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Chapter 7

Chief Designer of the Most Powerful Solid Propellant Motors of Ballistic Missiles*

V. F. Prisniakov† and V. P. Platonov‡

Abstract

This article describes the role that V. Kukushkin had in creating all the liquid fuel complexes of Design Bureau Yuzhnoye (DBY), which becam e the basis for the nuclear missiles of the USSR§ up to the middle 1960s. Created by V. Kukushkin, the solid propellant jet engine (SPJE), such as the Scalpel type, stood operational in Russia right up to 2005 in the system of the most powerful solid propellant missiles in the world. V. Kukushkin participated in the tragic launching of the rocket R-16 when the flower of the DBY was lost and he had himself hardly survived in the conflagration. The report also describes V. Kukushkin's participation in the unique tests of the space liquid rocket engine, suspended under the plane TU-16, in conditions of weightlessness, and about his role as chief designer of DB-5, his participation and leadership in more than 1,000 firing tests of the SPJE, of small sized SPJEs, of powder pressure accumulators and gas generators. Also described is the creation, for the first time in USSR and world practice, of the sustainer SPJE 15D15 ICBM. The Iron Maiden

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§ Union of Soviet Socialist Republics, or Soviet Union.

with mobile ground launching, created on the basis of the SPJE 3D65 solid-fuel railway complex, has been attested by many specialists, as the greatest achievement in world rocket technology. The report cites unknown new data regarding the whole spectrum of the Soviet SPJEs created by V. Kukushkin. A unique phenomenon in rocket technology is analyzed: for all the time of operation of products under the leadership of V. Kukushkin, there were no failures.

A list of acronyms is given at the end of the document to help the reader.

Figure 7–1: Vladimir Ivanovich Kukushkin.

Introduction

The purpose of this chapter is to tell the history of the life and activity of the chief designer of the most powerful solid propellant rocket motor for ballistic missiles—Vladimir Ivanovich Kukushkin. The surname Kukushkin is virtually unknown to the world. The life of V. I. Kukushkin may serve as an illustration regarding life in the Soviet engineering elite of the post-Stalin generation. As a graduate from the Moscow Aviation Institute (MAI), he was assigned to the Design Bureau Yuzhnoye (DBY) in 1955 and in 10 years advanced from an engineer in the project department to the youngest chief designer in the Soviet Union of the solid-propellant rocket motor (SPRM) in Yuzhnoye's Design Bureau 5. V. I. Kukushkin carried out the plan of the Soviet hawks; having lifted and enhanced the chemical industry, created new, particularly pure materials, developed the newest technologies, and created solid propellants. He created sustainer rocket engines for the most powerful and unique solid propellant missiles, which could be launched from submarines, from a railway car, and from silos. It was of such an advanced design with regard to on steering (change of a thrust vector direction) and specific impulse that nobody could repeat it. Kukushkin and V. Shkurenko, director of the Pavlograd plant, created seven of the most powerful solid propellant sustainer engines for strategic rockets, three engines for warhead separation, 85 unique small-size engines and powder pressure accumulators over a 30-year period.

Childhood, Studies, and War

Volodymyr Ivanovich Kukushkin was born on 23 July 1931 in Yaroslavl', an ancient Russian city founded 1,000 years ago. One of his grandfathers, Nikolay Yegorovich Kukushkin, was a coachman; another, Tushin Alexandr Yakovlevich, was a gold watch maker. Kukushkin's father, Ivan Nikolayevich, worked as a railroad worker, his mother, Alexandra, was a housewife. The prewar years of his childhood were the most tranquil: playing in the yard on the city's suburb with kind but strict parents, with his grandfathers and grandmothers nearby. In 1939 Volodya Kukushkin went to school where his teachers were much like his parents.

Figure 7–2: Kukushkin's house in Yaroslavl'.

Figure 7–3: Yaroslavskiy region and river Volga.

He was an "A" grade student. Life in the heart of Russia, in characteristically Russian fashion, cultivated in his heart a love for his native region, for nature, and for traveling that lasted throughout his lifetime. But then war broke out with its bombing, its ration cards, and other difficulties. Volodymyr had to work together with his mother (the father fought at the front at that time), who knitted mittens. Volodya prepared the yarn for her and helped catch fish with his grandfather. The Germans started bombing Yaroslavl', but the children quickly became accustomed to it. It was Volodya Kukushkin's first school of bravery.

Figure 7–4: First attempt to straddle a “lucky horse.”

Figure 7–5: Thousand-year-old Yaroslavl’.

Figure 7–6: Thousand-year-old Yaroslavl’.

Figure 7–7: Thousand-year-old Yaroslavl’.

Figure 7–8: Kukushkin’s parents, Ivan and Alexandra, 1948.

Figure 7–9: Left Photo: Kukushkin's mother, Alexandra, and grandmothers, Tat'yana Fyodorovna and Anna Fyodorovna, were the main breadwinners during the war.

Figure 7–10: Right Photo: On the beach, not yet cleared of mines, in Feodosiya in 1946. Second on the right is 15-year-old Volodya.

The hard famine during the war fostered and matured Volodya Kukushkin, a schoolboy at that time. It trained him for responsibility of all manner of work and determined his future destiny. His grandmother gave lodging to Soviet military pilots, and Volodya became friends with them. His uncle was also a pilot. All these circumstance and opportunities instilled in young Volodya a love of the sky and of aviation.

Figure 7–11: Thirteen-year-old Volodya, 1943.

Figure 7–12: Volodya as an amateur pilot, 1951.

After finishing school, Volodymyr Ivanovich entered the motor-building faculty at Military Aviation Institute, graduating from it in 1955. In 1951, while still a student at the institute, Kukushkin became an amateur pilot, and he remained with this avocation all his life.

Figure 7–13: At age 72, V. Kukushkin gave himself a birthday present in Antalia, Turkey.

Figure 7–14: Kukushkin with his fiancée, 1949.

After graduation from the institute, Vladimir Ivanovich tied his future destiny with Valentina Mikhailovna—his childhood sweetheart who had waited for him for seven years.

Dnepropetrovsk-1: Gateway

The First Projects: Wooden Box and Valves for Liquid Propellant Jet Engines (LPJE)

In 1955 after graduation from MAI, Volodymyr Ivanovich was sent to work in Dnepropetrovsk, where he received practical training. The young MAI graduates became the core of the future nerve center of DBY. But in the beginning they were put to work designing wooden boxes for packing liquid-fuel jet engines, and, as was generally practiced at that time, doing "social work." At the suggestion of M. Yangel, young Kukushkin was made the head of the Komsomol group in DBY during 1956–1957.

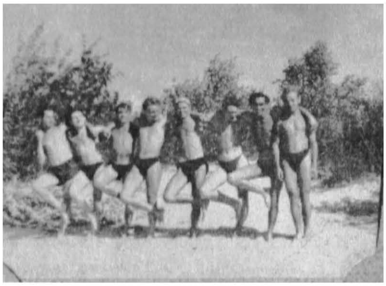

Figure 7–15/16: MAI students in Dnepropetrovsk in the Yuzhmash. Komsomol Bureau secretary is in the center.

Design (Project) Department: Pneumatic-Hydraulic Scheme (PHS) of a Rocket

The organization in DBY of one of the main design departments was headed by one of the luminaries of the new line of rocket technology at that time, V. Kovtunenko. Kukushkin was assigned by group chief E. M. Kashanov to a new task. This most talented engineer, Eric Mikhailovich Kashanov, was an extremely sociable and charming person. He became the first mentor of the young V. I. Kukushkin. The distinguishing and exceptional peculiarity of Kashanov was his ability to clarify any technical problem "with the feeling, with the senses, slowly and clearly." One of the authors of this article attended the lectures delivered by Eric Mikhailovich and remembers, 50 years later, everything that was discussed. Unfortunately, Kashanov died young. Nevertheless his plans, his ideas, put into circulation by this "pioneer," would nourish the work of DBY for years to come.

Figure 7–17: Eric Mikhailovich Kashanov, friend and mentor of V. Kukushkin.

Figure 7–18: Main designer M. K. Yangel.

The main activity of V. Kukushkin—as a beginning engineer capable of solving extremely complicated technical tasks clearly and quickly, and then, as head of a section of the design department at that time—was to create a complex pneumatic-hydraulic scheme, involving scores of different electro- and pneumatic valves, gas pressure reducers, membranes, and pipelines, which joined all the rocket's aggregates and systems like a man's blood system. V. Kukushkin participated in the creation of all rocket aggregates of DBY, which up to the middle of the 1960s formed the basis of the nuclear-rocket power of the Soviet Union.

The successful and productive work in DBY at that time was due to the working atmosphere, created by Yangel, where all people worked hard "not out of fear, but out of conscience," taking no consideration of, and sparing none of, their own time. Although they had a full schedule of work to accomplish, Yangel didn't prevent the young scientists from lecturing in Dnepropetrovsk State University (DSU). At that time any technical task in the rocket field required creative work, and the title of engineer corresponded to the role of scientist. The lectures encouraged the engineers themselves "to put their minds in order," and to place in the heads of the students some creative ideas. It also helped tie the university to DBY. The lectures of the young, 26-year-old V. Kukushkin in the course "Introduction to the Profession," "Hydraulics of PHS," which he delivered late in the evening after a hard-working day, left an indelible impression on one of the authors of this chapter.

Such a creative atmosphere gave quick results, and in two years specialist V. Kukushkin celebrated jointly with his colleagues, like-minded people, the launching of the first rocket by DBY, the R-12. Many new and original ideas, which now may seem obvious, were developed in Kukushkin's section. New practices, introduced in the new generation of rockets, such as the R-12 and R-14, and "hot" inflation (pressurization) of the fuel tanks, proved more effective, but were at the same time, extremely dangerous. This new technology became the basis of the candidate dissertation of Vladimir Ivanovich Kukushkin, which he defended in 1966.

Figure 7–19: The young specialists of DBY marked the first R-12 rocket launch (second on left, Y. Smetanin; third on right, V. Kukushkin).

Creation of powder pressure accumulators (PPA) provided for a reliable warhead separation and neutralized the impulse or after effect of the thrust when the liquid engine shut down. Placing the separating bottom partition on the R-14 gave, at first sight, a solution to its center of gravity, but it turned out that such a seemingly simple change of the tank construction caused the engine to shut down before the task was accomplished. Rockets working at the limit of their efficiency, practically at the point of bifurcations, meant that small construction "improvements" might cause substantial deviations of regimes as opposed to what had been estimated. Therefore, rocket system designers always carefully search for detecting "the good from the good." It turned out that fuel flowing from one part of the tank into another, due to big overloads, creates strains in the valve cavity, resulting in a drop in fuel consumption. Such phenomena were unpredictable and impossible to reveal during bench tests. Using telemetry information for this purpose during flight was very difficult. Nevertheless, after finding the cause of engine cut-off, a solution to the problem was found.

It is necessary to recognize, that the permanent collaboration of Kukushkin with DSU scientists enhanced the degree of project provision for creating the theoretical bases for rocket systems. For example, a theoretical definition of transitive processes in the elements of pneumo-hydroautomatic equipment, elaborated by DSU postgraduate I. I. Morozov laid the basis for liquid-fuel engine dynamics. V. I. Kukushkin—at first an associate professor and then full professor at DSU. He never gave up on creative collaboration. These intangible opportunities for enhancing the scientific level of project design work can be explained by the circumstance that at such a preliminary stage of rocket technology development, it was necessary to engage other branches grappling with similar tasks, and to bring them on as developing units. This is where the university's breadth provided huge advantages for the highly compartmentalized, top-secret rocket organization. With time, this collaboration gave birth to new solutions demanded by the economy.

Dnepropetrovsk-2: Fatal Tests Explosion ICBM 8K64 (SS-9-3 Scarp)

The Cold War, as with any other war, had its reasoning in the following thesis: he who first creates the more powerful weapons, wins. Therefore the competition between the two military–industrial complexes of the Soviet Union and the United States was fundamentally reduced to an aggressive, unlimited nuclear arms race. The administrative-command Soviet system had planned for achievements, especially in the field of rocket building, as it approached the various Soviet days of celebration: it was unalterable, intrinsic Soviet ideology. This was the way it was with the rocket of M. Yangel, the R16, the first launching of which was set on the eve of the 7 November celebration in 1960, and was therefore, attended by the senior Soviet Marshal, Mitrofan Nedelin. In violation of all rules and discipline, he was sitting in front of the rocket, which was fully fueled; and V. I. Kukushkin, as one of the PHS developers, was standing nearby. Before launching, during the ground check, a flaw in the wiring accidently triggered the second stage of the rocket. The blast of the engine then ignited the rocket fuel. The blast pressed M. Nedelin into the wall, incinerating him; and the flame lashed out at Kukushkin, who was standing in the passageway, and hurled him from the bunker. Kukushkin was placed in the care of the representative of the military reception service, B. A. Komissarov (later general-colonel and the head of the military-industrial complex). In that conflagration about 100 people were killed. Nevertheless, this event did not deter Kukushkin from taking dangerous risks, nor did it serve as a warning lesson to the Soviet system, which proclaimed the priority of a "business matter" over the value of human life, in this event to guarantee the military power of the Soviet Union against that of the United States. It is necessary to say, that such an official ideology was planting seeds on the fertile soil of an enigmatic "Slavic" feature, that is to act "on the off chance" that it might succeed, to trust to luck, enforced by the self-esteem of the young designers.

Airborne Liquid Engine Tests on the Bomber TU-16

The prehistory of these fatal tests is as follows. Placing the R-16 in the army as a weapon with the range of 9,000 km, the "lessons" of the Cuban crisis made two superpowers switch to a "war between headquarters," the tactical-technical basis of which required new, more advanced rockets. For a basic defense of their territory, the United States had built the defensive "Safeguard" system, which was to fend off a possible nuclear attack on its eastern coast. In response to this, the Soviet Union decided to create a missile that could deliver warheads to the southern borders of the United States, after flying over the South Pole. The orbital warhead (OW) of intercontinental ballistic missile 8K69 should reach U.S. territory south of the border, where there was no Safeguard coverage. Naturally, such unimpeded penetration of U.S. territory by Soviet rockets, which rendered the "Safeguard" system ineffective, changed military parity to a great extent.

In order to render such an attack effective, the technical problem of starting the liquid engine of the orbital warhead (ЖРД ОГЧ) in conditions of weightlessness had to be solved. V. Kukushkin was appointed in 1961 to be a technical manager in resolving this problem. A sufficient duration of weightlessness could be achieved while flying on the planes. One plane, the Tu-16, performed a special "steep climb" and during 20–30 seconds there was a condition close to weightlessness. It was necessary to attach a fueled LPJE (ЖРД) to the plane before take-off, and in the initial seconds of weightlessness to start the liquid engine converting the Tu-16 into a test bench (explosions and fires were normally conducted in that plane). During one of those flights the control system failed, but LPJE remained filled with fuel, and this circumstance did not allow landing of the plane. To get out of the critical situation it was possible to separate and discard the dangerous cargo. But nobody knew what might happen after separation of the LPJE and the subsequent shifting of the plane's center of gravity. And so it happened that the almost reckless decision was made to land the plane with the fueled LPJE onboard. Fortunately, everything turned out alright.

Tests of the Rocket D-19 from the Submarine Typhoon

As chief designer of the first stage of the rocket, D-19, V. Kukushkin, for three years beginning in 1981, took part in the testing with the Northern Navy. He also took part in the military rocket launchings, not because he did not trust his assistants, but because these tests involved fatal risk. The naval launching site is similar to Kapustin Yar, Baikonur, and Plesetsk in many aspects, but here are tested rockets designed for nuclear submarines. The length of the big missile submarine *Typhoon*, with a displacement of 25,000 tons, is 171 meters.

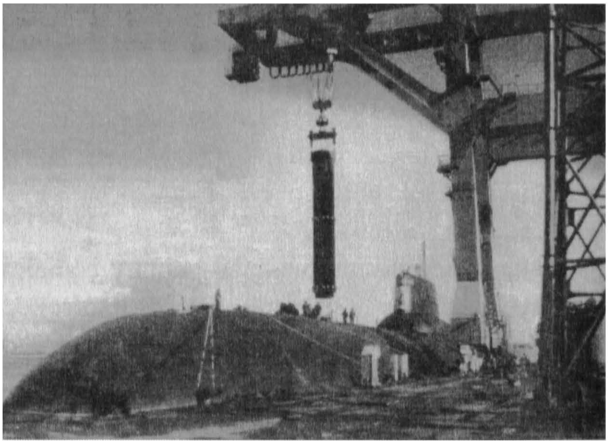

Figure 7–20: Loading of submarine-launched, solid-propellant rocket into catamaran *Shark* of the Typhoon class.

It was precisely in such a launching site that Kukushkin conducted the rocket tests. In these conditions, particular responsibility lay in fueling the 50-ton, solid-propellant jet engine (SPJE) 3D65 of the first stage of the sea-based missile designed by Kukushkin. This SPJE was able to steer and control the rocket after starting under water from the moving ship at the depth of 40–50 meters. It is not necessary to underline the danger and importance of these tests, especially at present, when we know about the catastrophe of the Russian submarine *Kursk.* We will add here, that only one heavy nuclear-armed submarine can destroy 200 targets, and it's very difficult to imagine the results. Peace was kept at this time by a "balance of fear"—an understanding that there could not be victors after a nuclear war. In this "fragile" peace the Dnepropetrovsk rocket builders had made an essential contribution, having created the most powerful solid-propellant engines in the world. Exceptional merit for this belongs to Vladimir Kukushkin.

Dnepropetrovsk-3: Submarine on the Steppes of Ukraine

Why SPJE?

In the 1960s appeared a paradoxical expression "underwater boat on the steppes of Ukraine." And only a few competent people knew, how close the steppes were to the city on the Dnieper River, because precisely here were created super-powerful engines for the nuclear submarines. The achievement in the field of liquid-fuel motor building was the development that made possible the launching of the first Soviet space vehicles, on the rocket the Americans had designated the "Satan." When the first solid-propellant rocket engines appeared, they were not competitive with the LPJE. Simple operation and long-term storage were one of their positive features, but as to their main characteristics, they were inferior to the LPJE. But the situation had changed when, at the beginning of the 1960s, American military personnel discovered signs of liquid fuel leaking from their heavy strategic Titan II rockets, which were standing in the silos ready for action. Having fantastic material resources, the military complex of the United States decided to convert America's strategic missiles into solid-fuel rockets. In time, there appeared solid-fuel rockets on the submarine-launched Polaris and on land-based intercontinental missiles like the Minuteman. The Americans—and here Kukushkin was giving them credit—were in some ways ahead of the Soviet Union. They were the first to begin developing solid-rocket motors. And they achieved impressive successes. But the issue was not that solid-fuel rockets were able to perform tasks that couldn't be solved in the Soviet Union by liquid-fueled rockets.

Chief Designer M. Yangel tried to calm the Soviet military, saying, "Our liquid-fuel rockets are not worse than the American solid-fuel rockets, but in many parameters they are better." And while the first rockets with cryogenic fuel required for prestart preparation several hundred servicemen (for example, the prestart team of the famous “seven” of S. Korolev amounted to 700 servicemen), the rockets of M. Yangel with their “high boiling” fuel components sharply enhanced their readiness for action and the length of their use, having simplified service technology and operation. (Now, for instance, action readiness for the “Satan” has lasted up to 20–25 years).

There was considerable obstruction in the attempt to realize the grandiose schemes of the Soviet “Yastrebs” (“hawks”). The country was not ready for production of solid-fuel engines; it was necessary to build an entire chemical industry, create new, particularly durable materials, develop new technologies, and create highly effective solid-fuel engines. But there entered always into the equation the “hawkish” psychology of the military chiefs, who would simply say: “The other side has it, why don’t we? The army must have solid fuel rockets!” But the decisive factor for transition to SPJE was an increased readiness for action, and to this must be added: new operational characteristics; long warranty terms for storage; reduction of maintenance expenses (simplifying terrestrial equipment, reducing the numbers on the start team); and more favorable opportunities for creating a less vulnerable mobile military rocket complex (MRC).

Figure 7–21: Left Photo: The main “pillars” of SPJE production: V. I. Kukushkin; A. M. Makarov, director of Yuzhnoye machine-building plant (YMP); V. M. Shkurenko, director of Pavlograd Mechanical Plant (PMP).
Figure 7–22: Right Photo: First mobile ICBM with SPJE, developed by V. Kukushkin, on parade in Moscow.

But it’s true they shut their eyes to the problems, in particular to that of rocket utilization after expiration of the period of readiness for action. This question greatly troubled Vladimir Ivanovich in those days, and he worked hard to resolve it. In general, after the decree of the Central Committee of the USSR was issued, there was an open research-and-development project on estimating the possibility of creating the mobile, land-based MRC based on an intercontinental ballistic missile (ICBM) using solid rocket propellant. For this purpose a number of organizational decisions had been made. One of the main questions was choosing the site for building production-test facilities for the engines and shops for assembling the rockets. Pavlograd city in the Dnepropetrovsk district, which had previously served as an artillery shooting site, was chosen for this production design bureau. In Design Bureau Yuzhnoye there was established a department of solid-rocket engine construction, and in Pavlograd—its department for special designing and testing.

Chief Designer of the Mid-Flight SPJE 15D15

It was exactly in this situation that academician M. Yangel appointed Vladimir Kukushkin to be a chief designer of solid-fuel rocket engines, and as his deputies—V. S. Kamenchuk, A. A. Makarov, A. L. Spivak, and N. N. Perminov. The new chief was 35—he was the youngest in the Special Design Bureau (SDB). It was officially established on 12 February 1966 by Order #3, which was signed by M. K. Yangel. Due to the superior management abilities of Chief Designer V. Kukushkin, there was quickly created in Design Bureau 5 a collective of absolutely unique specialists, whose work was realized in the field of physics, chemistry, plasma gas-dynamics, material durability, and new technologies. Academician M. Yangel approached the creation of solid-fuel rockets very gingerly, considering his every step. One of the new rockets was built as a combined (integrated) rocket: the first stage utilizing solid fuel, the second stage, liquid. Of course, this decision was not the optimal choice, but, all in all, the new rocket contained a number of valuable innovations and pioneer solutions. It was the first mobile "dirt-road" rocket complex RT-20P with intercontinental ballistic missile (МБР) 8K99 (0836). The launch of this rocket was done from a transport-launching container (ТПК) using a mortar-start scheme. Simply put, 8K99 is a launch site on wheels, with unrestricted radius of action. Let us underline the main point: for the first time in the Soviet Union and in the world, on the basis of a mid-flight SPJE 15D15, was created an intercontinental ballistic missile with land-based mobile launching. This engine made it possible afterward in the DBY to create the best fourth-generation, solid-fuel rockets. It had a steel frame, an inserted solid-fuel charge, and a four-chamber nozzle unit.

In principle, 15D15 was not inferior technically to the rocket engines of Minuteman and Polaris, although it was created when there was no real technical base for it. In the Soviet Union there were no composite materials, no developers of solid rocket propellants, and no chemical components. And designers did not have necessary experience. Perhaps it played a negative role. The complex, in the end, was rejected as a weapon, probably because of the absence of the necessary experience for operating it. All construction documentation after completion of its development was passed to Moscow Thermo-Technical Institute (MTTI), and this circumstance served as the basis for further development of Soviet rocket technology. Having an initial weight of 30.9 tons, of which 1.41 tons was the weight of the megaton war charge, the engine of the first stage 15D15 with a thrust of 61–70 tons made it possible to achieve a range of 9,000 km. The flight tests of 8K99 had begun in October 1967. By the beginning of serial production in 1969 the development of the rocket was discontinued. According to Kukushkin, this was due to the fear of operating the mobile rocket complex with the liquid second stage, but the main obstacle was the lack of readiness of the Rocket Forces of Strategic Designation (RFSD) for building launch sites. Two installations with the models RT-20P participated in the parade on the Red Square in Moscow on 7 November 1967. In the United States, these rockets were given the designation "Iron Maiden." They were the world's first intercontinental rockets of the mobile, "dirt-road" variety.

"Experience is a school where a man learns what a big fool he has been." Josh Billings (pen name of American humorist Henry Wheeler Shaw, 1818-1885)

Altogether the result of the experimental verification of the rocket 8K99 was ahead of its time: it was developed and tested successfully for mortar launching, for fuel damping in the tank system of the liquid propellant jet engine (LPJE), for discarding of the nose cone after passing dense layers of the atmosphere, and for the thermal and gas-dynamic work regimes of SPJE. There were also developed reliable packing assemblies of the moving nozzles. By the beginning of 1990, due to the efforts of two friends, one was the director of the plant, V. M. Shkurenko, and the other, V. I. Kukushkin, the bench base of Pavlograd Mechanical Plant (PMP). The work of the experimental subdivisions of the DBY on durability verification, and the technology of production aggregates, and the determination of its material characteristics created a powerful testing complex, which in terms of the level of technical equipment and functional possibilities, became the best in the homeland division branch of solid-fuel rocket construction.

Why Mortar Launching?

Design Bureau (DB)-5 participated in the development of a mortar-launch rocket system to a greater extent than the other DBs. Therefore, the history of this unique and incredible way of launching the rockets is the closest to the SPJE designers. In order to provide more protection for the rockets, they began to place them into silo launching aggregates (SLA) of closed type, that is, underground. Starting the engine in the silo required special gas diversion ducts, thus, for one rocket, it was necessary to build three silos. It is very difficult to provide SLA stability against the shock wave coming from a high-altitude nuclear explosion. This problem was solved by "mortar" launching. According to this scheme, the rocket pushes out from a silo in the launching-tube container by gases produced by powder pressure accumulator (PPA), and then, at an altitude of 20–25 m, the engine of the first stage starts up. The original scheme of the DBY made it possible, in the fixed, limited volume of the rocket, to place a PPA, the gases from which propelled the rocket out of its container, and the necessary force was achieved by the progressive consumption characteristic of PPA, increasing proportionally to the increase of the volume as the rocket exits the container.

Small Engines, PPAs, Engine Package of Separating Warheads, Developed by DB-5

Powder pressure accumulators (PPA), which are the basis of the whole launching system, were created in the DB-5 at Yuzhnoye and were accepted as component parts of the rockets 15A14, 15A15, 15A16, 15A18, 15A18M, 15A60, and 15A61. DB-5 has also developed scores of small engines for special functions, pyro-technical devices for stage separation, separation and removal fairings, and start pans for providing impulse, and rotating warheads for shooting off the devices that allow the missile to pass through an enemy's antimissile shield. Due to this fact, there was no other such multipurpose organization in the Soviet Union for development of solid-fuel rockets than DB-5. It makes sense to recognize in particular the development of engine units for warhead separation (EU WS). The need of such units was necessitated by the development of "cassette warheads" (a packet of warheads): the rocket is equipped not with one warhead, but with several.

Realization of a large number of complex space maneuvers of the multiple-reentry vehicles (MRV) required the creation of engines for long-duration operation (more than 300 sec) and highly-efficient guidance systems. Simplicity of construction, optimal arrangement in the compartment of the war stage, convenience in operation, and a high degree of reliability and safety necessitated using DBY liquid rockets and solid-fuel MRV engines. The practice of development and operation of the rockets 15A15, 15A16, and 15A14 has confirmed the correctness of the accepted solution. Because of the long-duration work period of the MRV engines, there were developed special "low temperature" composites for solid fuels (temperature [9] of combustion up to 2,000 °C), and for guidance, rotating nozzles with the a rotating angle of up to 70 degrees. Flight tests of the engines were conducted between 1973 and 1980. There were created by DB-5, four engine units for separating warheads.

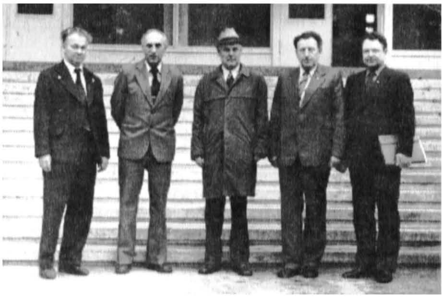 

Figure 7–23: Left Photo: In Biysk city at the Altay Chemical Institute (ACI), main producer of serial SPJE. From left to right, V. G. Sakovich, deputy director and chief chemist of solid propellants; Y. A. Smetani, head of DBY design department; A. F. Savchenko, director; V. F. Utkin, DBY general designer; and V. I. Kukushkin.

Figure 7–24: Right Photo: Meeting with submariners; seated on the right, S. N. Kovalyov, "Shark" chief designer; seated in the center, V.F. Utkin; standing in the center, Y. A. Smetanin and V. I. Kukushkin.

Chief Designer of the Mid-Flight Engine SPJE 3D65

"I have yet to see any problem, however complicated, which, when you looked at it in the right way, did not become still more complicated."
(Poul William Andersen (1926-2001)

In Leningrad in the "Rubin Central Design Bureau" with the shift from liquid rockets to solid-fuel rockets, there was realized the project Akula (project 941), in which were developed and produced six of the world's largest, two-framed submarines of the Typhoon class, equipped with 20 intercontinental solid-fuel rockets RCM-52 (D19) with a weight of 90 tons, carrying 10 individual warheads that could be targeted separately. One salvo from the Typhoon could cover an area of 600,000 square kilometers (equal to the area of Ukraine). The chief designer of DB-5 was charged with the task of developing a solid-fuel motor, 3D65, for the first stage of the RCM-52 ICBM produced by the design bureau of Viktor Makeyev. DB-5 started work on the 3D65 engine in 1973. Its development lasted nearly 10 years. The developers had to decide for the first time many extremely complex problems. In the engine construction were put the most advanced and progressive solutions: a solid-wound "cocoon" body (made of a glass-plastic material, later made of extremely durable organic plastic material), a super durable titanium alloy VTZ-1, the charge of the fuel was firmly fixed to the body, which was fully protected from the high-temperature gas flow of the combustion products.

Figure 7–25: Left Photo: V. Kukushkin (right) with V. P. Makeyev (left), general designer of submarine-launched ballistic missiles and captain of the first range, S. Rukhadze.

Figure 7–26: Right Photo: After completion of the flight tests of the Typhoon rocket in 1983: V. I. Kukushkin (top left); L. N. Lavrov, chief designer of second- and third-stage engines (right).

Missile guidance was done by means of a system, based on the principle of insufflating (injecting) a gas from the combustion chamber into the supersonic part of the nozzle with the help of eight valves made of refractory wolfram. The choice of this guidance system was based on the complex and turbulent character of the movement of the rocket during the initial underwater and above-water phases of the trajectory. This circumstance required an application of a guidance mechanism with highly dynamic characteristics, and this could be achieved only by an insufflating system. Given the impossibility of placing on the rocket an autonomous engine for guidance along the bank channel, the insufflating system could provide guidance for all three channels.

There was one more task for an insufflating system: the guidance on the underwater part of the trajectory from the depth of 50–60 meters. A great deal of theoretical and experimental work was conducted, which resulted in showing the possibility of solving this problem. It proved to be possible as a result of insufflating combustion products through the valves into the super-critical part of the nozzle. But precisely these valves caused a lot of problems. In the engine unit 3D65 were applied construction solutions, required by the specific nature of its use as a sea-launched missile—namely: prelaunch pressurization to compensate for the effect of the outside pressure during underwater "mortar" launch before engine start: the plastic nozzle membrane partition, which provided reliable closing of the hatch of the silo after rocket launch, being fully destroyed during its operation; absolute air-tightness of the engine to prevent the entrance of sea-water. It was the most powerful military solid-propellant engine in the world. The weight of the solid-fuel charge would reach nearly 50 tons. The engineers of DB-5 had to overcome considerable hardships during verification of the insufflating (injection) system and, in particular, of the wolfram valves. The melting point of wolfram is 3,400 degrees and the gas flow of the combustion products flowing through the valve nearly reaches such temperatures.

This situation was aggravated by the fact that the outer layers of the valve were heated considerably faster, than the inner ones, and this caused thermal strains and cracking of the construction. It is difficult to say, how much work had been done and how much effort was spent in order to make the valves work properly. A thorough examination was conducted on the wolfram for several different parameters: physical–mechanical characteristics, presence of dashes, tendency to agglomeration and so forth. Scores of options were developed for valve construction, including combined elements. Construction solutions were found with regard to providing heat resistance of the valve assembly and introduction of measures for stabilization of the wolfram characteristics. The problem of the insufflating system's efficiency was thereby solved.

Figure 7–27: Left Photo: Inspection of the first stage of the SS-24 rocket in the taiga near Archangel'sk (1987): DBY deputy general designer of DBY (center) with V. Kukushkin to his right.

Figure 7–28: Right Photo: Handing the Red Banner to V. Kukushkin (on the left) as an award for developing the SPJE for the Typhoon nuclear submarine.

In the beginning of the flight tests for rocket 3D65, there arose a number of questions regarding the efficiency of the units of the first stage, whose operating conditions could not be simulated on the ground. Because of that, it was necessary after each flight test, to separate the engine 3D65 of the first stage and bring it to the plant in order to analyze the state of the construction. The DB-5, headed by the chief designer, took responsibility for the rocket's first-stage search and its retrieval. Searching was difficult, owing to the peculiarities of the zone where it landed (taiga, marshes) and the rapidly changing weather conditions, which did not often permit aerial reconnaissance to locate the vehicle. And in winter the task was aggravated owing to hardship of extraction of the vehicle from the frozen ground. In addition, after unsuccessful tests, the landing area was often far from the estimated landing point, sometimes by as far as 20 km away. The analysis of the state of the material after the flight tests allowed reduction in the deadlines for the experimental verification and use of the gained experience in further work.

The static firing tests of the SPJE 3D65 (solid-propellant jet engine 3D65) had begun in 1977, and since 1979 the engine was utilized in flight tests. In 1982 the tests of the rocket RCM-52 were successfully completed. Some of them were conducted in submarine launches in the Barents Sea. In 1983 the system was accepted for the Soviet Navy. The creation of the engine 3D65 was an enormous contribution of Ukraine to rocket construction, and it promoted the development of the chemical industry, encouraged the development of new composite materials and the development of powder metallurgy and welding, as well as the development of other unique technologies. The chemical industry in Ukraine could produce the necessary epoxy resin (tar) and glass–plastic materials, and the material carbon-carbon fuel components. Thereby was created the analog of the Japanese Kevlar, which was needed for producing plastic bodies, which weighed much less than the steel ones and had high durability. Western specialists couldn't believe for a long time that the Soviet chemical plants could produce Kevlar thread thinner than web. In such a way, the Soviet Union was catching up with the technically developed world, owing to development of the rocket technology, including the SPJE.

Dnepropetrovskiye "Brave Lads" 15G60 and 15G61

During the senseless arms race, for achieving questionable, doubtful unilateral superiority, in the middle of the 1970s, DBY was charged with developing a solid-fuel rocket complex RT-23 for two variants of basing—silo launching aggregates (SLA) and a military railway rocket complex (MRRC). Concerning this subject, DBY General Designer V. F. Utkin (1971–1990) said, "Why are mobile complexes necessary? It might seem we have such a big country, and it has so many secluded spots, that stationary complexes could be easily concealed." But that is not correct. The Soviet Union had to take measures for providing a reliable, second-strike capability. It had to take into consideration that Pershings were A-number-one rockets, with a range of 3,000 km and the accuracy of hitting within several meters. Due to that, the Soviet Union began to make "rocket trains." DB-5 had been charged with development of mid-flight engine units for the first and second stages (15D206 and 15D207), as an analog of the engine unit 3D65, but having an enhanced level of consumption-thrust characteristics. Because missile guidance, when the engines of the third and second stages are active, is accomplished by deflection (that is, turning) of the head unit, the engine of the 15D207 had a stationary nozzle without guidance mechanisms. In order to decrease the dimensions of the rocket and transport launching container (TLC), it was constructed with a telescopic nozzle, which unfolded in flight before the engine started. In order to prevent the rocket from damage on the railway train, or from it being overturned or set on fire during off-loading, it was suggested to "tilt" the rocket. After being pushed out from the railway car, the rocket was tilted from the vertical axis, in order that the gas stream from the engine not hit the car, but rather bypassed it. When the rocket was tilted, the engine was started. The tilt was accomplished by means of a pneumatic actuator, developed also in DB-5. The first flight tests of the rocket 15G44, with engine units 15D206 and 15D20, were performed in late 1982.

Figure 7–29: V. F. Utkin's guests, academicians B. E. Paton and G. I. Marchuk.

Figure 7–30: Observing the launch of SS-24 rocket from its railway-based container.

Nevertheless in 1983 the decision was made to discontinue development and instead to start on the development of rockets 15G60 and 15G61 with improved characteristics and improved degree of withstanding the destructive effects of a nuclear explosion (DFNE). For the rail-mobile rocket 15G61 with the first level of durability against DFNE, there was conducted modernization of the mid-flight SPJE for the first and second stages. In the engine of the second stage (15D290) was applied a high-energy fuel "Start," which permitted the enhancement of the engine's power by nearly 3–4 percent (increase of the range by 500 km). Apart from that, on account of the reduction of the amount of fuel component containing chlorine, it was substantially more eco-friendly.

On 18 January 1984 flight construction tests of RT-23 were carried out on the world's first ICBM firing from a railway-based aggregate. This complex became the first and only rocket train, which utilized a three-stage, solid-fuel rocket with 10 individually targeted warheads. The creation of a solid-fuel railway complex, as has been attested by many specialists, was the greatest achievement in world rocket technology. It was virtually impossible to distinguish the launch cars from ordinary railway cars, thousands of which were traveling on the expanses of the USSR. One car served as a post, three others with removable roofs with launching aggregates with the rockets RT-23 "Molodets" ("brave lad") (the U.S. designated SS-24 Scalpel). The remainder of the cars held provisions. In 24 hours, the MRRC could traverse up to 1,500 km. What's more, launching could be carried out from preplanned positions, as well as from any point along the route. In order to keep rail-mobile systems on alert, 18 satellites were placed in permanent operation over the Soviet Union. The silo-based 15G60 rockets required enhanced durability against second-level nuclear explosions, since the silo locations were generally known. Obviously, the additional weights, necessary for providing greater durability, required more energy consumption by the mid-flight engines.

For this purpose a principally new engine for the first stage (15D305) was created, and the engine of the second stage (15D339) was modernized. The concept of the "back-counter" hit required launching rockets and delivering warheads to the aimed targets, while launching sites were under nuclear attack. During a nuclear explosion a rocket is subjected to a great deal of destructive factors. The effect of shock waves required the development for the first stage of entirely new guiding mechanisms with a great number of possibilities to provide sustained flight. The insufflating system did not answer these requirements, and therefore the DB-5 developed a new guiding mechanism—a revolving nozzle with an elastic supporting hinge. The specialists of DB-5 had to apply a lot of efforts to create a revolving nozzle, which could steer the flight under the effect of a shock wave of a nuclear explosion. In the engine, 15D305, a more effective and eco-friendly pure fuel with additives of the explosive substance octagon was used. Its characteristics had been substantially reinforced (more than one ton of fuel was burned per second). As a result of the new guidance scheme of the rocket, the engine of the second stage was made stationary, that is, without elements of thrust vector control, but in order to decrease the length of the rocket, the "telescopic" nozzle was utilized. With regard to energy and weight, the characteristics of this engine have not yet been surpassed. Created at the State Design Bureau, Yuzhnoye rockets 15G60 (PC-225, silo based) and 15P61 (PC-228, rail-mobile) remain for the time being the most absolute perfect complex in a technical sense in the world.

By the time of the signing of the START agreement between the Soviet Union and the United States limiting strategic offensive arms in 1991, there were, among the 24 strategic rocket complexes in the Soviet Union, 16 that were created by Dnepropetrovsk rocket builders, carrying two thirds of all war charges of the land-based system (444 rockets), which comprised 42 percent of the nuclear armament of the Soviet Union. "If you do not think about your future, you cannot have one" (John Galsworthy). Already during work on 15G60 and 15G61 DB Yuzhnoye, including DB-5 started to conduct fundamental research and development, the results of which should serve as basis of the creation of rockets of a new generation with enhanced durability against nuclear attack, as well as against laser and beam weapons, with the time of work at most 100 sec.

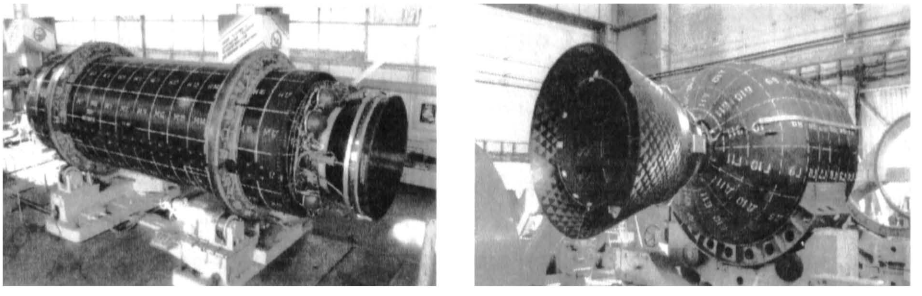

Figure 7–31: SPJE rocket engine, developed by V. I. Kukushkin, chief designer of Design Bureau 5.

The reason for the development of a new rocket was the declaration by the United States of its intention to create the technology for the Strategic Defense Initiative (SDI). The project work on this theme was completed with the development of technical proposals and the creation of the enforced SPJE with high pressure for the first stage. Five successful tests of this engine were conducted. For the second stage, there was developed and tested a drive of an unfolding nozzle which was discarded during flight. While still in 1988 DB Yuzhnoye, together with MTTI, was charged with developing a universal intercontinental ballistic missile with a mono-block warhead ("universal"). DB-5 was developing the engine unit for the first stage. This required only six static-firing tests of the engine, thanks to the experience, accumulated in over 20 years of testing, and then the rocket was accepted for flight tests. "All is not as bad as it seems, it is much worse." The further development of a more advanced SPJE for ballistic missiles of the fifth generation in Ukraine was never accomplished due to political reasons. Even the new concept of the application of paste-like fuels was never developed in DB-5. It didn't attempt to use the silo-based 15G60 for satellite launches. Taken down from their readiness status, the rockets were dismantled, and 163 SPJEs with the weight of 50 tons each were sent to storage to be used by the Pavlograd plants, where they had been produced.

The results of all these developments remain uncontested: DB-5 has carried out altogether more, than 1,000 static-firing bench and flight tests of mid-flight engine units, and engine units for separating aimed warheads—cassette ones, small SPJEs, PPAs and gas generators. The total weight of solid fuel charges, put into the engines of DB-5 and tested, was more than 20,000 tons. The DB-5 specialists put a lot of novelties into these developments (more than 1,000 inventions), and that allowed its engine construction to reach the level of a world-class technology.

The Conversion and SPJE

The deterioration of the state of the economy in the 1980s and early 1990s and the cuts in funding for the defense industry resulted in a sharp reduction of the work volume in Design Bureau Yuzhnoye in the field of military rockets. At the end of the 1980s, all work on building solid-fuel engines was virtually stopped. In those conditions urgent measures in the field of conversion had to be taken, in order to find new fields in construction design work connected with a scientifically meaningful, high-technology orientation that could utilize the scientific and technological know-how of the DB-5 team, as well as the achievements in the rocket-space branch. On the initiative of V. I. Kukushkin such a line of activity was found for the team in the area of wind- and thermal-power energy. Here it must be recognized, that the subject of the wind-power industry was suggested to him by the head of the department at Dnepropetrovsk State University, Nikolay Mikhailovich Belyayev, who was connected with Vladimir Ivanovich through a long-standing personal friendship and a long period of cooperation. Soon wind-power energy became the main line of Kukushkin's activity in the Yuzhmash, where there was established a special subdivision for producing wind turbines. There they began to produce wind turbines of various power and battery emulgators for purification of smoke gases of the coal thermal-energy stations.

V. I. Kukushkin—Chief Designer, Outstanding Individual

During 30 years V. I. Kukushkin had worked jointly as a team with the director of the Pavlograd Mechanical Plant (PMP) V.M. Shkurenko and conquered some of the highest peaks. The bureau created seven of the most powerful solid-propellant, mid-flight engines for strategic missiles, three engines for separating and aiming warheads, eighty-five unique small-sized engines, and PPAs. If one were to compare the activity of the chief designer of SPJE with others, one might say the scale of DB-5's activity is equal to that of the LPJE Design Bureau of V. P. Glushko. But the uniqueness of the activity of the design team of Vladimir Ivanovich Kukushkin in the field of rocket technology is that there was not a single failure for the entire period of SPJE operation! And this can only be explained by one thing: the outstanding managerial and creative capabilities of the Chief Designer of DB-5. The secret of all this, the principles which V. Kukushkin followed, the style of his work, which are necessary for a chief designer, are revealed by Kukushkin himself:

> Besides common, generally accepted qualities, such as professionalism, the ability to organize the work of the team in the proper manner, the ability to see the prospects in store, I always adhered to the following principles, which I developed myself, although they might not have always worked.
>
> I have never respected the people who always agree, always say "yes" to their boss, whether it was to the point or not. A man should always have his own opinion, even if somebody doesn't like it. The laws of mechanics tell us that one can rely only on that thing which resists. I always was very glad when my colleagues had different suggestions about one subject or another, because through argument, truth is born. And if two persons always say the same thing, it means, that one of them is unnecessary.
>
> A big virtue for the chief designer is not only his ability to develop a new technical idea by himself (though it is very important quality), but the ability to select out of the suggested options the correct one. The leader, having based his knowledge on the available facts, should posses in some measure an intuition, in order to not be mistaken in his decision. It is very important, because, as Johann Wolfgang von Goethe said, "Once you have missed the first buttonhole, you'll never manage to button up." In principle, each problem has its solution, and the only difficulty is to find it. Now, about risk. Caution in a task is a good thing, if it is not excessive. Even a tortoise won't make a single step, if it will not risk sticking out its head or legs. If the chief designer wants to achieve success, he must take a reasonable risk. It was, for instance, like this when the DB began developing the insufflating system. The leader's work-style should not be that of standing behind the back of an employee to force him ahead, to find faults with him in details, to interfere in his work, to disturb him. Real leadership is to find an individual approach to each employee, since there are as many ways to work with

people as there are people. I've always tried to act in accordance with this principle: the leader is answerable for everything, and to never let his subordinate workers down. It is very important for a chief designer to establish the right and amicable relationships with his related companies. Surely your success fully depends on their work.

Figure 7–32: A present from V. P. Glushko, main specialist in LPJE, to V. I. Kukushkin, main SPJE engine builder.

Figure 7–33: On the bright path toward capitalism.

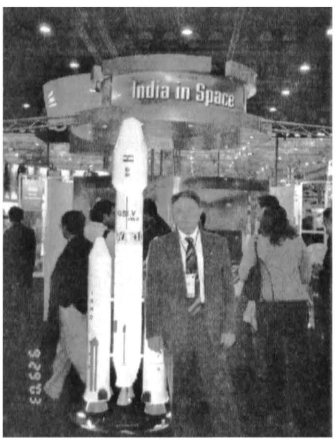

Figure 7–34: First presentation of a new space system, Bremen, 2002.

Figure 7–35: Vladimir Ivanovich and Valentina Mikhailovna Kukushkin.

Apart from industrial activity, V. I. Kukushkin was engaged in scientific work and in teaching. In 1966 he defended his candidate dissertation on the theme "hot inflation of the fuel tanks of the liquid fuel rockets," and in 1984, his doctoral dissertation was on the theme of the design of a theoretical and experimental research on midflight solid propellant motors, PPAs, and engine separation and the targeting of warheads.

V. Kukushkin fondly recalls the people, with whom he worked together for scores of years. He attributes nearly all his successes to one person only—to his wife Valentina Mikhailovna, who always understood him and, most important, supported him in the difficult times, and shared with him the joy, when there was cause for such.

V. Kukushkin's Renaissance

They are writing in the press that Ukraine has lost its leadership in rocket technology and its space potential. In fact, during all the years of our independence we can boast having launched several improved rockets and satellites of the Soviet period. We have not seen for 17 years a single worthy project, corresponding to the space potential of the DB Yuzhnoye. It can be said with confidence, that, while working in the DBY, V. Kukushkin did not allow a slowdown of our space branch. Fifteen years ago Professor V. I. Kukushkin was taken from rocket technology—crudely, brutally, dishonorably . . . for no reason. Such is the Slav—he is thrown down on the ground, but gets up. But the human being is created for creation, for creative work, and because of that, envious persons could do nothing with V. I. Kukushkin. In spite of his age, any young man would envy the energy and his enthusiasm—he drives, skis, hang-glides, and he creates the new rocket technology. He is the same all the time—energetic, striving for the future, for new prospects. In fact, in the "dodgy enterprise" he shares with enthusiasts like himself— not profitable people—he represented in the National Space Agency the new concept of development of the rocket-space potential of Ukraine and has developed Ukrainian air-space systems, creating possibilities based on the achievements of the domestic rocket—and plane building.

Glossary of Acronyms

Although most of the acronyms have been explained in the text, here is a list (in alphabetical order), all in one location, to help the reader:

ACI Altay Chemical Institute
BM Ballistic Missile
°C Degrees Celsius
DB Design Bureau
DBP Design Bureau Pivdenne (named after M. K.Yangel)
DBY Design Bureau Yuzhnoye (Southern)
DFNE Destructing Factors of Nuclear Explosion

DSU	Dnepropetrovsk State University
EU	Engine Unit
EUWS	Engine Units for Warhead Separation
ICBM	Inter-Continental Ballistic Missile
LPJE	Liquid Propellant Jet Engine
MAI	Moscow Aviation Institute
MIC	Military-Industrial Complex
MRC	Military Rocket Complex
MRRC	Military Railway Rocket Complex
MRV	Multiple-Reentry Vehicles
MTTI	Moscow Thermo-Technical Institute
OW	Orbital War-Head
PHS	Pneumatic-Hydraulic Scheme
PPA	Powder Pressure Accumulator
PMP	Pavlograd Mechanical Plant
R&D	Research and Development
RFSD	Rocket Forces of Strategic Designation
SAW	Separating Aimed Warheads
SDB	Special Design Bureau
SDB-586	Special Design Bureau #586
SDI	Strategic Defense Initiative
SLA	Silo Launching Aggregates
SPJE	Solid Propellant Jet Engine
SPRM	Solid Propellant Rocket Motor
START	STrategic Arms Reduction Treaty
TLC	Transport-Launching Container
USSR	Union of Soviet Socialist Republics (or Soviet Union)
YMP	Yuzhnoye Machine-building Plant (named after A. M. Makarov)

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