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Chapter 25

Organization and Initial Period of Activity of the Enterprise to Develop Liquid Propellant Rocket Engines in the Russian Federation*

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The practical development of liquid rocket engines in the U.S.S.R. was begun in the beginning of the 1930s. It involved the first practical attempts to use a new type of engine for the movement of flying vehicles. It was the period of the definition of the basic laws of propulsion movement, the choice of propellant components, the study of the features of their combustion in the chamber, and the search for an optimum design. It was still far before the practical application of liquid propellant rocket engines as a new type of engine. Further development was still needed, such sciences as thermodynamics, hydro and gas dynamics, heat transfer, chemistry, the theory of strength, metallurgy, radio electronics, and gyroscopics; there should also be new technologies and new measurement engineering.

The oldest Russian enterprise for the development of liquid rocket engines is the Research and Production Association of Power Mechanical Engineering named after the academician V. P. Glushko (NPO Energomash)—a recognized leader of liquid rocket engine development. It began its history on May 15, 1929, when V. P. Glushko, its founder and permanent scientific chief, began

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systematic scientific researches in the field of rocket engines at the Gas Dynamics Laboratory (GDL) in Leningrad.

NPO Energomash, in its almost 70-year history, has changed the name and the place of location a few times, but always kept its thematic basis—the development of liquid rocket engines and the scientific and technical management of works by V. P. Glushko. As a matter of fact, his creative biography, involving his work with rocket engineering is a history of NPO Energomash.

Valentine Glushko began the research and production activity for the development of an electrical rocket engine. It was the first electrothermal rocket engine. And, as frequently happens in life, the time of its birth has outstripped much more time than its application. Only in the middle of the 1960s was a similar design used in space engineering. In 1930, V. P. Glushko with a group of employees, had a lot of fruitful work with the choice of propellant components and their combinations. Practical work on designing and experimental testing of the first liquid rockets was begun simultaneously. These engines have received the common name ORM—experimental rocket engine—with additional digital indexes for the subsequent design variants.

In 1930-1933 the engines from ORM-1 up to ORM-52 were designed and tested, on which the serviceability of various variants of a design and the materials of the engines, problems of ignition, the combustion processes of various propellants, and the methods of chamber cooling were studied, and the optimum profile of the chamber's nozzle was chosen. From the whole series of ORM engines, developed in 1930-1933, the ORM-52 engine, which was developed under the order of the Air Force, as the accelerator for a fighter airplane, received the greatest historical acclaim. The engine operated on a nitric acid-kerosene propellant, had a thrust of 300 kg, and had a specific impulse of thrust of 210 seconds. It passed official acceptance stand tests in 1933, but due to circumstances independent of the engine, further work on its use on an airplane were stopped.

The works of V. P. Glushko at GDL in the field of development of liquid propellant rocket engines received wide popularity in scientific and technical circles, and caused interest at the Moscow "Group of Study of Reactive Motion" (GIRD). In the summer of 1932 and in January of 1933 the chiefs of GIRD—S. P. Korolev, F. A. Tsander, M. K. Tikhonravov, Y. A. Pobedonostev — visited GDL. S. P. Korolev recalled his visit: "We became the witnesses of a large scope of works, and huge enthusiasm with which the experiments were conducted... At GDL the engines, the designer of which was V. P. Glushko, had attracted us first of all..."

At the beginning of 1933 the great military leader M. N. Tukhachevsky visited GDL. He appreciated the successes in the creation "of liquid propulsion engines" and saw prospects for their use. With the purpose of joining the forces of isolated organizations, Tukhachevsky in September of 1933 made a decision to organize on the basis of GDL and GIRD the world's first Reactive Research

Institute (RNII), which now carries the name "Research Center named after M. V. Keldysh." The creation of a uniform center for research and development in the field of propulsion engineering was a big stride in terms of scientific and technical progress. The creative researches of the leading experts of that time in the field, including V. P. Glushko and S. P. Korolev, were incorporated at the institute.

In the memoirs of V. P. Glushko, when transferred from GDL to RNII, he once again critically comprehended the future prospect of the use of his own creative forces: "In 1933, when RNII was organized on the basis of GDL and MosGIRD, the necessity of specialization in the development of either rockets or the engines for them became obvious. It was necessary to choose, and I chose what for rocket engineering is the beginning, that lays in its basis, and determines its opportunities and character—rocket engine development."

At RNII V. P. Glushko worked on the creation of liquid propellant rocket engines and pre-burners for use on them as main engines for flying vehicles and sea torpedoes. In 1936-1938 he achieved his greatest success with the development of the ORM-65 engine, which was intended for winged rockets and rocket gliders designed by S. P. Korolev. This engine was the best domestic engine of its time. It operated on a nitric acid-kerosene propellant, had a thrust (controlled in flight) from 50 kg up to 175 kg, and a specific impulse of thrust of 215 seconds in a nominal mode of operation. Official stand tests of the engine were carried out at the end of 1936. In 1937, and at the beginning of 1938, the engine performed successfully at ground tests on the structure of the rocket glider and winged rocket. In 1937-1938 there were carried out ground firing tests: 30 on the structure of a rocket glider and 13 on the structure of a winged rocket. In 1939 two tests of a winged rocket were carried out.

Further on in the life of V. P. Glushko there were dramatic events, the result of which deprived him of the opportunity to be engaged in creative activity for 15 years. In March of 1938 he was arrested, and in August of 1939 he was unjustly condemned to incarceration in a corrective-labor reformatory (ITL) for 8 years. However, taking into account the knowledge and experience of V. P. Glushko, he was directed to go from his prison to the technical bureau of a Moscow aircraft factory, and then in 1940 to an aircraft engine factory in Kazan. These bureaus were part of the system of corrective enterprises organized in those years by the Ministry for Internal Affairs (NKVD).

Thus, in 1939 V. P. Glushko was able to renew his engineering activity. Together with a group of similarly condemned experts he developed a project to install liquid propellant rocket engines on airplanes as the accelerator. This project was accepted and for its practical realization the experimental design bureau (OKB) was organized at a Kazan factory. V. P. Glushko was named the chief designer. OKB was completed by highly skilled scientists, designers, testers, and technologists. The experience and knowledge brought by these individuals from different areas of science and engineering, in which they had worked earlier, allowed OKB to successfully solve difficult problems regarding rocket engine development. At OKB the divisions engaged in the design, manufacture, and testing of developed engines were organized.

In 1942, S. P. Korolev, who was also unjustly condemned in 1938 to a 10-year term, was directed to work in Kazan. At OKB he worked as the deputy of the chief designer for flight tests, being engaged in the development of a design for installing engines on airplanes, and the talent he displayed shone brightly in this work.

As a result of this work in the 1940s OKB developed for increasing the maneuvering speed of airplanes the auxiliary airplane RD-1, RD-1KhZ (chemical ignition), RD-2, and RD-3 liquid propellant engines, with a pump feed of nitric acid and kerosene, an unlimited number (within the limits of a resource) of repeated automatic start-ups, with controllable thrust in ranges from 300 kg up to 900 kg. These engines in 1943-1946 passed all kinds of ground and flight tests on airplanes of the following design: V. Petljakov's PE-2R, S. Lavotchkin's LA-7R and LA-120R, A. Yakolev's YaK-3R, and P. Sukhoy's SU-6R and SU-7R. On August 18, 1946, the LA-120R airplane at the air show in Tushino flew with a working RD-1KhZ engine. It was the first public demonstration of a flying vehicle in flight with a working liquid propellant engine.

Owing to the achieved successes in the creation of rocket aircraft, in July 1944 a group of the condemned specialists at OKB, including V. P. Glushko and S. P. Korolev, was discharged ahead of schedule from their confinement, and in 1945 the leading employees of OKB received state awards.

However, wide use of liquid propellant engines as auxiliary engines for installation in aircraft was not achieved, and the concept of liquid propellant rocket engines on airplanes was shelved with the emergence of air-jet engines.

But there was a huge area for the application of liquid propellant rocket engines—powerful rockets for various purposes. And in this area liquid propellant rocket engines are not unrivaled among a variety of other engines.

For the first time missiles with a flight range of some hundreds of kilometers utilizing liquid propellant rocket engines were utilized by German experts in the construction of the A-4 (commonly known as the V-2—an abbreviation from its propaganda name "Vergeltung Waffe," or Weapon of Vengeance) during the final phase of the Second World War for use in the bombardment of the British Isles. Nothing similar was in the arsenal of other countries during those years.

The first samples of German rocket engineering were received in the U.S.S.R. at the end of 1944, and made a big impression on our experts. Our experts had never envisioned liquid propellant rocket engines of such sizes. Without a detailed comparison, we shall note a difference in only one characteristic: the thrust of the A-4 engine was approximately 25 tons, while the thrust of the largest domestic engines of that time did not exceed 1.5 tons.

After the capitulation of Nazi Germany, the special commission on the study of the trophy weapons and the features in the organization of its manufacture was directed in the Soviet occupation zone. In the structure of this commission in 1945-1946 the leading experts of many industrial branches of the U.S.S.R. were involved. Among them were the future outstanding creators involved in rocket engineering: S. P. Korolev, V. P. Glushko, V. P. Barmin, N. A. Piljugin, M. S. Ryazansky, V. I. Kuznetzov, and others.

V. P. Glushko was twice sent on business trips to Germany. The first business trip was from July to December 1945, while the second was from May to December 1946. During the first business trip he familiarized himself with the workings of rocket manufacturing plants located in Germany, Austria, and Czechoslovakia. As a member of a delegation under the management of General A. I. Sokolov he was present in the English occupation zone for an A-4 launch demonstration.

Under the management of V. P. Glushko a group of the leading experts from the Kazan OKB worked in Germany. To these experts were put the tasks of mastering this new area of engineering, restoring a complete set of engineering specifications for the engine of the A-4, and ensuring the collection of trophy hardware involving A-4 engines and their ground support equipment.

It was rather difficult to execute this task because part of the objects involved in manufacturing missiles was located in territory occupied by the U.S. Army, having been transported (contrary to the Yalta agreements) out of the occupation zone of the U.S.S.R. The Americans left this territory after carrying out Operation "Paperclip," having taken out everything that it possibly could, including the best experts such as Wernher von Braun. The rest they had destroyed. Our experts got incomplete drawings and only parts of both the rockets and the engines. But the group from OKB worked actively. At Nordhausen the "Montania" factory was reorganized, and at Leehsten on the basis of the "Forwek Mitte" factory a stand for engine test firings was restored and reequipped.

German specialists also worked with our experts: 20 doctors and graduated engineers, 11 technicians and foremen, and 24 qualified workers. But as V. P. Glushko remarked, there was no one among them that had played an appreciable role in the development of the engine, so the staff involved was not suitable for independent work.

The experience of German missile manufacturing had shown that for the practical use of powerful rocket engineering it was insufficient to only manufacture the missiles. The rocket industry needed wide cooperation to obtain the necessary advanced infrastructure, large ground complexes, and well organized personnel.

V. P. Glushko stated the result of the work by the OKB experts in a report addressed to the chairman of the Special Government Commission in Germany.

In this report, alongside his statement about the work done by his team, he stated the concept of rocket engine development organization in the U.S.S.R.

A little outside the historical sequence of events, it is possible to ascertain that the offered concept, or more correctly the program of organization for the basic scientific-industrial centers, was executed. Not all was accomplished at once, but all was realized in the end. And it displayed the skill of V. P. Glushko to think broadly about a subject, recognizing the germination of the prospect to develop a large business.

A study of the military engineering and organization of that industry at the state level gives the results. The combat experience in the final phase of the Second World War, the acquaintance with the trophy air and rocket engineering products, and the work of the domestic experts in the field of rocket engines showed that technical progress hinged on a new strand of development—propulsion engineering.

This ushers in the era of jet aircraft and long range rockets.

It was a period in the history of domestic science and engineering development when the development of propulsion engineering became an important state task, and when the scientific and technical base of the future space rocket branch was created. The beginning of this process was established by a pronouncement regarding a decision of the government of the U.S.S.R. in May 1946 about the development of propulsion engineering in our country. To realize this decision, the Minister of the air industry in July 1946 released an order to change the profile of an aircraft factory in Khimky of the Moscow region to rocket engine manufacturing. In September 1946 there was an order of the government of the U.S.S.R. regarding the transfer of the OKB led by V. P. Glushko from Kazan to Khimky.

The factory in Khimky was organized in 1932 for the assembly and repair of Aeroflot airplanes. In the beginning of the war with Germany in October 1941, the factory was evacuated to Tashkent, Uzbekistan. In the reserved industrial area using equipment that had been evacuated, repair shops were organized, and in 1942 this became a factory to repair aircraft from the front.

At the time the OKB was transferred back to Kazan from Khimky—November 1946—there was an absence of heating and electric power at the factory. Shops had been trashed, and there were no rooms suitable for the accommodation of the design bureau and for test laboratories. There were also not enough personnel: the collectives of the OKB and the factory were small for the task put to them.

The task can be stated as follows:

- on the basis of the trophy drawings to issue a complete set of the design documentation and to organize for the manufacture of A-4 missile engines;
- to master the technology used in manufacturing and testing the rocket engines for the further development of rocket engineering;
- to create a research-and-production base and create collectives to design, manufacture, and test powerful liquid propellant rocket engines for rockets.

According to the decisions of state bodies, the equipment of the OKB from Kazan and from Germany (the "Montania" factory and the test station at Leehsten) were received at the factory in Khimky. Simultaneously with the equipment from Germany the components of a German-manufactured A-4 engine and a complete set of the design documentation collected in Germany by the OKB experts were received.

From the second half of 1946, on at the reorganized industrial base in Khimky, the intensive work on the creation of the enterprise for the full development cycle—designing, manufacturing, and testing of rocket engines—was begun.

Design departments reissued the drawings in conformity to domestic standards, translating the textual part into Russian. The basic difficulty involved in the reissue of the drawings was the correct replacement of the types of materials used by the Germans with domestic ones. For this purpose chemical analyses of materials were carried out and similar materials were found, although this was not always possible.

Our technologists, on the basis of German technologies, developed technologies for the manufacturing of units, components, and the assemblage of the A-4 engine. The missing technological equipment was designed and produced simultaneously.

The specialists of the test divisions had designed stands for cold and firing tests of the components and of the engine as a whole. These stands needed to be constructed and put in order for the realization of the tests.

Appreciable help in mastering the A-4 engine was rendered by the German experts, which were directed to work in the OKB. Twenty-three experts (there were 65 persons altogether with the members of their families) participated in the work at Khimky. There were designers and engineers on tests, and foremen on engine assembly, test equipment, and welding. Ten persons had completed their higher education, while others had not completed their higher education or had only an average technical education. In 1947, and in the first half of 1948, they worked in the positions of assistant to the production chief, lead engineer, chief of oxygen manufacture, assistants to the shop chiefs, assistant to the test station chief, and foremen. They were acquainted with all documents necessary for their work. As they were concerned to work honestly and with discipline, our experts drew on their technical erudition. V. P. Glushko said the task put before them—to help us master trophy engineering and to organize pilot production—was decided satisfactorily and they brought doubtless benefit. But there were remarks about some German experts, which concerned how their reluctant, even lazy work broke with labor discipline.

In household relations the Germans were arranged quite well. They settled in the first houses constructed near the factory in Khimky. They had good salaries: in 1948 the monthly salary of V. P. Glushko was 6000 rubles, his first deputy made 4000 rubles, and Osvald Putze, the assistant to the production manager, received 5000 rubles. The German experts had the opportunity to transfer money to their relatives in Germany, and they had an annual holiday, etc.

In the second half of 1948, when work at the OKB on further modifications of the A-4 engine was conducted, the German experts were transferred to conduct auxiliary minor work, and at the end of 1950 they were returned to Germany. The return was carried out in an organized manner: railway cars were provided especially for them, and the necessary monetary resources were provided.

Simultaneously, with the creation of the manufacturing and technological base at Khimky, work on rocket engine manufacture was conducted.

The technique of consecutive achievements was used as the basis for mastering trophy rocket engineering, and the creations from this basis for further variants of engines and rockets had perfect characteristics.

So the realization of the experimental launch of two sets of A-4 rockets assembled in Germany and in the U.S.S.R. from German hardware with technology restored by the Soviet experts was the first phase of such activity. In September-October of 1947 11 launches of rockets were carried out, but only 5 of them were successful. The malfunctioning of engines, control systems, and other defects were the reasons for these failures.

During the following phase, engine manufacturing was conducted according to drawings adapted for domestic manufacturing using domestic materials with the realization of stand and flight tests of R-1 rockets (the A-4 rocket of domestic manufacture). The RD-100 engine—a copy of the German engine—made in Khimky from domestic materials was installed on this rocket. The first set of such rockets was made at the end of 1947; the first firing at the Khimky test facilities was in May of 1948, and flight tests of the R-1 rockets were carried out in September-November of 1948. The results of the launch of the first set of 9 R-1 rockets were extremely unsuccessful—only one rocket hit its target. Such results required the realization of additional improvements in the RD-100 engine, during which a number of changes were incorporated into its design: in the chamber the design of the oxidizer injectors was improved, in the

TPU a change in the design of the vane device was implemented, the replacement of materials on a number of parts was carried out, and new protective coatings were utilized. For the elimination of "claps" at the start, the pyrotechnic ignition was replaced with a liquid ignition device.

After the elimination of defects in the workings of all systems, the R-1 rocket successfully passed a flight test and was accepted into operation.

At the same time the factory and the OKB continued to increase their industrial opportunities. At the factory new shops were built, new machine tools and equipment were mounted, and the departments of the chief technologist and chief metallurgist became stronger because of the new specialists. In the structure of the OKB the pilot production division of a few shops was organized. Its tasks were to conduct the manufacturing of experimental engines, and to fulfill the technologies of manufacturing the new design engine components. At the beginning of 1948, the first new buildings for the test facilities were constructed: in May the first fire stand for tests of engines was put into operation; the laboratories for "cold" tests of components and units had come into operation at the same time.

The first state order was executed, but even during its fulfillment the development of the following RD-101 engine for the R-2 rocket with an increase of a doubled flight range of 600 km was begun, to be ensured by an increase of the engine thrust.

The research on engine performance stocks had shown that it could ensure a required thrust of 37 tons with a specific impulse of 210 sec at sea level. The carried out modernization of the base design had allowed the creation of the RD-101 engine, with the total weight reduced 1.4 times, the quantity of automatic units was reduced from 26 to 20, the TPU capacity was forced up to 1000 h.p. instead of 540 h.p., a solid catalyst weighing 3 kg was used instead of the liquid catalyst weighing 14 kg, and perfected pneumohydraulic and electrical engine schematics were used.

The test stand development of the RD-101 engine was carried out in 1948-1950. Flight tests of the engine in the structure of an R-2 rocket were carried out in various phases, and the rocket was accepted into operation in 1952.

The work on the creation of the RD-101 engine and the R-2 rocket can be related already to the first success of domestic rocket engineering. The modernized rocket had a doubled flight range and increased accuracy for hitting a target resulting from the engine's two-step shutdown. Engine reliability was increased noticeably in comparison with the base design of the A-4.

Work on the further improvement of the rocket's range was not terminated. Greater modernization was carried out which resulted in the creation of a new R-5 rocket with the RD-103 engine. To provide a rocket flight range of 1200 km, the engine was forced up to a thrust of 44 tons at sea level and up to 51 tons in the upper layers of the atmosphere. This was provided by the installation of a special uncooled steel extension section with the lining of the internal surface with graphite tiles on the chamber nozzle. The thrust increase was ensured with a pressure increase in the chamber and an increase in TPU revolutions. All of this required an increase in the safety factors of the units and better chamber cooling. The use of a pump feed of hydrogen peroxide instead of a pressure feed was an essential achievement, and resulted in the replacement of a heavy steel tank with a pressure of 50 atm with a light aluminum one with a pressure of 3.5 atm. Significant changes were made in the TPU and automatic control units, and thrust throttling of the engine in flight was added.

The changes to the RD-103 engine were so marked that it resembled its forefather (the A-4 engine) only in its external shape, and thus represented a new development resulting from the efforts of the domestic specialists in relation to parameters and characteristics. And the whole R-5 rocket became qualitatively a new stage in the development of ballistic rockets—the first strategic rocket for delivering a nuclear charge to a distance up to 1200 km.

The high reliability of all rocket systems allowed us in February of 1956 to successfully carry out an experimental launch with a nuclear charge.

In the beginning of the 1950s an attempt to create an engine with a thrust of 100 tons on the basis of the German design by the scale increase of the sizes of the chamber and other components was not crowned with success. With the development of the modernized RD-103 engine, the resources and opportunities of the base design A-4 engine had run out.

The military-political conditions of those years required the creation of a ballistic rocket capable of delivering a nuclear warhead at a distance of 8,000 to 10,000 km. The development of such a rocket was assigned to the OKB led by S. P. Korolev; the engines were entrusted to be developed at the OKB of V. P. Glushko.

For the new intercontinental rocket, liquid oxygen and kerosene were chosen as the propellant. The accepted parameters of the engine and the use of kerosene as a fuel required decisions along a line of new technical questions, among them:

- How to master kerosene, having a greater heat capacity, but a lower cooling ability than alcohol;
- How to provide the greatest possible pressure of gases in the chamber for an increase of the gases' expansion, since a decrease of pressure on the nozzle exit results in an increase of the dimension and weight of the chamber;
- How to provide a high quality of the propellant components mixing in the chamber for a combustion rate close to 100%.

The correct answer to the specified questions required the creation of a new chamber design having serviceability under more extreme conditions than in the chamber of the RD-100 engine and its modernized variants.

Development of a chamber design for the new rocket (which received the designation R-7) was not begun in a vacuum. First, there was the experience gained through the development and firing tests of the engines of the ORM family and the RD-1, RD-2, and RD-3, working with kerosene, and the RD-100, RD-101, and RD-103 engines, which worked with liquid oxygen. Second, at the beginning of the design period for the new rocket there were available techniques of analysis developed over 30-40 years relating to thermodynamics and the cooling of the chamber, the gas dynamic profile of the nozzle, the gas dynamics and hydraulics of the turbopump unit, and the safety factor criteria for the designs. Design experience was also available since during the work on mastering the A-4 engine and the manufacture of its modernized variants, the OKB under the management of V. P. Glushko had continued work on chamber design on the basis of domestic development.

The KS-50 chamber ("Lilliputian") developed in 1948 was the first in a line of experimental chambers. The flat fire bottom of the injector head, the walls of the chamber, and the nozzle were made of copper, thus the walls were brazed on the tops of the milling ribs to the steel case of the chamber. It was the first design of a chamber with a high heat conductive wall having a strong brazed connection with the forged case of the chamber. The development of a brazed package of an internal wall with a forged case was a real revolution in rocket engine engineering. It allowed for the creation of engines practically without any restriction on the pressure in the chamber; this raises the efficiency of liquid propellant rocket engines ten-fold.

The second experimental design of a chamber, which as a matter of fact was transitive to the design of the chambers for the R-7 rocket engines, was developed and tested in 1949. It was the experimental AD-140 chamber, with a thrust of up to 7 tons. It had a flat injector head and a cylindrical combustion chamber. The various injector elements and injector head designs were tested on this chamber. The bipropellant injector elements were chosen due to a complex of characteristics: the specific impulse of thrust, steady combustion, and the adaptability of the design manufacture. Their characteristics and location schematics were optimized. All the design and experimental experience was incorporated with the AD-140 regarding belts for internal cooling with a tangential swirling of the coolant (i.e. film cooling). At the same time the injector head was developed, in which the flat bottom is connected by means of punched cylindrical shells to the forged outside bottom of the spherical form.

After mastering the technology of manufacturing the basic elements of the chamber and the other components of the engine through work on experimental samples, we were confronted with the problem of ensuring highly reliable stability for combustion in a large-diameter cylindrical chamber with a flat injector head in the firing tests of a full-size engine of a single-chamber variant. The continuing attempts to create a single-chamber engine with a thrust of 60-70 tons were not crowned with success. The development of a four-chamber engine with the same thrust was a brilliant decision to solve this problem. Chambers of this engine had a cylindrical part with a smaller diameter; this has essentially simplified the task of ensuring the highly reliable stability of the combustion. With this purpose of achieving stability during the combustion process for the main mode of engine operation, the optimum differences in pressure at the injector elements and the propellant mixture ratio in the boundary layer of combustion were determined experimentally. The highly reliable stability at ignition was ensured by special schematic design measures for acceleration at ignition.

As a result of the intense development work sometimes accompanying engine failures at test stands and at various rocket staging areas, the RD-107 and RD-108 engines of the first and second stages of the R-7, which was a prototype of the Vostok, Voskhod, Molnia, and Soyuz launch vehicle family, were developed and handed over for operation. Due to these engines, entry into space became possible, especially the first Earth satellite in 1957, and the first man in space in 1961. Up to the present day the Russian space program uses updated variants of these engines.

The deafening thunder of RD-107 and RD-108 engines in operation announced to all the world that the enterprise to develop liquid propellant rocket engines for the Russian Federation was done by NPO-Energomash and worked successfully. In a special message to the American Congress on May 25, 1961, President Kennedy said that the Soviet Union had pioneered space exploration because it had high thrust engines, and it had been precisely that factor that put the Soviet Union in the lead.

Since then all Russian space rockets have used engines developed by NPO-Energomash. Indeed, all of the first stage engines and about 60-70% of all second stage engines are from NPO-Energomash.

Today, NPO-Energomash, named after academician V. P. Glushko, looks confidently towards the future: the development of the RD-180 engine for the Lockheed-Martin Atlas 2AR is being conducted under contract with Pratt& Whitney, tests of experimental rigs using a tripropellant engine concept are continuing, the development of engines using natural gas, and a number of other projects are being conducted.

NPO-Energomash, the leading Russian enterprise for the development of liquid rocket engines, continues to create history.