Joseph Stalin, USSR GKO chairman, signed a decree on the creation of the Special Committee under the GKO, a special body to manage uranium-related work, which included high-ranking officials and physicists [3] (Fig. 1). *This date is considered to be the birthday of the Russian atomic industry*.

On April 9, 1946, the USSR Council of Ministers decreed the creation of Design Bureau No. 11 at Laboratory No. 2 of the USSR Academy of Sciences to develop the design and start production of prototypes of atomic bombs. The new facility had to be located at the administrative border of the

KHARITON
Yulii Borisovich (1904–1996)

ZERNOV
Pavel Mikhailovich (1905–1964)



Совершенно секретно

Особая папка.

РАССЕКРЕЧЕНО

ПОСТАНОВЛЕНИЕ

ГОСУДАРСТВЕННОГО КОМИТЕТА ОБОРОНЫ

N 9887сс/оп.

"20" августа 1945 года Москва, Кремль.

"О Специальном Комитете при ГОКО"

Государственный Комитет Обороны ПОСТАНОВЛЯЕТ:

1. Образовать при ГОКО Специальный Комитет в составе т.т.

1. БЕРИЯ Л.П. (председатель)
2. МАЛЕНКОВ Г.М.
3. ВОЗНЕСЕНСКИЙ Н.А.
4. ВАННИКОВ Б.Л.
5. ЗАВЕНЯГИН А.П.
6. КУРЧАТОВ И.В.
7. КАПИЦА П.Л.
8. МАХНЕВ В.А.
9. ПЕРВУХИН М.Г.

2. Возложить на Специальный Комитет при ГОКО руководство всеми работами по использованию внутриатомной энергии урана:

развитие научно-исследовательских работ в этой области,

5.

справок о его работе или работах, выполняемых по заказам Первого Главного Управления. Вся отчетность по указанным работам направляется только Специальному Комитету при ГОКО.

12. Поручить Специальному Комитету в 10-дневный срок внести на утверждение Председателю ГОКО предложения о передаче Первому Главному Управлению при СНК СССР необходимых для его работы научных, конструкторских, проектных, строительных организаций и промышленных предприятий, а также утвердить структуру, штаты и оклады работников аппарата Комитета и Первого Главного Управления при СНК СССР.

13. Поручить тов. БЕРИЯ принять меры к организации закордонной разведывательной работы по получению более полной технической и экономической информации об урановой промышленности и атомных бомбах, возложив на него руководство всей разведывательной работой в этой области, проводимой органами разведки (НКГБ, РУКА. и др.).

ПРЕДСЕДАТЕЛЬ ГОСУДАРСТВЕННОГО КОМИТЕТА ОБОРОНЫ И.СТАЛИН

Figure 1. Decree of the State Defense Committee dated August 20, 1945.

Gorky (now Nizhny Novgorod) region and the Mordovian Autonomous SSR (now the city of Sarov, formerly known as Arzamas-16). P M Zernov was appointed head of DB No. 11 and Yu B Khariton, its chief designer.

It is worth noting the main elements of the Atomic Project, which included:

• solving the most challenging scientific and engineering problems related to the development of RDS-1, developing technologies for the production of key nuclear materials;

• creation of a new nuclear industry;

• creation of a nuclear weapons center;

• creation of a nuclear test site;

• arrangement of cooperation among enterprises, organizations, and institutes of the Academy of Sciences aimed at achieving a common goal — the implementation of the Atomic Project;

• development of basic and applied research in the new areas;

• accelerated training of next-generation specialists at universities and developing scientific schools.

We now list the main features of the Soviet Atomic Project, which include new knowledge, new technologies, and new production facilities.

New knowledge in:

• nuclear physics,

• physics of explosions and hydrodynamics of high energy densities,

• radiochemistry,

• special materials science.

New technologies for:

• nuclear reactors,

• separation of plutonium from irradiated nuclear fuel,

• gas diffusion and electromagnetic separation of isotopes.

New production facilities for:

• mining and processing of uranium,

• plutonium production plant,

• integrated facilities for the production of highly enriched uranium [4].

Intelligence played an immense positive role. The scale and efficiency of the activities of our intelligence agents is amazing. More than 10,000 pages of text, technical documentation, drawings, and even samples of materials (uranium, beryllium) related the atomic issue were delivered. Information was obtained from the UK, Canada, and the USA.

The post-WWII military and political situation in the world was extremely tense, especially in the context of the US monopoly on nuclear weapons.

In 1949, United States operated four industrial nuclear reactors which produced weapons-grade plutonium; two of these reactors were launched at the end of 1944 and one at the beginning of 1945. By the end of 1949, they had produced about 700 kg of weapons-grade plutonium, of which about 120 kg were produced as early as late 1945. By the end of 1949, the USSR was unlikely to have available an amount of plutonium noticeably exceeding 10 kg.

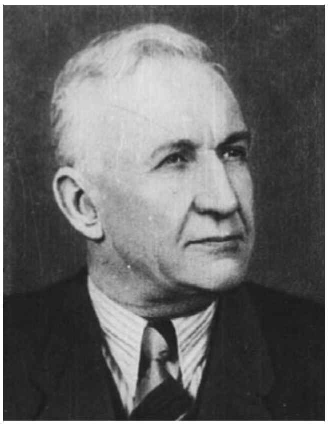
• In 1949, the United States already had 170 nuclear warheads with a total energy release of 4.2 Mt. The average energy release of one nuclear charge was about 25 kt. In essence, by 1949, the entire US operational stock was based on the physical scheme of an implosion-type plutonium nuclear charge.

• Strategic aviation was considered a means of delivering nuclear weapons to the territory of the USSR, and, to expand its combat capabilities, military bases were actively deployed around the USSR.

• These facts clearly indicate the utmost necessity to eliminate the US nuclear monopoly, and this goal was achieved on August 29, 1949.

KHARITONOV
Yulii Borisovich (1904–1996)

ZEL'DOVICH
Yakov Borisovich (1914–1987)



TAMM
Igor' Evgenyevich (1895–1971)

SAKHAROV
Andrei Dmitrievich (1921–1989)

BOGOLIUBOV
Nikolai Nikolaevich (1909–1992)

LAVRENTYEV
Mikhail Alekseevich (1900–1980)

FLEROV
Georgii Nikolaevich (1913–1990)

FRANK-KAMENETSKII
David Albertovich (1910–1970)

Heads of KB-11 (VNIIEF) scientific schools in the early 1950s.

On September 28, 1945, the Special Committee [5] ordered that researchers be appointed from the Academy of Sciences to key positions of the Atomic Project [6]. In addition to the institutes of the USSR Academy of Sciences, the Council of People's Commissars extended the project to another 10 institutes subordinate to various People's Commissariats [7–9].

To develop draft proposals for coordinating the research work of newly participating organizations, the Engineering Council recommended the creation of three permanent commissions under the council, namely:

(1) Commission on the Study of the Ion Method chaired by Academician A F Ioffe, which included:

• Academician A A Lebedev (State Optical Institute),

• Professor S A Vekshinsky (Laboratory of the People's Commissariat for the Electrical Industry (NKEP)),

• Professor L A Artsimovich (Laboratory No. 2),

(2) Commission on the production of heavy water chaired by Academician P L Kapitza, which included:

• Professor M O Kornfeld (Laboratory No. 2 of the USSR Academy of Sciences),

• Professor V N Kargin (Karpov Institute of the People's Commissariat of the Chemical Industry),

• Professor A G Kasatkin (People's Commissariat of the Chemical Industry),

• engineer L S Genin (State Specialized Design Institute No. 3 of the People's Commissariat of the Chemical Industry),

• G I Gavrilov (State Research Institute No. 42 of the People's Commissariat of the Chemical Industry).

(3) Commission for the study of plutonium chaired by Academician V G Khlopin (Radium Institute of the USSR Academy of Sciences); Deputy Chairman, Corresponding Member of the Academy of Sciences B A Nikitin, which included:

• Candidate Sci. (Physics) B V Kurchatov (Laboratory No. 2);

• Academician I I Chernyaev (Institute of Inorganic Chemistry of the USSR Academy of Sciences);

• Institute of Physics and Engineering of the USSR Academy of Sciences (director Academician A F Ioffe): D G Alkhazov, E F Gross, S E Bresler, and A P Aleksandrov;

• Physical Institute of the USSR Academy of Sciences (director Academician S I Vavilov): I M Frank, E L Feinberg, L V Groshev, D V Skobel'tsyn, and V I Veksler;

• Radium Institute of the USSR Academy of Sciences (director Academician V G Khlopin): B A Nikitin, A P Ratner, A A Greenberg, K D Petrzhak, M G Meshcheryakov, and A P Zhdanov;

• Institute of Inorganic Chemistry of the USSR Academy of Sciences (director Academician I I Chernyaev);

• Institute of Chemical Physics of the USSR Academy of Sciences (director Academician N N Semyonov);

• Ural branch of the USSR Academy of Sciences (chairman of the Branch Academician I P Bardin): F F Lange;

• Biogeochemical Laboratory of the USSR Academy of Sciences (director Corresponding Member A P Vinogradov);

• Physical Institute of the Ukrainian Academy of Sciences (director Academician of the Ukrainian Academy of Sciences A I Leipunsky): N D Morgulis;

• Institute of Physics and Engineering of the Ukrainian Academy of Sciences (director Professor K D Sinelnikov): A K Walter.

The success in creating the atomic bomb crucially depended on the availability of raw uranium. The need for the development of the uranium mining industry in the USSR was stressed even before WWII by the Uranium Commission, which included prominent geochemists V I Vernadsky and A E Fersman. On July 30, 1943, the GKO ordered the organization of geological surveys and the mining of uranium; the corresponding activities were to be carried out by the Committee for Geology under the USSR Council of People's Commissars.

At the beginning of 1946, I V Kurchatov wrote: "Until May, there was no hope of building a uranium-graphite pile, since we only had available 7 tons of uranium oxide, and there was no hope whatsoever that the required 100 tons of uranium would be produced before 1948... ."

Before 1949, the amount of mined natural uranium available in the USSR was 25% of the US amount. Moreover, the USSR received about 73% of its natural uranium from abroad, mainly from Germany and Czechoslovakia. The capacities of the uranium mining industry gradually increased to the US level: in 1949, the disposable amount of natural uranium in the USSR was already 86% of that in the United States.

As a result of the decade-long activity of large teams of geologists, geophysicists, and other specialists, in total more than 50 uranium deposits with combined reserves of 84,000 tons were discovered, explored, and put into operation in the USSR and Eastern Europe. Thus, a stable base for the development of the Soviet Atomic Project was successfully created.

Obtaining plutonium was the main technological stage in creating the first atomic bomb. In 1946, the first nuclear reactor F-1 [6] (Fig. 2) was commissioned at the Kurchatov Institute, after which the construction of an industrial reactor in the Urals region started.

Listed below are the stages of creating an industrial plutonium-breeding reactor:

— December 1, 1945 — Decree of the USSR Council of People's Commissars on the establishment of Integrated Plant 817 (now the Mayak production association); the scientific issues in constructing the A reactor (Fig. 3) were supervised by I V Kurchatov, while N A Dollezhal was the reactor's chief designer;

— June 19, 1948 — reactor A was started from scratch under the guidance of I V Kurchatov;

— December 22, 1948 — plant B was commissioned, which was designed to carry out radiochemical separation of plutonium contained in spent nuclear fuel from reactor A;

— radiochemical processes for plant B were developed at the Radium Institute under the guidance of V G Khlopin;

— August 1949 — metallic plutonium hemispheres were made for RDS-12 at plant V;

— the technology to produce pure metallic plutonium was developed at NII-9 (Research Institute No. 9) under the guidance of A A Bochvar, scientific director of plant V.

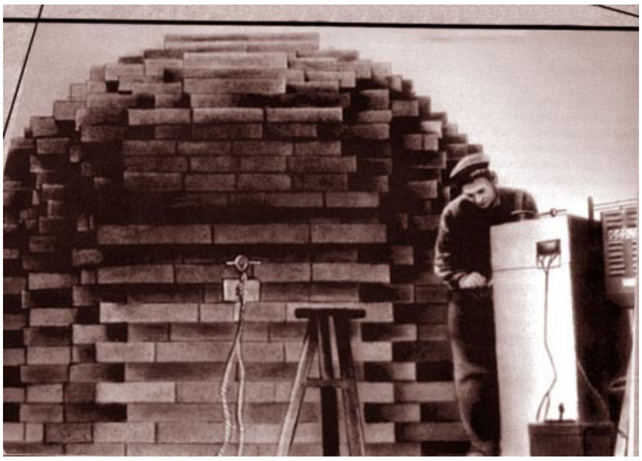


Figure 2. Atomic reactor F-1 launched by I V Kurchatov on December 25, 1946.

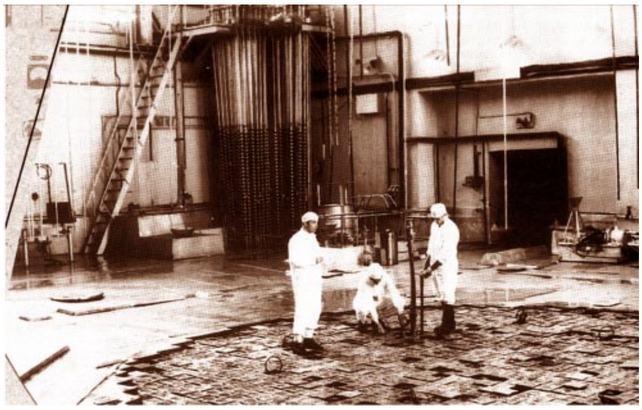


Figure 3. Central hall of reactor A.

We now present the main results of the creation of RDS-1, which, in addition to fulfilling the primary task, contributed to the modernization of the USSR:

• development of computational mathematics;

• creation of a base for the development of nuclear energy and nuclear power plants;

• creation of the foundations for high energy density physics, including means for diagnosing explosive processes;

• development of accelerator technology and the physics of the atomic nucleus;

• development of radiochemistry and physical chemistry for the production of high-purity and special materials;

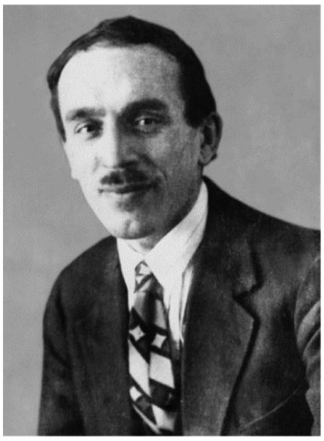
• creation of radiation biology.

The creation of the RDS-1 was not only a demonstration of the outstanding capabilities of Soviet science, technology, and industry, but also a starting point for the industrial production of atomic weapons [10].

On March 3, 1949, the USSR Council of Ministers ordered that the assembly plant, founded at KB-11, produce 20 RDS-1 bombs per year.

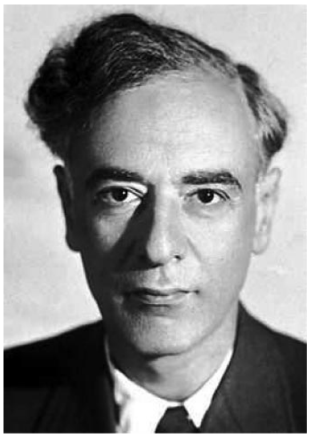
In 1953, the international situation was very tense. The USA had 10 times more atomic charges and more than 1,800 bombers to deliver them. In addition, the United States had significantly advanced in creating high-yield thermonuclear weapons. Making thermonuclear weapons became a task of utmost importance.

At the first stage of the Atomic Project, the Leningrad school of physics was a leader, while at the second (thermo-



SEMYONOV
Nikolai Nikolaevich (1956)

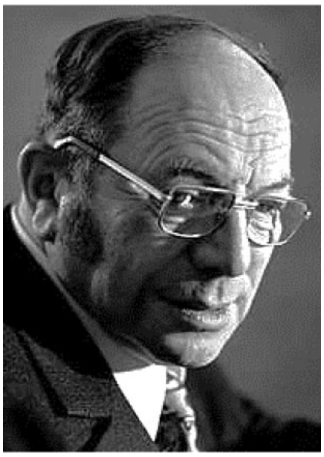
TAMM
Igor' Evgenyevich (1958)



LANDAU
Lev Davidovich (1962)

KAPITZA
Petr Leonidovich (1978)

FRANK
Ilya Mikhailovich (1958)



KANTOROVICH
Leonid Vitalyevich (1975)

GERTS
Gustav Lyudvigovich (1925)

GINZBURG
Vitaly Lazarevich (2003)

Participants in the development of thermonuclear weapon prototypes who later won the Nobel Prize (date in parentheses is the year when the Nobel Prize was awarded).

nuclear) stage, the Moscow school of physicists with its young leader, A D Sakharov, came to the forefront.

In 1953, the Sakharov sloika (puff) was successfully tested [11–13]; in 1955, the principle of radiation implosion was implemented [14].

Thus, the Soviet Union succeeded in creating the basic scientific foundations for the development of atomic and thermonuclear weapons.

One task, which was very challenging from both economic and scientific/engineering perspectives, was to stand on a par with the United States.

After the first basic physical laws operating in the development of atomic and thermonuclear weapons had been established, the rivalry between the two great powers in the creation of all types of nuclear weapons commenced.

The USSR responded to the challenges of the arms race actually initiated by the United States. The Soviet response was timely and adequate, including the naval component of the strategic forces, MIRVs, and neutron charges for tactical weapons.

The country duly rewarded scientists for their work.

In addition to the All-Russian Research Institute of Experimental Physics (VNIIEF), these challenging and intense activities included the participation of the Zababakhin Russian Federal Nuclear Center — the All-Russian Research Institute of Technical Physics (RFNC–VNIITF), the Dukhov All-Russian Research Institute of Automation (VNIIA) (both organized in 1955), and the entire staff of Rosatom that worked in 10 closed administrative-territorial jurisdictions.

The weapon of deterrence was created and deployed at full scale. A major military conflict with the USSR was now impossible. This has been the contribution of Rosatom and the Academy of Sciences to the maintenance of peace for 75 years.

Since Russian nuclear weapons are the basis of military security, the activities that ensure nuclear deterrence enjoy a priority.

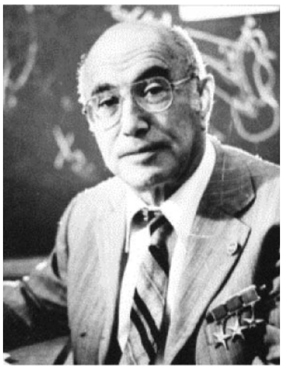
This area offers a wide field of activity for both Rosatom and the Russian Academy of Sciences, as the example of cooperation between the Academy and Rosatom in the implementation of the Atomic Project shows.

Given the terms of the Comprehensive Nuclear-Test-Ban Treaty, which was signed and ratified by Russia, we need much more information about the physical processes that occur in nuclear warheads. All physical models used in computational and theoretical studies to substantiate the reliability, safety, and efficiency of nuclear weapons need to be improved. The focus of work on reliability and safety is

KHARITON
Yulii Borisovich
(1904–1996)

VANNIKOV
Boris L'vovich
(1897–1962)

KURCHATOV
Igor' Vasilyevich
(1903–1960)



ZEL'DOVICH
Yakov Borisovich
(1914–1987)

SHCHELKIN
Kirill Ivanovich
(1911–1968)

SAKHAROV
Andrei Dmitrievich
(1921–1989)

SLAVSKII
Efim Pavlovich
(1898–1991)

ALEKSANDROV
Anatolii Petrovich
(1903–1994)

DUKHOV
Nikolai Leonidovich
(1904–1964)

Thrice Heroes of Socialist Labor — participants in the Soviet Atomic Project

thus transferred to research laboratories and mathematical centers operating a powerful computing base. Therefore, the creation and maintenance of a world-class experimental and computational base is a top priority for us.

The importance and diversity of today's tasks of maintaining and supporting the reliability of nuclear weapons are comparable to those of the problems resolved during the implementation of the Soviet Atomic Project.

Several world-class research centers are now operated by Rosatom, including:

(1) Centers for physics of high energy density.

(2) Centers for the development of applied mathematical software.

(3) Tritium center.

(4) Laser facility.

(5) Center for particle accelerators.

(6) Radiochemical facility.

(7) Irradiation facility.

(8) Electromagnetic radiation center.

A program of joint work between Rosatom and the Russian Academy of Sciences should be developed; it should be financed in defense-related areas by Rosatom and, in basic research, by the Russian Government.

This will be Russia's new nation-wide project that will promote the development of science and ensure national security; the world-class level of work in these areas will be ensured by Rosatom and the Russian Academy of Sciences.

Lessons learned from the Atomic Project:

— first, it was an example the concentrated and rational organization of all activities related to the atomic issue;

— second, it showed how the intellectual power of the entire nation can be included in the fulfillment of the government's assignment;

— third, it serves as an example of how a breakthrough in a scientific area which has an immense impact on defense should be handled;

— fourth, it was the first example of the creation of a deterrent weapon based on the most advanced technologies driven by the achievements of fundamental science; this is an example that should be followed by Russia's defense doctrine in the 21st century.

The creation of thermonuclear weapons in the USSR was a turning point in the mid-20th century, due to which WWIII is now not possible.

The physicists who participated in the thermonuclear project were the first to comprehend that they had created a deterrent weapon, and they conveyed this understanding to national leaders. In 1954–1956, political figures developed on this basis the concept of peaceful coexistence.

The first prototypes of thermonuclear weapons were created in the USSR and the USA at almost the same time, but they were based on fundamentally different configurations of thermonuclear blocks. Approximately 1 year and 8 months passed from the emergence of the concept of an atomic implosion to testing in both the USA and the USSR. These were the periods from March 9, 1951 to November 1,

Table. Comparison of today's military and economic indicators of the Russian Federation and NATO (table complied by A K Chernyshev).

	RF	NATO countries
Population, mln (1)	144.48 (31.12.2018)	937.294 (31.12.2018)
GDP, trillion USD (2)	1.46 (exchange rate 71.49 rub/USD, 2020)	39.616 (2021 in 2015 prices) 19.015 (European countries and Canada, 2021 in 2015 prices)
Military budget, bln USD (2)	40.7 (2021, National Defense budget item, Rosstat) 57.1 (2020, NATO's estimate in 2015 prices)	1048.511 (2021 in 2015 prices) 322.8 (European countries and Canada, 2021 in 2015 prices)
Military personnel, mln (3)	0.900 (2021)	3.317 (2021) 1.966 (European countries and Canada, 2021)

Sources: (1) www.EconomicData.ru (economy and finances).
(2) Defense Expenditure of NATO Countries (2014–2021). 1 June/Juin 2021 COMMUNIQUE PR/CP (2021) 094.
(3) THE MILITARY BALANCE 2021.ISS. 2021.
Note: the sources quote data pertaining to NATO in the prices of a certain year; in this table, in 2015. In comparing the RF with NATO, it is reasonable to quote prices using the PPP (which is 20% larger than the ruble exchange rate).

1952 in the USA and from March 1, 1954 to November 22, 1955 in the USSR.

In the mid-1950s, the size of the army was reduced from 5,763,000 in 1955 to 3,623,000 in 1958.

Below is a list of the problems related to the maintenance of the competitiveness of the nuclear weapons complex in the 21st century:

— creation and development of a fundamentally new experimental, testing, and computing base, which would make it possible to ensure the safety and reliability of Russia's nuclear arsenal to the end of the 21st century;

— reliability, safety, and efficiency of a range of nuclear charges and nuclear weapons significantly wider than those in the United States (regional nuclear deterrence, overcoming a deployed anti-missile defense, enhanced efficiency of armed forces in the theater of operations under the conditions of asymmetry in nonnuclear weapons and armaments);

— efficacy of nuclear weapons and nuclear warheads in the conditions of a retaliatory strike to cause unacceptable damage to the aggressor;

— uninterrupted maintenance of unique know-how, technologies, and methods in the context of a relative decline in Russia's science and education and the brain drain of the best specialists.

Given today's turbulent global processes, Russia's shrinking population (146 million), vast territory (17 mln km^2), and limited global resources, nuclear weapons guarantee the national security of the Russian Federation, being an effective tool to prevent large-scale military threats to the nation (a comparison of modern military and economic indicators of the Russian Federation and NATO countries is displayed in the table).

The creation of nuclear weapons in the Soviet Union ensured global peace in the second half of the 20th and early 21st centuries.

In the short and medium terms, Russia has no alternative to nuclear weapons as an effective means of deterring possible military aggression.

The most important components of national security, i.e., military-technical and economic security, are determined in the 21st century by the level of scientific and technical development of the nation, which, in turn, are determined by the state of basic and applied science and education.

If we are lagging behind, straightforward borrowing of advanced technologies is not possible, because, first, they contain 'secrets' (know-how) and, second, competencies (knowledge and specialists) generally corresponding to the advanced world level are needed to reproduce them.

These activities require the involvement of highly professional specialists, whose availability depends on educational standards and social priorities in labor activity.

Russia's nuclear weapons contain in a concentrated form the talent and knowledge of several generations of outstanding Russian scientists and engineers. Therefore, it is natural that this intellectual base should be fully used to benefit Russia in these difficult times for the nation.

The 20th century was turbulent and controversial, but it was a great century. It has ended, but neither people's lives nor their scientific aspirations, nor their hopes have come to an end. Answering the eternal question: 'How do you get what you want?,' Yu B Khariton calmly and simply answers us: "By working... ."

The highest professionalism and the labor heroism of the outstanding creators of nuclear weapons and the significance of their deeds for Russia's security are inscribed in the history of the Fatherland. They are a wonderful example to new generations of how the nation's most challenging national problems can be resolved under the most difficult conditions.

Conclusion. Celebrating the 75th anniversary of the nuclear industry, it should be emphasized that its creation started immediately after the great victory that our country won in the war, in fact, with all of Europe, *which has no equal in world history*.

Immediately after the war, a new challenge emerged: it was connected with the creation by the USA of an atomic bomb, which was developed by the world's best scientists. The challenge was answered, and the [Soviet] atomic bomb was created.

For the first time in history, the Soviet Union became a superpower. This historic event included contributions, to a significant extent, from Rosatom and the Academy of Sciences and their institutes and production facilities.[1] It is also the first time in history that such a long period, 75 years, has not witnessed major military conflicts. This is also due to Rosatom and the Academy of Sciences.

The 75 years of Rosatom's development have shown that our country can fulfill the most complex nation-wide tasks.

This only requires a reasonable concept, the political will, and the unity of the entire nation.

[1] See the history of the Soviet Atomic Project in [15–29].

Everything else — experience, traditions, personnel, and resources — are already available.

References

1. Ryabev L D (Ed.) *Atomnyi Proekt SSSR. Dokumenty i Materialy* (Soviet Atomic Project. Documents and Materials) Vol. I *Atomnaya Bomba. 1938–1945* (Atomic Bomb. 1938–1945). Part 1 (Comp. L I Kudinova, G S Sinitsyna, N M Osipova) (Moscow: Nauka, Fizmatlit, 1998)
2. Khramov Yu A *Fiziki. Biograficheskii Spravochnik* (Physicists. Biographical Guide) (Moscow: Nauka, 1983)
3. Ryabev L D (Ed.) *Atomnyi Proekt SSSR. Dokumenty i Materialy* (Soviet Atomic Project. Documents and Materials) Vol. 2 *Atomnaya Bomba. 1945–1954* (Atomic Bomb. 1945–1954) Book 1 (Comp. G A Goncharov, P P Maksimenko, V P Feodoritov) (Moscow: Nauka, Fizmatlit, 1999)
4. Andryushin I A, Chernyshev A K *65 Let Mira. K Shestidesyatiletiyu Ispytaniya Pervoi Sovetskoi Bomby, 1949–2014* (65 Year of Peace. On the Sixty-Fifth Anniversary of the Test of the First Soviet Bomb, 1949–2014) (Sarov: RFYaTs–VNIIEF, 2014)
5. Ryabev L D (Ed.) *Atomnyi Proekt SSSR. Dokumenty i Materialy* (Soviet Atomic Project. Documents and Materials) Vol. 2. *Atomnaya Bomba 1945–1954* (Atomic Bomb. 1945–1954) Book 2 (Comp. G A Goncharov, P P Maksimenko, V P Feodoritov) (Sarov: RFYaTs-VNIIEF, 2000)
6. Andryushin I A, Ilkaev R I, Chernyshev A K *Osnovatel' Atomnoi Otrasli* (Founder of Atomic Industry) (Sarov: RFYaTs–VNIIEF, 2015)
7. Ilkaev R I "Major stages of the Atomic Project" *Phys. Usp.* **56** 502 (2013); "Osnovnye etapy Atomnogo proekta" *Usp. Fiz. Nauk* **183** 528 (2013)
8. Ilkaev R I "Fundamental physics research at the All-Russian Research Institute of Experimental Physics" *Phys. Usp.* **54** 387 (2011); "O fundamental'nykh fizicheskikh issledovaniyakh vo Vserossiiskom nauchno-issledovatel'skom institute eksperimental'noi fiziki" *Usp. Fiz. Nauk* **181** 405 (2011)
9. Zabrodskii A G "Scientists' contribution to the Great Victory in WWII on the example of the Leningrad (now A F Ioffe) Physical Technical Institute" *Phys. Usp.* **56** 493 (2013); "Vklad uchenykh v Velikuyu Pobedu na primere LFTI" *Usp. Fiz. Nauk* **183** 518 (2013)
10. Andryushin I A, Chernyshev A K, Yudin Yu A *Ukroshchenie Yadra: Stranitsy Istorii Yadernogo Oruzhiya i Yadernoi Infrastruktury* (Taming Atomic Nucleus: Pages of the History of Nuclear Weapons and Nuclear Infrastructure) (Sarov: RFYaTs–VNIIEF, 2003)
11. Andryushin I A, Ilkaev R I, Chernyshev A K *'Sloika' Sakharova. Put' Geniya* (Sakharov's 'Puff'. Path of Genius) (Sarov: RFYaTs–VNIIEF, 2011)
12. Ilkaev R I "Sakharov at KB-11. The path of a genius" *Phys. Usp.* **55** 183 (2012); "Sakharov v KB-11. Put' geniya" *Usp. Fiz. Nauk* **182** 195 (2012)
13. Ritus V I "A D Sakharov: personality and fate" *Phys. Usp.* **55** 170 (2012); "A D Sakharov: lichnost' i sud'ba" *Usp. Fiz. Nauk* **182** 182 (2012)
14. Andryushin I A, Ilkaev R I, Chernyshev A K *Reshayushchii Shag k Miru. Vodorodnaya Bomba s Atomnym Obzhatiem RDS-37. K 100-letiyu so Dnya Rozhdeniya A.D. Sakharova* (Decisive Step to Peace. Hydrogen Bomb with Atomic Implosion RDS-37. To the 100th Anniversary of the Birth of A.D. Sakharov) (Sarov: RFYaTs–VNIIEF, 2010)
15. Shpol'skii E V "Fifty years of Soviet physics" *Sov. Phys. Usp.* **10** 678 (1968); "Pyat'desyat let sovetskoi fiziki" *Usp. Fiz. Nauk* **93** 197 (1967) about the role of Kurchatov
16. Lemberg I Kh, Naidenov V O, Frenkel' V Ya "The cyclotron of the A.F. Ioffe Physico-Technical Institute of the Academy of Sciences of the USSR (on the fortieth anniversary of its startup)" *Sov. Phys. Usp.* **30** 993 (1987); "Tsiklotron Fiziko-tekhnicheskogo instituta im. A.F. Ioffe AN SSSR (k 40-letiyu so dnya puska)" *Usp. Fiz. Nauk* **153** 497 (1987) this publication contains photos of Ioffe, Alikhanov, and Kurchatov
17. Goncharov G A, Ryabev L D "The development of the first Soviet atomic bomb" *Phys. Usp.* **44** 71 (2001); "O sozdanii pervoi otechestvennoi atomnoi bomby" *Usp. Fiz. Nauk* **171** 79 (2001)
18. Sivintsev Yu V "Igor' Vasil'evich Kurchatov and his greatest cause" *Phys. Usp.* **48** 755 (2005); "Igor' Vasil'evich Kurchatov i delo ego zhizni" *Usp. Fiz. Nauk* **175** 791 (2005)
19. Kiselev G V "Moscow State University physics alumni and the Soviet Atomic Project" *Phys. Usp.* **48** 1251 (2005); "Fiziki — vypuskniki Moskovskogo universiteta i sovetskii Atomnyi proekt" *Usp. Fiz. Nauk* **175** 1343 (2005)
20. Kiselev G V, Konev V N "History of the realization of the thorium regime in the Soviet Atomic Project" *Phys. Usp.* **50** 1259–1282 (2007); "Istoriya realizatsii torievogo rezhima v sovetskom Atomnom proekte" *Usp. Fiz. Nauk* **177** 1361–1384 (2007)
21. Kiselev G V "L D Landau in the Soviet Atomic Project: a documentary study" *Phys. Usp.* **51** 911 (2008); "Uchastie L.D. Landau v sovetskom Atomnom proekte (v dokumentakh)" *Usp. Fiz. Nauk* **178** 947 (2008)
22. Mesyats G A "P N Lebedev Physical Institute RAS: past, present, and future" *Phys. Usp.* **52** 1084 (2009); "Fizicheskii institut im.P.N. Lebedeva RAN: proshloe, nastoyashchee, budushchee" *Usp. Fiz. Nauk* **179** 1146 (2009)
23. Tan'shina A V "Akhiezer Institute for Theoretical Physics at the National Science Center "Kharkov Institute of Physics and Technology", National Academy of Sciences of Ukraine: origins, events, facts, comments" *Phys. Usp.* **56** 932 (2013); "Istoki Instituta teoreticheskoi fiziki imeni A.I. Akhiezera Natsional'nogo nauchnogo tsentra "Khar'kovskii fiziko-tekhnicheskii institut" Natsional'noi akademii nauk Ukrainy (sobytiya, fakty, kommentarii)" *Usp. Fiz. Nauk* **183** 987 (2013)
24. Ritus V I "Tamm–Sakharov group in work on the first hydrogen bomb" *Phys. Usp.* **57** 903 (2014); "Gruppa Tamma–Sakharova v rabote nad pervoi vodorodnoi bomboi" *Usp. Fiz. Nauk* **184** 975 (2014)
25. Altshuler B L "Andrei Sakharov's research work and modern physics" *Phys. Usp.* **64** 427 (2021); "Nauchnaya deyatel'nost' A.D. Sakharova i sovremennaya fizika" *Usp. Fiz. Nauk* **191** 449 (2021)
26. Khariton Yu B, Adamskii V B, Smirnov Yu N "On the making of the Soviet hydrogen (thermonuclear) bomb" *Phys. Usp.* **39** 185 (1996); "O sozdanii sovetskoi vodorodnoi (termoyadernoi) bomby" *Usp. Fiz. Nauk* **166** 201 (1996)
27. Ritus V I "V L Ginzburg and the Atomic project" *Phys. Usp.* **60** 413 (2017); "V.L. Ginzburg i Atomnyi proekt" *Usp. Fiz. Nauk* **187** 444 (2017)
28. Goncharov G A "American and Soviet H-bomb development programmes: historical background" *Phys. Usp.* **39** 1033 (1996); "Osnovnye sobytiya istorii sozdaniya vodorodnoi bomby v SSSR i USA" *Usp. Fiz. Nauk* **166** 1095 (1996)
29. Goncharov G A "On the history of creation of the Soviet hydrogen bomb" *Phys. Usp.* **40** 859 (1997); "K istorii sozdaniya sovetskoi vodorodnoi bomby" *Usp. Fiz. Nauk* **167** 903 (1997)