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Инновационные технические решения, разработанные под руководством М. Ф. Решетнева при создании первой сибирской ракеты-носителя «Космос-3М»

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Академик Михаил Федорович Решетнев входит в число выдающихся ученых, конструкторов и организаторов производства, которые стояли у истоков развития ракетно-космической техники в нашей стране и внесли значительный вклад в отечественную и мировую космонавтику. В 2024 г. исполняется 100 лет со дня его рождения и 60 лет первого запуска ракеты-носителя (РН) «Космос-3», созданной под его руководством в Красноярском крае.

В статье рассматриваются основные этапы проектирования, опытно-конструкторской отработки, летно-конструкторских испытаний и выхода на серийное производство ракеты. Отмечается, что создание РН осуществлялось, в основном, на производственной базе Красноярского машиностроительного завода. В хронологической последовательности описываются наиболее крупные события, связанные с организацией работы филиала ОКБ-1, который затем был преобразован в самостоятельное ОКБ. Показана роль личности М. Ф. Решетнева в решении сложных научно-технических, организационных и производственных проблем освоения новой техники в Сибирском регионе, удаленном от ракетно-космических и научных центров страны.

Представлена информация о инновационных технических решениях, разработанных под руководством М. Ф. Решетнева при создании РН «Космос-3» и её последующей модификации. Отмечается, что М. Ф. Решетнев в своей научно-технической деятельности постоянно получал поддержку С. П. Королева и М. К. Янгеля, успешно сотрудничал с крупнейшими конструкторскими организациями, которые возглавляли В. П. Глушко, А. М. Исаев, В. Г. Сергеев и другие известные руководители и специалисты ракетно-космической промышленности.

Ключевые слова: ракетно-космическая техника, ракеты-носители, космические аппараты.

Innovative technical solutions developed under the leadership of M. F. Reshetnev in the creation of the first Siberian launcher "Cosmos-3M"

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Academician Mikhail Fedorovich Reshetnev is one of the outstanding scientists, designers and production organizers who stood at the origins of the development of rocket and space technology in our country and made a significant contribution to domestic and world cosmonautics. 2024 marks the 100th anniversary of his birth and the 60th anniversary of the first launch of the Kosmos-3 launch vehicle (LV), created under his leadership in the Krasnoyarsk Territory.

The article discusses the main stages of design, development work, flight design tests and the launch of mass production of the rocket. It is noted that the creation of the PH was carried out mainly at the production base of the Krasnoyarsk Machine-Building Plant (Krasmash). The most important events related to the organization of the OKB-1 branch, which was then transformed into an independent OKB, are described in chronological order. The role of M. F. Reshetnev's personality is shown. Reshetnev in solving complex scientific, technical, organizational and production problems of mastering new technology in the Siberian region, remote from the rocket, space and scientific centers of the country.

Information is provided on innovative technical solutions developed under the guidance of M. F. Reshetnev during the creation of the Kosmos-3 launch vehicle and its subsequent modification. It is noted that M. F. Reshetnev in his scientific and technical activities constantly received the support of S. P. Korolev and M. K. Yangel, successfully cooperated with the largest design organizations headed by V. P. Glushko, A. M. Isaev, V. G. Sergeev and other well-known leaders and specialists of the rocket and space industry.

Keywords: rocket and space technology, launch vehicles, spacecraft.

Introduction

November 2024 marks the 100th anniversary of the birth of academician Mikhail Fedorovich Reshetnev, chief designer of rocket and space communication, navigation, and geodesy systems, Hero of Socialist Labor, laureate of the Lenin and State Prizes, and founder of the Siberian scientific school in space technology. The life and work of M. F. Reshetnev were filled with bright and unusual events. After graduating with honors from secondary school in Dnepropetrovsk in 1940, he entered the Moscow Aviation Institute (MAI) at the age of just 16. His studies at MAI were interrupted by the war. Due to his age, Reshetnev was not subject to conscription into the Red Army, but he voluntarily went to the military enlistment office and was sent to a military school for aircraft mechanics. After graduating, he served as a mechanic in a fighter aviation regiment, preparing aircraft for combat missions until 1945. In 1945, he resumed his studies at MAI, actively combining his academic work with sports and student research.

M. F. Reshetnev's diploma project focused on the development of liquid-fuel jet engines for fighter aircraft. The Chairman of the State Examination Commission, the head of OKB-301, and the renowned Soviet aircraft designer S. A. Lavochkin, highly praised Reshetnev's work. The excellent grade earned him the right to choose his place of employment. Lavochkin advised him to join S. P. Korolev's team.

Thus, after graduating with honors and earning a degree in mechanical engineering with a specialization in aircraft construction, Mikhail Reshetnev began his career at OKB-1 in 1950 under the leadership of S. P. Korolev. It was here that his engineering expertise, organizational skills, and distinctive personal qualities, such as a high sense of responsibility, dedication, and integrity, became evident. These attributes helped Reshetnev rise to become one of the leading designers of missile systems with mobile launch capabilities and eventually led to his promotion to deputy chief designer.

The rapid development of the USSR's rocket and space industry in the mid-20th century led to the involvement of several mechanical engineering and instrumentation enterprises located in the Siberian region in this emerging sector of the economy. On June 4, 1959, the State Committee for Defense Technology issued an order to establish a branch of OKB-1 at Production Site No. 2 of the Krasnoyarsk Machine-Building Plant (Krasmash), located in the closed city of Krasnoyarsk-26 (now the closed administrative-territorial entity of Zheleznogorsk, Krasnoyarsk Territory). By the same order, M. F. Reshetnev, a 34-year-old Candidate of Technical Sciences and deputy to S. P. Korolev, was appointed head and chief designer of the OKB-1 branch.

The main task of the branch was to provide design support for the serial production of ballistic missiles, which were being developed under the leadership of S. P. Korolev at OKB-1. Initially, government decisions stipulated that the production of the 8K74 (R-7A) missile would be launched at the main site of the Krasmash plant in Krasnoyarsk and at Site No. 2 in Krasnoyarsk-26. Then, in 1960, the plant and the OKB branch were relieved of developing this missile and began preparing for the production of the two-stage 8K75 missile, also developed at OKB-1 under S. P. Korolev. However, already in 1961, the production plans of the enterprise and the design organization of M. F. Reshetnev changed again. According to a Resolution of the Central Committee of the CPSU and the Council of Ministers of the USSR dated April 7, 1961, No. 314-135, the Krasmash plant was instructed to master the production of the R-14 (8K65) missile [1–3].

Such rapid changes in large-scale state planning can be explained by the dynamic development of the defense industry, the formation of a new structure of the rocket and space industry, the emergence of new scientific and design ideas, and the strengthening of the technological base of enterprises involved in the creation of new technology.

Organization of production of the R-14 ballistic missile

The single-stage ballistic missile R-14 (8K65) was developed in 1960 at OKB-586 (Yuzhnoye Design Bureau, Dnipropetrovsk) under the leadership of Chief Designer M. K. Yangel. The missile was classified as a medium-range strategic ballistic missile. Its maximum flight range was 4,500 km, with a launch weight of up to 85 tons and a warhead weight of up to 1.5 tons. The missile's length was 24.4 meters, and its maximum body diameter was 2.4 meters. It was equipped with a monoblock nuclear warhead that separated at a specified point in the flight trajectory. The missile featured an autonomous inertial guidance system.

The missile was equipped with the 8D514 engine, developed at OKB-456 (NPO Energomash) under the leadership of Chief Designer V. P. Glushko. The 8D514 engine consisted of two two-chamber units, the 8D513, which ran on hypergolic propellants: the fuel was unsymmetrical dimethylhydrazine (UDMH), and the oxidizer was a mixture of nitric acid and nitrogen tetroxide (AK-27I).

In mid-1961, the design documentation for the missile was transferred from Dnipropetrovsk to Krasnoyarsk and Krasnoyarsk-26, and simultaneously, the technological preparation for production began at both plant sites.

In light of the new tasks related to the production of the 8K65 missile in Krasnoyarsk, it became clear that there was a need to elevate the status of the OKB-1 branch. Therefore, on December 18, 1961, by order of the State Committee for Defense Technology, the branch was reorganized into an independent design bureau, OKB-10 (Design Bureau of Applied Mechanics). M. F. Reshetnev was appointed as the Chief Designer, with N. F. Kupriyanov (responsible for airframe designs) and A. Ya. Kitaev (responsible for propulsion systems) as his deputies.

By the end of 1961, the missile had completed experimental design and production testing at the Yuzhnoye Machine-Building Plant in Dnipropetrovsk. However, it was still necessary to adapt the design and technological documentation to the production conditions at the Krasnoyarsk Machine-Building Plant, which had previously been involved in the manufacture of anti-aircraft artillery. During the production preparation of the 8K65 missile, new manufacturing facilities were put into operation at the plant, and more than 16,000 types of technological tooling were produced. A new workshop was created for the manufacture of the gyrostabilized "Korund" platform, which was mounted on an air-bearing suspension along the precession axis of the gyroscopes and included a separate electronic unit and gyro-integrator.

The construction and commissioning of the testing complex for conducting static fire tests of liquid rocket engines presented particular challenges. The construction work was carried out by the military construction organization "Sibkhimstroy", headed by the renowned military engineer, Hero of Socialist Labor, Lenin Prize laureate, Major General P. T. Shtefan. The unique terrain of the Eastern Sayans allowed for the construction of massive test stands on the edge of a mountain-taiga gorge, which made it possible to conduct static fire tests of the rocket engines in a vertical position, fully simulating the launch conditions of the missile.

The construction of the testing complex was carried out around the clock with a large-scale effort, under the supervision of the leadership of the defense industry. Simultaneously, test stands, energy facilities, rocket fuel component storage warehouses, and an industrial wastewater neutralization station were being built. During the commissioning and adjustment work, significant assistance was provided by the leading enterprise in the field of rocket technology testing – the Research Institute of Chemical Engineering (NIIKhM) in Zagorsk.

The first static test of the 8D513 engine (a two-chamber unit of the 8D514 engine) took place on February 28, 1962. The engine met the required technical specifications, and the test stand systems functioned properly. It is noteworthy that the initial test report for the engine was signed by V. I. Novikov, the head of the calculation and analytical sector, who later became a Candidate of Technical Sciences and the head of the M-2 department at the Krasnoyarsk Institute of Engineering (now the Department of Aircraft Engine Engineering at the Siberian State University of Science and Technology named after academician M. F. Reshetnev).

In the first half of 1962, the first test launches of the 8K65 missiles, assembled at Site No. 2 of the Krasnoyarsk Machine-Building Plant with partial components and assemblies produced at the Yuzhmash plant, were conducted at the Kapustin Yar test range. Throughout 1962, Krasmash, in cooperation with OKB-10, fully mastered the production of the R-14 (8K65) missile. The regular delivery of missiles to military units began.

The serial production of these missiles continued at the plant until 1965. For a long time, the R-14 missile systems were on combat duty. The last six missile systems were decommissioned in the late 1980s.

Creation of the launch vehicle Kosmos-3

In October 1961, a resolution was adopted by the Central Committee of the Communist Party of the Soviet Union (CPSU) and the Council of Ministers of the USSR to develop a launch vehicle for placing small and medium-weight spacecraft into circular and elliptical orbits, in the interests of both the national economy and defense. In the initial documents from the governing bodies, the rocket complex and launch vehicle were assigned the index 65S3, which was later transformed into the more commonly used index in the rocket and space industry, 11K65 ("Kosmos-3").

The preliminary design of the rocket was developed at the "Yuzhnoye" Design Bureau under the leadership of the chief designer, academician M. K. Yangel. The designers proposed creating a new rocket based on the military ballistic missile R-14 (8K65). This proposal allowed for a significant reduction in the design and testing timelines, as well as a decrease in the economic costs associated with creating a new rocket and space complex.

Due to the heavy workload of his design organization with other critical state tasks, M. K. Yangel suggested transferring the rocket's design work to Krasnoyarsk OKB-10, led by M. F. Reshetnev, and designating the Krasnoyarsk Machine-Building Plant as the lead enterprise for its development and production. This proposal was likely motivated by the successful experience of collaboration between OKB-10 and the Krasmash plant during the serial production of the R-14 (8K65) missile. It is also important to note that during this period, specialists from the Yuzhnoye Design Bureau and the Yuzhnoye Machine-Building Plant (Dnipropetrovsk) provided active support to their Krasnoyarsk colleagues. Several specialists from Yuzhmash were sent to work permanently at Krasmash.

The design documentation for the new rocket, at the preliminary design stage, was transferred to OKB-10 for the completion of the project and the development of the working design documentation. Overall supervision of the project was entrusted to academician M. K. Yangel.

The technical assignment for the development of the 11K65 launch vehicle defined its functional purpose: to launch various artificial Earth satellites with masses ranging from 100 to 1500 kg onto circular orbits with altitudes between 200 and 2000 km and elliptical orbits with a high apogee. To achieve this complex technical task, it was necessary to create a propulsion system and rocket engine capable of multiple firings in space and stabilizing the rocket during flight between these firings.

The multifunctional rocket engine with the index 11D47 for the second stage of the rocket was developed in OKB-2 (KB Khimmash) under the leadership of chief designer A. M. Isaev, who was widely known in the rocket and space industry for his original innovative design solutions and the high level of technology of the engines created in KBKhM.

The 11D47 liquid rocket engine is a single-use engine that operates on a two-component hypergolic propellant (NDMH + AK27I). The engine generates thrust along the axis of the rocket, as well as the lateral forces and moments required for controlling the rocket. Thrust is generated by the expulsion of combustion products from the combustion chamber through four gimbaled nozzles, whose design allows them to pivot in a single plane, thereby enabling control of the rocket's pitch, yaw, and roll angles. The engine is designed for two separate burn phases during the main cruise modes, generating a thrust of up to 15.7 tons (157 kN). The duration of the first mode (Mode I-2) is 360 seconds, while the second mode (Mode I-6) lasts for 15 seconds. Before reaching the first cruise mode, the engine operates in a low-thrust start mode for 2 to 10 seconds, generating 5.8 tons (58 kN) of thrust, ensuring smooth separation from the first stage and a seamless transition to the main cruise mode.

Through the collaborative efforts of A. M. Isaev's design bureau and M. F. Reshetnev's OKB, a low-thrust system was developed for the second stage engine, ensuring stabilized flight between the two burn phases. The fuel for the stabilized flight mode was stored in two special tanks located on the outer surface of the main tank of the second stage. Thus, the dual-impulse configuration of the main engine allowed the task of placing an artificial Earth satellite into orbit to be completed in two stages: the first engine burn creates an elliptical trajectory, and at the apogee, the second burn places the satellite into a circular orbit. This launch scheme significantly improved the energy efficiency of the launch vehicle.

The technical assignment for the development of the missile system opened up opportunities for upgrading the rocket, including during the experimental design phase. Therefore, alongside the preparation of the design documentation for the 11K65 system, work was underway on the development of an upgraded version – 11K65M – which was planned for experimental operation after the initial flight and design tests of the first version of the missile. Simultaneously, on the main site and at site No. 2 of the Krasnoyarsk Machine-Building Plant, technological preparation for production was being carried out at an accelerated pace, along with the development of a large volume of technological documentation [4–6].

The task of designing and producing a new launch vehicle required OKB-10 and the main enterprise to develop and master fundamentally new design solutions, progressive production technologies, and highly organized joint work. The main ones were:

– design and manufacture of large-sized, thin-walled tank structures made of aluminum alloys, welded using automatic welding;

– manufacturing of large-sized riveted structures;

– ensuring a high degree of tightness of structures and tightness control with a high degree of reliability;

– development and production of durable and hermetic housings from aluminum alloys.

A special calculation team was formed at OKB-10 to conduct ballistic calculations of the orbits of spacecraft and the flight paths of carrier rockets. Due to the lack of its own computational resources at that time, the calculations were carried out at the Computing Center of the Siberian Branch of the USSR Academy of Sciences (Novosibirsk). The ballistic programs developed during this period later ensured high accuracy in tracking the movement and determining the coordinates of satellites at any given moment in time.

The guidance system for the 11K65 rocket was developed by the Kharkiv Design Bureau under the leadership of V. G. Sergeev. A key feature of this system was the use of computing and decision-making devices, as well as new principles for launching the rocket. Additionally, the system included an automatic self-checking function that eliminated the need for operator involvement during the verification process.

In order to ensure the required reliability of the guidance system during flight, the chief designer implemented a "triplication" of the system. By that time, a system for interacting with suppliers of component parts had been established, along with the organization of failure analysis and systematization, as well as a procedure for developing measures to prevent their recurrence.

In the first half of 1963, as a result of intense collaborative work between the teams at OKB-2, OKB-10, and the Krasmash, dimensional and weight prototype models were created, followed by full-scale experimental samples of the 11D47 engines, which incorporated the small-thrust system as a standard feature. At the same time, the testing complex at the Chemical Plant underwent reconstruction of Test Stand No. 1, adapting it for the firing tests of the new engine.

The first test of the engine was conducted on the stand in August 1963. Due to the complexity of the test program and its duration, it remains unparalleled for liquid rocket engines to this day. The development of the engine's operating modes, the sequence, and the precision of the commands during the execution of the test program took a considerable amount of time. However, by the beginning of 1964, the developers of the engine and the rocket concluded that the 11D47 engine could be installed in the second stage of the rocket for flight design testing [7–9].

In May 1964, two 11K65 rockets were transported from Krasnoyarsk-26 to Baikonur. The rockets were equipped with 8D514 engines (first stage) and 11D47 engines (second stage). The payload of the carrier consisted of three models of artificial Earth satellites – Kosmos-38, Kosmos-39, and Kosmos-40 (of the Strela-1 type) with radio transmitters installed for monitoring the launch and operation in orbit. After completing the preparatory and assembly testing work, the rocket was transported to the launch pad (site 41).

The first launch of the 11K65 carrier rocket took place on August 18, 1964. A report from the Soviet News Agency (TASS) about the event stated that all three satellites were successfully placed into orbit by a single new-type carrier rocket. The satellites were placed on nearly identical orbits with initial parameters as follows:

– orbital period 95.2 min;

– maximum distance from the Earth's surface (at apogee) 876 km;

– minimum (at perigee) – 210 km.

Thus, the first Siberian carrier rocket was launched into space. It is profoundly symbolic that in 2024, we celebrate both the 100th anniversary of M. F. Reshetnev's birth and the 60th anniversary of the first launch of the space rocket developed under his leadership.

According to published information, several more launches of the 11K65 carrier rocket took place in 1964–1965, during which groups of three Strela-1 satellites were launched into orbit, with indices such as Kosmos 54-56, Kosmos 61-63, and others. The Strela-1 spacecraft was designed as a non-orientable, small-sized satellite weighing 50 kg, equipped with a relay operating in electronic mail mode. It simultaneously performed the functions of transmitting telemetry data on the status of the spacecraft's onboard systems to Earth and receiving control commands from the ground.

The satellite was developed at OKB-586 (Yuzhnoye Design Bureau) under the leadership of M. K. Yangel as part of the 65C3 rocket and space complex, designed as a special communications spacecraft for the security and defense systems of the state. During the R&D phase, at M. K. Yangel's initiative, the order for the satellite's development was transferred to OKB-10 under M. F. Reshetnev, and it was further designed and technologically refined at the production facilities of the Krasnoyarsk Machine Building Plant. Later, its mass production was organized at OKB-10's own industrial base (Mechanical Plant), which was established in the late 1960s.

Modernization of the 11K65 launch vehicle, creation of the Kosmos-3M launch vehicle

Modifications introduced during the rocket's modernization process led to changes in the designation of both the engines and the entire rocket. Regarding the first-stage engine, operational adjustments included removing the engine's functionality at the final flight phase (62% of nominal chamber pressure), adding requirements for operational capability across a temperature range of -40 to +50 °C due to launches from open sites, and incorporating a telemetry measurement system for in-flight monitoring. This engine was then designated RD-216M (11D614) [10].

The second-stage engine, designated 11D49, underwent modernization of specific components within its automatic control system, along with adjustments to operational parameters during flight. These enhancements were implemented to achieve the necessary precision for placing spacecraft into their designated orbits.

One of the distinctive features of the 11D49 engine was its use of non-detachable (welded) joints for structural components, which eliminated the need for stand-based quality and technical testing (QTT) of each rocket engine followed by disassembly. Instead, the engine's operability and reliability were assessed through results from selective fire tests (SFT). Additionally, specialized periodic testing (SPT) was conducted under conditions closely approximating operational scenarios. This approach allowed for monitoring of the manufacturing process stability and periodic reliability checks of the engine under challenging combinations of structural and technological factors.

During the development of the 11D49 engine, the designers at OKB-2 (KB Khimmash) led by A. M. Isaev introduced innovative (for that time) technical solutions that significantly enhanced the engine's energy efficiency and functional effectiveness. For instance, much of the supersonic nozzle lacked an external jacket. Instead, a set of corrugated sections was soldered to the nozzle's heat wall, forming an internal cooling channel within the corrugations. This design reduced the number of soldered joints by half and decreased the use of expensive heat-resistant solder. However, it imposed strict requirements for the preservation of the thin-walled chamber structure during in-plant handling and transportation. One of the authors of this article, V.P. Nazarov, who worked at that time as an assistant test engineer at the Krasmash plant, was involved in refining the technology for strength and leak testing of the chamber, utilizing special protective devices to shield the structure from mechanical damage.

To reduce the axial dimensions of the engine chamber, a radial oxidizer feed into the mixing head was employed. This design incorporated additional components to ensure the even distribution of oxidizer in the cavity between the head's endplates. Plate-like anti-pulsation baffles were installed on the combustion-facing side of the head, a feature that was in the experimental phase in rocket engine design at that time.

The turbopump assembly (TPA) featured a single-rotor, single-shaft configuration with a cantilever-mounted turbine, positioned in the critical section of the rocket engine's chamber for a compact engine layout. The gas turbine disk was manufactured from a heat-resistant chrome-nickel alloy, with symmetrically profiled blades formed using electro-erosion machining. To enhance turbine efficiency, a thin segmented band (up to 2 mm thick) was installed and vacuum-brazed onto the blade tips along the outer edge of the disk.

The centrifugal impellers for the oxidizer and fuel were made from high-strength aluminum alloy and comprised three parts: a front disk, a rear disk, and a central hub with machined blades. These components were joined by vacuum brazing in an induction chamber furnace.

Due to the complex operational cycle of the engine and the resulting changes in the operating parameters of the turbopump assembly (TPA) across a wide range of functional metrics, stringent requirements were applied to the sealing of the gas-hydraulic channels within the assembly. To meet these demands, the fuel and oxidizer pumps, as well as the gas turbine unit, were equipped with a combination of seals. These included contact-type seals (such as gaskets and face seals with non-metallic contact rings) and non-contact static and hydrodynamic seals (floating rings and radial impellers). The coordinated interaction of all elements within this sealing system combination provided enhanced reliability and airtightness of the assembly.

According to E. N. Golovyonkin, one of the article's authors who worked as a design engineer at OKB-10 during that period, the collaboration among specialists from OKB-2, OKB-10, and the Krasmash plant was conducted at a high professional level in a creative, business-oriented atmosphere. OKB-2's Chief Designer, A. M. Isaev, visited Krasnoyarsk multiple times, meeting with M. F. Reshetnev and Krasmash Plant Director P. A. Sysoev, which facilitated the prompt resolution of numerous technical and organizational issues.

It should be noted that numerous innovative design and technological solutions, developed and implemented through the collaborative efforts of OKB-2, OKB-10, and the Krasnoyarsk Machine-Building Plant in the creation and production of the 11D49 rocket engine, contributed significantly to advancements in rocket engine technology. These innovations were successfully applied in subsequent rocket and space projects, providing valuable scientific and technological contributions to the field. The specifications of the propulsion systems for the stages of the Kosmos-3M launch vehicle are presented in a Table 1.

Table 1

The specifications of the propulsion systems for the stages of the Kosmos-3M launch vehicle

Parameters		
Stage	First	Second
Engine	RD-216 (11D614)	11D49
Type	Four-chamber liquid rocket engine (two two-chamber blocks)	Single-chamber liquid rocket engine + 4 control nozzles
Thrust, kgf (kN): at sea level in vacuum	 151 000 (1 481) 177 400 (1 740)	– 16 060 + 4 × (1.4–1.8) (157.6 + 4 × (0.014–0.018))
Specific impulse, sec: at sea level in vacuum	 246 289	 – 303
Chamber pressure, atm (MPa)	75 (7.5)	102 (10.2)
Dry mass of the engine, kg	1325	185
Operating time, sec	125	350
Fuel components: Oxidizer Fuel	 Nitrate UDMH (Unsymmetrical Dimethyl-hydrazin)	 Nitrate UDMH (Unsymmetrical Dime-thylhydrazin)

End table 1

Parameters		
Stage	First	Second
Mass ratio of fuel components	2.5	2.65
Fuel delivery system	Turbopump assembly	Turbopump assembly
Engine diameter, mm	2 260	1 900
Engine length, mm	2 195	1 800

In July 1965, a successful group launch of five Strela satellites (Kosmos 71 – Kosmos 75) was conducted from the Baikonur Cosmodrome to a circular near-polar orbit at an altitude of approximately 1500 km. This marked the first launch of the upgraded carrier rocket, designated 11K65M, which was referred to in public media as Kosmos-3M. For the first time in the history of Soviet space exploration, a single rocket successfully placed five operational artificial Earth satellites into orbit. These satellites were fully equipped with onboard radio-technical systems, an electrical power supply system, and a passive thermal regulation system, all housed in a thermocontainer with a shape resembling a sphere [11].

Starting with the first launch at the Baikonur Cosmodrome as part of the flight-design testing program, a total of fourteen launches were conducted using the carrier rocket, which was manufactured at Site No. 2 of the Krasnoyarsk Machine-Building Plant in collaboration with OKB-10. In 1966, the production of the rocket was fully transferred to the main production site of the Krasnoyarsk Machine-Building Plant. In the same year, by order of the Ministry of General Machine Engineering of the USSR, OKB-10 was renamed the Design Bureau of Applied Mechanics (KBPM).

From this time, a new professional specialization began for KBPM and the Krasnoyarsk Machine-Building Plant: the design bureau became a design and production organization focused on creating space vehicles for communication systems, space navigation, and information systems for various purposes. Krasmash was positioned as the country's largest enterprise for the production of space launch vehicles and ballistic missiles for the Armed Forces.

In 1967, the first launch of the 11K65M launch vehicle (Kosmos-3M) took place from the Plesetsk test site. For the first time, the new Cyclone navigation communication satellite, developed by KBPM, was placed into orbit.

The Cyclone satellite featured an innovative and advanced design for its time. Its structural and layout scheme, along with onboard service systems, became the foundation for a series of satellites on low Earth orbits. This includes a family of satellites for navigation, communication, geodesy, and scientific research: Tsikada, Sfera, Nadezhda, and Ionospheric Station. All of these were launched using the Kosmos-3M launch vehicle [12]. The main tactical and technical characteristics of the Kosmos-3M launch vehicle are provided in a Table 2.

Table 2

The main tactical and technical characteristics of the Kosmos-3M launch vehicle

Parameters	
Launch vehicle starting mass, t	108
Dimensions, m: Length Diameter	 32.4 2.4
Payload mass (t) for circular orbits: 200–1 700 km, $i = 51^o$ 200–1 700 km, $i = 66^o$ 200–1 700 km, $i = 74^o$ 200–1 700 km, $i = 83^o$ 1000 km, $i = 83^o$	 1.500–0.780 1.400–0.700 1.350–0.660 1.250–0.600 0.930

End table 2

Parameters	
Launch vehicle starting mass, t	108
For solar-synchronous orbit: 475км, i = 97.3°	0.600–0.850
Accuracy of placing the spacecraft into a circular orbit at an altitude of 200 km: Altitude, km Inclination ° Orbital period, sec	 ~ 40.0 ~ 8.0 ~ 30.0
Volume of the payload accommodation zone, m³: Diameter, m Height, m	10.0 2.2 4.7

The 1165M rocket (Kosmos-3M) was produced at the Krasnoyarsk Machine-Building Plant until 1971. Subsequently, due to the new complex tasks related to the development of ballistic missiles for the Navy, the serial production of the space launch vehicle was transferred to the Polyet Production Association in Omsk. Meanwhile, the production of the first stage engines (11D614) was transferred to the Yuzhmash plant in Dnipro. The production of the 11D49 liquid rocket engine remained at the Krasnoyarsk Machine-Building Plant, which continued to produce this engine until 1992.

By the resolution of the Central Committee of the Communist Party of the Soviet Union and the Council of Ministers of the USSR under No. 949-321, dated December 30, 1971, the 11K65M launch vehicle was officially adopted into service as part of a special-purpose space complex. From that time on, it facilitated the creation of a number of space systems and complexes with significant defense, economic, and scientific importance.

The Kosmos-3M launch vehicle was used to place a variety of satellites into orbit, including the Nadezhda series satellites for the international COSPAS-SARSAT search and rescue system, as well as geodetic, navigation, communication, and other spacecraft. It also launched Indian satellites Aryabhata, Bhaskara, and Bhaskara 2; the French satellite Unamsat-2; the Italian satellites MegSat 0 and M1TA; the German satellites TubsatB, Abrixas, and CHAMP; the British satellite SNAP-1; and the Chinese satellite Tsinghua 1. The rocket was also used to conduct astrophysical, technological, and other experiments for the Soviet Academy of Sciences, the international Intercosmos organization, and industry-specific research organizations, including missions that involved returning spacecraft to Earth.

The Kosmos-3M launch vehicle played a key role in the experimental work conducted during the development of the Energy-Buran reusable space system. Using this rocket, launches were carried out from the Kapustin Yar launch site of the BOR-4 and BOR-5 unmanned orbital spaceplanes along orbital and suborbital trajectories. These flights included landings near Lake Balkhash or splashdowns in designated areas of the Indian Ocean and the Black Sea. The main goal of these tests was to evaluate the performance of the selected thermal protection materials and the structural integrity of the orbital spacecraft components under conditions close to those expected during actual operations [13–17].

Conclusion

The Kosmos-3M launch vehicle can rightfully be considered an outstanding scientific and technological achievement in the history of domestic space exploration. Its competitive advantages include cost-effective production, reliability, and safety. The rocket participated in the international Med-Lite light launch vehicle competition for NASA. In 1995, after a comparative analysis of eighteen types of light-class rockets from different countries, independent American experts recognized the Kosmos-3M as one of the most advanced. This recognition stands as the best tribute to the creator of the rocket, academician Mikhail Fedorovich Reshetnev.

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