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Chapter 18

Solid Propellant Rockets in the Soviet Union*

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Background

The history of solid propellant rockets in the USSR began with the first powder-rocket plant in 1680 and the works of A.D. Zasyadko (1779-1837), K.I. Konstantinov (1817-1871) and N.I. Tikhomirov (1860-1930) in Saint-Petersburg. The GDL, merged with RNII in 1933, created the famous Katyushas in 1938, which were mass produced during World War II. On July 24, 1945, the NII-147 (GNII TotchMach in 1966, GNPP SPLAV in 1992) was created in Tula to continue work on multiple launch rocket systems (MLRS).

On May 13, 1946, the Munitions Ministry was transformed into the Agricultural Machine-building Ministry, which was headed by P.N. Goremykin between 1946 and 1953. A main directorate, in charge of solid propellant and rockets, it created an institute combining GSKB-1 (NII-1), a design bureau from the subsidiary no. 2 of NII-1 (KB-2) and a test site in Sofrino near Moscow. This activity was moved to Ministry of Defense Industry in 1953 and finally to the Ministry of Machine-building in from 1968-89, where it was headed by V.V. Bakhirev, followed by B.M. Belyusov).

The NII-1 (designated MIT in 1967), headed by General S. Ya. Bodrov, began work on anti-submarine missiles (RPK) for the Navy (Naval Katyusha).

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They were designed by N.P. Mazurov and V.A. Mastalygin. N.P. Mazurov then designed the tactical rockets Filin and Mars in 1955, Luna in 1961, Luna-1 and Luna-2 in 1964, Luna-M in 1965 (Frog series) as well as the meteorological rockets MMR-05 in 1956-59, MMR-08 in 1959-65, M-100 in 1963, MR-12 in 1964 and MMR-06 in 1968. However, the first meteorological rocket MR-1 had been developed by A.D. Nadiradze between 1945 and 1951 at OKB of the Moscow Mechanical Institute (which became the MIFI in 1953). Equipped with a liquid rocket engine, this rocket had been used between 1951 and 1958.

In 1946, the KB-2 began work on German missiles: Hs-293A (D.L. Tomasevitch and M.V. Orlov) in 1947-49 and RS-1400 Fritz-X (A.D. Nadiradze) in 1950-51. Orlov also developed the RAMT-1400 Shuka-A and B between 1949-52, which became the KSCh (SSN-1 Scrubber) between 1953-59, while Nadiradze worked on the guided aircraft bombs UB-2000F Chaika, UB-5000F Condor, UBV-5, URB-100 and the Strizh missile (the German Taifun with solid propellant) until 1958.

On December 15, 1951, KB-2 was merged with the factory no. 67 "Mostiazhart" (Moscow Tiazhelny Artillerii) to become the institute SNII-642. The factory, created in 1916, had also hosted the GSKB-47 since 1938 (now GNPP Bazalt). From 1953-54, V.N. Chelomei worked there before the opening of OKB-52 at Reutov (cruise missiles for the Navy). On November 6, 1957, SKB-2 was merged with OKB-52 and Nadiradze became Chelomei's deputy. In 1961, Chelomei took over the OKB-23 of V.M. Myasishchev and his deputy, G.I. Arkhangelsky, assumed responsibility for ground equipment for rockets. In 1963, this activity was transferred to the subsidiary no. 2 headed by V.M. Baryshev and located on the site of the former NII-642 abandoned by the Nadiradze team in 1958. The main constructor, V.M. Baryshev (1913-1992), a former deputy of Myasishchev, developed the ground equipment for the rockets UR-200, UR-100 and UR-500 between 1963 and 85. He was replaced by O.S. Baskakov, from 1985-95, and then D.K. Dragun from 1995. This subsidiary no. 2 became OKB Vympel in 1991.

Within the Ministry of Aviation Industry, the KB-2 of factory no. 81 (now MKB Iskra at Leningradsky prospekt no. 35, Moscow) began work on all kind of solid propellant rocket boosters for aviation in 1946. It was headed by I.I. Kartukov, B.A. Raisberg, and then Yu. K. Kulikov. This factory made the 1.5 t thrust engines for the experimental gliders of P.V. Tsybin in 1946-48, the PRD-22 engine of 400 kg thrust for the SM-30 (MiG-19 launched from a catapult), the SPRD-99 of 2.5 t thrust for the MiG-21PFM, engines for the missiles P-5, P-6, P-35, Chelomei's Ametist from 1955 to 1968, and many others. Now they produce

engines for stage separation, hot gas generators, soft landing engines, the emergency escape tower for the Soyuz spacecraft, etc.

Two other firms within the Ministry of Defense Industry deal with powder rockets. One is GSKB-47/GSKB Priborostroenye/GNPP Bazalt at Velyaminovskaya Street no. 32, Moscow. Created in 1938, at factory no. 67, this OKB headed by N.T. Kulakov worked on the first Soviet atomic bomb in 1947-49. Now headed by Anatoli Obukhov, it works on guided aircraft bombs, anti-submarine missiles and anti-tanks weapons. The second is the Institute of Applied Hydro-dynamics/GNPP Region at Kachirskoye Chaussée no. 13A, Moscow. Headed by Evgeny Shakhidzhanov and Boris Mertsalov, it made the Shkval anti-submarine missile. Both employed the guidance systems of NII-173 (now TsNII of automatics and hydraulics at Ulytsa Sov. Armii no. 5, Moscow). Created in 1949, it was recently headed by A.S. Parfenov (1931-1996).

Work on solid propellant was carried out by NII-6 (now TsNII of chemistry and mechanics), factory no. 98 (then NII-130/NII of polymer materials/NPO Kirov of Perm), NII-125 (then NIKhTI/LNPO Soyuz) and the Institute of Applied Chemistry (now NPO GIPKh) of the Ministry for Chemical Industry in Leningrad. NPO GIPKh, which made new solid propellant, was headed by V.S. Shpak from 1952-77, then by B.V. Gidaspov, 1978-88. NII-6, located at Nagatinskaya no. 16a, Moscow began as a chemical laboratory in the powder factory at Okhtinsk in 1894.

Amongst those who worked on pyroxyline, there was A.P. Zakochikov, I.M. Neiman, etc. The OTB office was formed in an institute of the Munitions Ministry in 1938. In 1941, it was divided into three sections, for balistite (powder with nitroglycerine), pyroxyline and pyrotechnic means. Each of these groups was in different factories. Pyroxyline had been mass produced for a long time, but balistite was only at the beginning of its production. It was produced the Morozov factory at Schlissenburg, near Leningrad, from 1931 and at a factory in Pavlograd, in the Ukraine, from 1934 (where 12 t of ammonite exploded on May 12, 1988).

The OTB was a prison (Sharaga). From October 1941 to July 1943, it was evacuated to factory no. 98 at Perm (D.G. Bidinsky, A.G. Kallistov, D.E. Gorbachev, D.I. Galperin). OTB returned to the new factory no. 512, near Moscow, in 1943-47. Then, it was transferred to the Institute of Chemical Technology (NII-125/NIKhTI/LNPO Soyuz). B.P. Zhukov headed this institute, located at Ulytsa Sovietskaya no. 6, Dzerzhinsky, near Moscow, from 1951-1988. It produced the solid propellant for the rockets of S.P. Korolev (RT-1, RT-2), M.K. Yangel (RT-20, RT-23), V.P. Makeyev (RIF), P.A. Tyurin (D-6, RT-15, D-11), A.D. Nadiradze (Pioneer, Topol), S.P. Nepobedimy (Oka, Totchka), etc. Factory no. 98

and the Institute of Polymer Materials (NII-130) became the NPO Kirov of Perm (A.M. Sekalin, L.N. Kozlov, Yu. S. Klyachkin). In 1959, a subsidiary of NIKhTI was created at Biisk (Altai). This institute later became the NPO Altai, headed first by Ya. F. Savchenko, then by G.V. Sakovitch.

The Powder Rockets of OKB-1

In 1958, Yu. A. Pobedonostsev asked S.P. Korolev to make a powder rocket with a range of 2,000 to 3,000 km. At this time, the United States was developing their Polaris and Minuteman missiles. NII-125 proposed to build balistite blocks of 5-6 m long, with a maximum diameter of 1 m, instead of the usual blocks with a maximum diameter of 300-400 mm. However, the press method didn't allow for blocks of more than 800 mm diameter and it was necessary to create a new technique to produce the larger blocks. It was decided to make a cluster of 4-8 blocks of 800 mm to form the first stage. On November 20, 1959, the order for the rocket RT-1 (8K95) was given to Korolev, Zhukov and Pilyugin. RT-1 had to carry a nuclear warhead of 0.8 t, with a range of 2,500 km.

In 1959, TsNII-58 of V.G. Grabin merged with Korolev's OKB-1 and became its powder rocket department (600 people), with sector no. 23 headed by A.G. Donsky (deputy P.F. Muravyev, S.E. Bardenshtein) and no. 24 headed by A.A. Smerdov (deputy D.P. Krutov). The technical director was Korolev's deputy, I.N. Sadovsky, who had contributed to the creation of powder gas generators for liquid engine rockets. His group included E.A. Verbin, F.A. Titov, Yu. V. Sungorov, etc. At NII-125, Pobedonostsev's laboratory became a sector, with the laboratories of I.P. Putintsev (design), I.A. Volovinsky (powder blocks), V.I. Fyonichev (heatshield) and O.N. Ivanov (strength).

The fiberglass casing was made by the winding method in the ElectroIzolit plant headed by Yu. I. Lebedev. The press method worked out by A.S. Bakayev and K.I. Bazhenov in NII-6 had been transferred to factory no. 98, which was producing the three stages of the rocket.

The concept was ready in August 1960. All three stages were composed of four blocks. The diameter of first stage blocks was 800 mm, but those of second and third stage were 700 mm. The mass at take off was 34 t (80% of that weight being propellant), for a range of 2,400 km (by comparison, the Katyusha weighed 42.5 kg, only 17% of which was propellant, for a range of 7.2 km). Guidance was achieved with gimballed powder verniers and aerodynamic fins.

Ground tests were done on a special bench, built by the group headed by A.S. Viktorov at Krasnoarmeisk (near Zagorsk), between March 1961 and March

1963. More than 100 engines were fired (39 blocks and three first stage clusters, 42 blocks and three second stage clusters, 35 blocks and four third stage clusters). NII Geodesia and NII Mechanizatii of the Ministry of Munitions were located at Krasnoarmeisk, while the NII of Applied Chemistry (pyrotechnics) was situated in Zagorsk. Flight tests began in early 1962, at Kapustin Yar. The State Commission was headed by Colonel-General V.I. Voznyuk, L.N. Sadovsky, E.V. Shabarov and P.I. Drebezgov. Nine flights were performed, with only three successes. The first flight was on April 28, 1962, although the first successful test was on March 18, 1963. The last flight was in June 1963.

The rocket weighed 36 t at take off and was 18.3 m long, with a diameter of 2 m. The first stage (4 blocks of 800 mm) had a thrust of 100 t for 30 sec. Pressure in the combustion chamber reached 40 atmospheres. The second stage (2 blocks of 800 mm) had a thrust of 50 t, whereas the third stage thrust (1 block of 800 mm) was 25 t. Three RT-1-1963 rockets were built to test the ICBM RT-2. They were equipped with the prototype of RT-2's third stage. Launched between September and November 1965, there was only one success in three flights.

The order for rocket RT-2 (SS-13 Savage), dated April 4, 1961, was given to Korolev's OKB-1, with participation by: M. Yu. Tsyrulnikov, of the Motovilikhinsk factory near Perm, for the first and third stages; P.A. Tyurin of TsKB-7 at the Arsenal factory in Leningrad (second and third stages); B.P. Zhukov of NII-125 and Ya.F. Savchenko of NPO Altai (solid propellant); N.A. Pilyugin of NII AP (guidance system); V.V. Chernetsky of TsKB-34 (launch system); A.M. Goltsman of NII-686 (electric systems), etc. The chief constructors were S.E. Bardenshtein and F.A. Titov.

The rocket, of 51 t take off weight, was 21.1 m long, with a diameter of 1.84 m. It carried a warhead of 0.6 t to 9,500 km, with an accuracy of 4 km. The 30.8 t first stage had a thrust of 91 t for 75 sec. The 9.6 t second stage produced 44 t of thrust for 60 sec, while the 3.5 t last stage had a thrust of 22 t for 45 s. The propellant was a mixture of butyl rubber-compound, ammonium perchlorate and aluminum. Each stage had four nozzles with fixed and mobile parts (using materials based on graphite, metallic ceramic, Molybdenum and Titanium alloys). The third stage had a throttle-able thrust.

Production began in 1965 and the rocket was immediately shown in Red Square that year, before flight tests. Those 32 flights were performed in 1966-68 (with seven launches from Kapustin Yar and 25 from Plesetsk). At Kapustin Yar, flights were made between February and July 1966 (first success came on Feb. 26), launched from a silo used for one of Yangel's rockets. There was only one failure in this group. Flights from Plesetsk were made between November 1966

and October 1968 from silos (21 were directed towards Kamchatka, 4 towards the Pacific Ocean). The last three flights were fired in a salvo. There were 16 successful flights and 9 failures. The State Commission was headed by General P.V. Rodimov, followed by General A.A. Vassiliyev, then General G.E. Alpaidze. The technical direction was overseen by I.N. Sadovsky and Ya. I. Tregub. The missile became operational on December 18, 1968 and was deployed in 60 silos at Yoshkar-Ola. From 1968, regular flights were carried out (the 100th was in 1979).

An enhanced version RT-2P (8K98P) was tested in Plesetsk between January 1970 and January 1972. It was equipped with new third stage engine, more efficient propellant, more powerful warhead, electronic counter-measures and decoys. There were 15 test flights (12 toward Kamchatka and three towards the Pacific Ocean) with two failures. The State Commission was headed by G.E. Alpaidze. This missile became operational on December 28, 1972. Between December 1974 and December 1975, there were five successful flights of the RT-2P. The lifetime for the rocket was 15 years, and 20 years for the launch system, which then ceased. However, the American Minuteman was lighter, carried a heavier warhead and had greater accuracy.

TsKB-7 began to work on powder rockets starting in 1960. The first project was the SLBM D-6 but, at this time, Soviet technology was not adequate to develop an equivalent of the American Polaris. It was necessary to use powder blocks from the Luna missile (Frog), as was seen on the dummy SSN-4 Snark in 1964. From 1961, TsKB-7 built the second and third stages of RT-2 for the mobile version RT-15 (8K96). The rocket, with a 20 t launch weight, was 12.6 m long and had a diameter of 1.4 m. But the RT-15 (SS-14 Scamp), capable of carrying 1.4 t to 4,500 km, would be abandoned in 1970, after 19 flights. The version using first and third stages of RT-2 (8K97), with a range of 5,000 km, had to be made by KB Mach, under Yu. Tsyrulnikov in Perm: but it was replaced by a RT-2 with a shorter range. In 1961, the RT-15 had been studied as a SLBM for the D-7 system. It was replaced by a RT-15M in 1964, but this was also abandoned.

The first powder SLBM 3M17/R-31 (RSM-45/SSN-17) was produced by TsKB-7 between June 1971 and September 1980. At that time, the tanks of the SLBM, with liquid propellant (Heptil), were filled and sealed at the factory. 3M17 was a medium range rocket using a powder gas generator for silo ejection and ignition of the engine over the water. Ground tests and test-flights were carried between 1976 and 1979. The missile's launch weight was 26.9 t. It was 10.6 m long, with a diameter of 1.54 m and had two monoblock stages. Twelve missiles equipped a Yankee-2 submarine (system D-11) until 1989.

The first one, produced by NPO Iskra in Perm, weighed 7.5 t. Between the first stages of RT-2 and 3M17, there was the monoblock stage of about 25 t, for the first stage of the A-350 missile (Galosh-IB) for the A-35 anti-missile system around Moscow.

Factory no. 172 Lenin of Motovilikhinsk, near Perm, began producing solid propellant rockets in 1955. The rockets were made for I.I. Kartukov, V.N. Chelomei (the engine for the Grom missile, 1969-83), S.P. Korolev (RT-2), P.A. Tyurin (3M17), V.P. Makeyev (RIF/SSN-20), A.D. Nadiradze (Topol) and others. The OKB was headed by M.Yu. Tsyrulnikov, then, in 1976, by L.N. Lavrov, who had been previously working at KB Mach in Miass. The Factory and OKB merged to form the NPO Iskra in 1978.

The Powder Rockets of SKB-586

SKB-586/NPO Yuzhnoye of Dniepropetrovsk (Ukraine), headed by M.K. Yangel, began work on powder rockets in November 1960. The first project, the mobile missile RT-20P/8K99 (SS-15 Scrooge), was produced in December 1964. Test flights were undertaken between October 1967 and October 1969 in Plesetsk, but after 8 flight tests, this contemporary of the RT-15 had been abandoned. The rocket was 30.2 t at take off, 17.8 m long, and had a diameter of 1.6 m. It was equipped with a warhead of 0.54 or 1.41 t, with a range of 7,000 km. The RT-20 was filled with 25.4 t of propellant (85% of its weight). The first stage, with 16.7 t of solid propellant (monoblock), had a thrust of 62 t (sea level). The second stage, with 8.7 t of liquid propellant (N_2O_4-UDMH), had a thrust of 14 t, with a specific impulse of 335 s. Guidance was achieved with four gimballed powder verniers on the first stage. On the second stage, the four nozzles, working with gas from the turbine, were used for roll; but for pitch and yaw, the gas was directed into the nozzle of the main engine.

In January 1969, Yuzhnoye received the order to develop a train-launched ICBM (RT-23). In July 1976, it was decided to use the first stage 3D65 of the SSN-20 (monoblock of 52.8 t) on the RT-23 launched from a silo (15J44). The flight tests were made between December 1982 and April 1985, but in February 1983 it was decided that 15J44 would not become operational, but would be used on a train for an experimental trial. The train-launched RT-23 program began in June 1980 (15J52). Flight tests began in April 1984, with the experimental trials carried out between November 1987 and November 1989.

The program to create an enhanced RT-23 UTTX began in December 1979. In August 1983, it was decided to use the RT-23 UTTX "Molodyetz" in

three versions. Tests of the new stage 15D305, with a moveable nozzle, began in November 1984. The SS-24 has three stages and has a take off weight of 104.5 t, with a diameter of 2.4 m. It was 22.4 m long and carried a payload of 4.0 t (10 warheads), delivered with an accuracy of 0.5 km. The first (15D305) and second (15D339) stages were from the Pavlograd chemical factory, while the third stage came from NPO Iskra in Perm. 15D305 has a moveable nozzle on 15J60 and a fixed one on 15J61 (this stage was 0.2 m longer and 1.2 t heavier, for the train version). The second and third stages had extending nozzles. Guidance was effected by aerodynamic fins on the shroud and small liquid engines on the warhead.

The version RS-22A (the silo-launched 15J160) was tested in flight between July 1986 and November 1988, while the RS-22V (the train-launched 15J61) was tested in flight from February 1985 to December 1987. They are both operational since November 28, 1989. 10 silo units have been deployed and 36 on trains.

The Powder Rockets of SKH-385

SKB-385/KB Mach of Miass (Ural), headed by V.P. Makeyev, began developing a solid propellant SLBM from 1971 (RIF/RSM-52/SSN-20). In October 1975, the production of the 3D65 engine began in Pavlograd. The first static test was made in January 1980 and the first flight test in December 1981. A similar first stage (52.8 t) was used on the SS-24 missile (SKB-586/NPO Yuzhnoye). A third stage was mounted inside the payload, which carried 10 warheads, the guidance system and liquid propellant engines to carry each warhead to his target. The RSM-52 became operational on Typhoon submarines in 1983.

The Powder Rockets of NII-1/MIT

A.D. Nadiradze became section head of tactical rockets at NII-1 in 1958. He developed the Temp-S missile (OTR-22/9K76/SS-12 Scaleboard) between 1958-1962. It consisted of two identical stages of 4.1 t, weighing together 8.2 t without the warhead. The 9.4 t missile was equipped with a nuclear warhead of 1.2 t (range of 900 km). From 1961 to 1987, Nadiradze was director and main constructor of NII-1/MIT. There, he developed the missiles Temp-2S (SS-16), Pioneer (SS-20), Topol (SS-25) and Topol-M (SS-27). When the SS-14 and SS-

15 programs were abandoned, the Army decided to transfer this activity to A.D. Nadiradze at MIT in July 1969.

MIT developed the ICBM 15J42 Temp-2S (SS-16 Sinner) in 1972-74. This missile, with its 44 t take off weight, had three solid propellant stages (each stage with one nozzle). It measured 18.5 m long, with a diameter of 1.79 m and carried a warhead of 940 kg to 9,000 km with an accuracy of 1.2-1.6 km. However, after the SALT-2 treaty, it was abandoned. Then, the first mobile IRBM, 15J45 Pioneer (RSD-10/SS-20 Saber) was tested in Kapustin Yar from September 1974 to January 1976. It was launched like a mortar, with the help of a powder gas generator.

The rocket, weighing 37 t at launch, used two stages taken from Temp-2S. Guidance was achieved with aerodynamics fins and gas ejection from the first stage nozzle, then by cold gas injection in the nozzle (second stage). They were mass produced by the Votkinsk Factory, near Izhevsk, and the first regiment was formed in August 1976. More than 400 missiles replaced the older R-12 and R-14 in eastern and western parts of the country, before being eliminated by the INF treaty: 72 missiles were launched without failure.

In July 1977, MIT received the order for the ICBM 15J58 Topol (RT-2PM/RS-12M/SS-25 Sickle). This 45.1 t rocket was 21.5 m long, with a diameter of 1.8 m. It carried a warhead of 1.0 t to its target with an accuracy of 0.9 km. Flight tests were made from 1983 to 1987 and the missile became operational in December 1988. The new version, Topol-M (SS-27), is 22.7 m long, with a diameter of 1.95 m, and has a take off weight of 47.2 t. It carries a warhead of 1.2 t (550 kt). Flight tests were made from December 1994 to 1998. MIT received help from TsNII SpecMach of Khoktovo. This organization, headed by general director V.D. Protasov, specializes in composite materials. Serial production is carried out at the Votkinsk factory, near Izhevsk. Headed by V.G. Sadovnikov, this factory has mass produced the solid propellant rockets SS-20, SS-23, SS-25, SS-26, SS-27.

The Powder Rockets of KB Mach

KB Mach, headed by B.I. Shavyrin, had been created from SKB of NII-13 and the mortar group of Factory no. 7 in 1942. It was transferred to Factory no. 4 in Kolomna near Moscow. This organization, headed by S.P. Nepobedimy in 1965, built the short range missiles SS-21 Totchka and SS-23 Oka.

Summary

Solid propellant rockets were built by:

- NII-147/NPO Splav in Tula (BM, Smerch, Uragan).
- NII-1/MIT under Nadiradze in Moscow (Frog/Luna, SS-16, SS-20/Pioner, SS-25/Topol): in association with the factory of Votkinsk, near Izhevsk (Udmurtia).
- OKB-1 under Korolev, from 1960 (RT-1, RT-2/SS-13, RT-15/SS-14 by I.N. Sadovsky): in association with Factory no. 172 of Motovilikhinsk, near Perm, and the Arsenal factory in Leningrad.
- SKB-586 under Yangel, from 1960 (RT-20P/SS-15, RT-23/SS-24 by P.I. Nikitin): in association with the Pavlograd factory (Ukraine).
- TsKB-7 under Tyurin (SSN-17): in association with the Arsenal factory in Leningrad.
- SKB-585/KBM under Makeyev, in Miass (SSN-20): in association with the factory of Zlatoust (Ural) and Krasnoyarsk (KrasMach).
- KBM under Nepobedimy in Kolomna (SS-21/Totchka, SS-23/Oka): in association with the factory of Votkinsk, near Izhevsk (Udmurtia).
- KB-2/MKB Iskra under I.I. Kartukov in Moscow: in association with Factory no. 81.
- OKB-52/NPO Machinostroyenya of Chelomei in Reutov (sea-to-sea missiles).
- OKB-155-2 "Raduga" under Bereznyak in Dubna (air-to-ground missiles).
- OKB-455 "Zvezda" in Kaliningrad (air-to-ground missiles).
- OKB-2 "Fakel" under Grushin, in Khimki (ground-to-air missiles): in association with the "Nord" factory in Leningrad.
- OKB-8 "Novator" under Lyulev, in Sverdlovsk (ground-to-air missiles): in association with the "Kalinin" factory in Sverdlovsk (Ural).
- OKB-4 "Molniya" under Bisnovat, in Tushino (air-to-air missiles).
- OKB-134 "Vympel" under Toropov, in Tushino (air-to-air missiles): in association with the Kommunar of Moscow factory.
- PO "Chapayev" in Cheboksar (the "Alazan" rocket).

Appendix 1: Biographies

P.N. Goremykin (1902-1976): Deputy Minister of Munitions, 1942-46; Minister of Agricultural Machine-building 1946-53; deputy of MOP, 1953-55; Minister of MOM, 1955-57.

V.V. Bakhirev (1916-1991): Graduated Moscow University in 1941; engineer in "Degtyarev" factory at Kovrov, near Vladimir, where he became director; first deputy of MOP in 1965; Minister of Machine-building, 1968-87; HTS in 1976, PL in 1964, PE in 1978.

B.M. Belyusov (1934): Graduated Taganrog Institute of Radiotechnic in 1958; work at Izhevsk, where he headed the mechanical factory; deputy in 1980, then first deputy of MOP in 1985; Minister of Machine-building in 1987; then Minister of MOP in 1989; CTS, PL, President of MetalKhim.

A.S. Bakayev (1895-1977): DTS in 1944; Professor in 1950; PE in 1946-47; work in OTB of NII-6, at Factory no. 98, then at NII-125.

D.I. Galperin (1903-1977): Work at OTB of NII-6; main engineer in Factory no. 98 in 1943; scientific director of an institute in Ural.

A.D. Artyushenko (1905-1976): Director of the Morozov factory at Schlissenburg, near Leningrad.

Yu. I. Krasnoshekov (1927): Graduated MVTU in 1952; work in NITI; then director of the TsNII of Chemistry and Mechanics; academician in 1984; HTS in 1976, PL and PE.

K.N. Shamshev (1925): graduated MVTU in 1952; worked in GSKB-47, 1952-64; then at the TsNII of Chemistry and Mechanics (deputy director in 1976); MC AN SSSR in 1987, PL in 1984, PE in 1979.

B.P. Zhukov (1912): Graduated Moscow Chemico-technology Institute in 1937; work in NII-6 (powder for Katyushas); director of NII-125 (NIKhTI), 1951-88; Deputy Minister of MOP, 1953-55. He developed a solid propellant generator of cold plasma for a MGD installation. Academician in 1968, HTS in 1966-82, PL in 1976, PE in 1951-67.

Yu. A. Pobedonostsev (1907-1973): Graduated MVTU in 1930; work in TsAGI, in GIRD, in RNII in 1933; Colonel-Engineer in Germany, 1945; main engineer of NII-88, 1946-47; Professor at Academy of Defense Industry, 1947-56 (Vice Chancellor in 1950); head of department at NII-125, 1956-73. DTS, Professor, PE in 1941.

Z.P. Zak (1939): Graduated Lvov University; general director of NPO Soyuz, 1988-95. DTS in 1985, Professor in 1987, PL in 1984, PE in 1980.

Yu. Milekhin: general director of NPO Soyuz in 1995.

N.A. Krivosheyev (1930): Graduated Moscow Chemico-technology Institute in 1954; work in NII-125 (from engineer to first deputy in 1988); Deputy President of scientific council for solid propellant at Academy of Sciences; MC AN SSSR in 1979, PL in 1976, PE in 1967.

V.V. Vengersky (1932-1989): Graduated MVTU in 1956; work in NPO Soyuz, where he became deputy general director. DTS, Professor, MC AN SSSR 1981, PL in 1966, PE, 1977.

Ya. F. Savtchenko (1913-1984): general director of NPO Altai, 1959-84. CIS 1967, Professor 1980, HTS 1971-83, PL in 1976.

G.V. Sakovitch (1931): Graduated Tomsk University in 1953; work in NPO Altai, where he became general director in 1984. DTS 1969, Professor 1972, MC AN SSSR 1981, Academician 1992, HTS in 1990, PL in 1984, PE in 1970.

L.N. Kozlov (1927): Graduated MVTU in 1955; work in NII of polymer materials; became general director of NPO Kirov. Specialist in Chemistry and the technology of special materials. MC AN SSSR in 1987, HTS, PL, PE.

Yu. S. Klyachkin (1934): Graduated from Chemico-technology Institute of Kazan, 1959; work in NII of polymer materials; work at Institute of Mechanics in Sverdlovsk, 1983; then director of Chemico-technology Institute of Perm, 1985; MC AN SSSR in 1991.

V.S. Shpak (1909): general director of GIPKh, 1952-77; Academician in 1981, HTS in 1961.

B.V. Gidaspov (1933): general director of GIPKh, 1978-88; President of TechnoKhim (Leningrad), 1988; First Secretary of Leningrad region PC, 1989; MC AN SSSR in 1981, PL in 1976, PE in 1981.

N.K. Egorov (1929): DTS 1974, Professor 1976, PE 1979, specialist in chemico-technology, solid propellants and composite polymer materials.

I.N. Sadovsky: deputy main constructor of OKB-1; DTS, Professor, PE 1973.

P.A. Tyurin (1917): Graduated MVTU in 1941; work in Factory no. 92, 1941-53; chief and main constructor of TsKB-7 in Arsenal factory, 1953-81; work on missiles D-6, RT-2, RT-15, D-11; PE 1968.

L.N. Lavrov (1933-1994): Graduated Mechanical Institute of Leningrad, 1956; work in OKB Makeyev, 1968-76; then main constructor of PO Iskra (NPO in 1987); MC AN SSSR in 1987, HTS in 1984, PL in 1990, PE in 1973.

A.D. Nadiradze (1914-1987): Graduated Moscow Aviation Institute, 1940; chief and main constructor of SKB in TsAGI in 1941-46; main constructor in OKB, 1946-50; in KB-2/NII-642, 1950-58; in NII-1/MIT, 1958-87 (director in 1961). Academician in 1981, HTS 1976-82, PL in 1966.

B.N. Lagutin (1927): general constructor at MIT, 1987-97. DTS 1983, Professor 1986, HTS in 1977, PL in 1966, PE in 1981.

Yu. S. Solomonov: general constructor at MIT; DTS, Professor.

Nikolai Karyagin: deputy general constructor at MIT.

V.D. Protasov (1931): DTS 1975, Professor 1978, MC AN SSSR 1987, HTS in 1990, PL 1976, PE in 1981.

V.G. Sadovnikov (1928-1990): Graduated Kazan Aviation Institute, 1953; work in Dniepropetrovsk factory; then in mechanical factory of Izhevsk; then in factory of Votkinsk (director, 1966-88). Twice HTS and PE.

B.I. Shavrin (1904-1965): Graduated MVTU, 1930; main constructor at KB Mach, 1942-65; DTS 1952, FITS 1945, PL 1964, PE 1942, 50, 51.

S.P. Nepobedimy (1921): Graduated MVTU, 1945; main constructor KB Mach, 1965-89; MC AN SSSR in 1984, HTS in 1971, PL 1964, PE 1969, 76, 81.

N.I. Gonenin (1932): Graduated Radiotechnic Institute of Riazan; work in KB Mach, where he became chief and main constructor in 1989; DTS in 1992, PE 1984.

A.S. Ter-Stepanian (1918-1996): Graduated MVTU; work in KB Mach, 1946; deputy main constructor; HTS, PL, PE.

Evgeny Shakhidzhanov: general director of GNPP Region; DTS, Professor, PL.

Boris Mertsalov (1931): Graduated MVTU, 1955; work in KB Mach, TsKB Loutch, NII Mach until 1975; then NII of Applied Hydrodynamics, 1975-86; main constructor of GNPP Region, 1986.

Appendix 2: Acronyms

NII: Institute of Scientific Research

KB, OKB, TsKB: design office

MB: Munitions Ministry

MSKhM: Agricultural Machine-building Ministry

MOP: Ministry of Defense Industry

MM: Ministry of Machine-building

MOM: Ministry of General Machine-building

MAP: Ministry of Aviation Industry

MVTU: Bauman Technical University

CTS: Candidate in Technical Sciences

DTS: Doctor in Technical Sciences

MC AN SSSR: Corresponding Member of the Academy of Sciences

HTS: Hero of Socialist Labor

PL: Lenin Prize

PE: State Prize

Appendix 3: Bibliography

Books

Military Space Forces, T.I , 1997.

"Strategic Missile Forces," *Russia's Arms Catalog* (vol. 4), Military Parade and Zig-Zag, 1997.

Rakety Nad Moryem, Alexander Shirokorad, Tekhnika & Voruzhenye, Nov/Dec 1997.

Energiya 1946-1996, 1996.

Intercontinental Ballistic Rockets of the USSR and USA, E.B. Volkov, 1996.

Strategicheskoye Raketno-Yadernoye Oruzhiye, S.G. Kolesnikov, 1996.

Iz Istorii Razvitia Raketnoye Tekhniki i Kosmonavtiki, 1995.

Chronicle of Basic Events in the History of RVSN, 1994.

Dniepropetrovskii Raketno-Kosmicheskii Tsentr, 1994.

Nautchnaya Elita: Kto Est Kto v Rossiiskoi Akademii Nauk, 1993.

Rossiiskoye Raketnoye Oruzhiye 1943-1993, A.V. Karpenko, 1993.

Raketnye Voiska Strategicheskovo Naznachenia (RVSN), 1992.

Iz Istorii Aviatsii i Kosmonavtiki" from IIET RAN.

"Shchit i Metch *Satan*-Strategicheskoye Oruzhiye Mikhail Yangel," *Soverchenno Sekretno*, no. 1, 1993.

Magazines

Military Parade and *Aerospace Journal.*

Krylia Rodina and *Aviatsia i Kosmonavtika* (A&K).

Nevskii Bastion no. 2/97, no. 1/98, supplement no. 1, 1996 (mobile rocket complexes for strategic forces), supplement no. 3, 1997 (S-300), supplement no. 4, 1998 (PRO and PKO). *Novosti Kosmonavtiki.*

Booklet

50 years of LNPO Soyuz, 1997.

LES FUSÉES A ERGOLS SOLIDES EN URSS

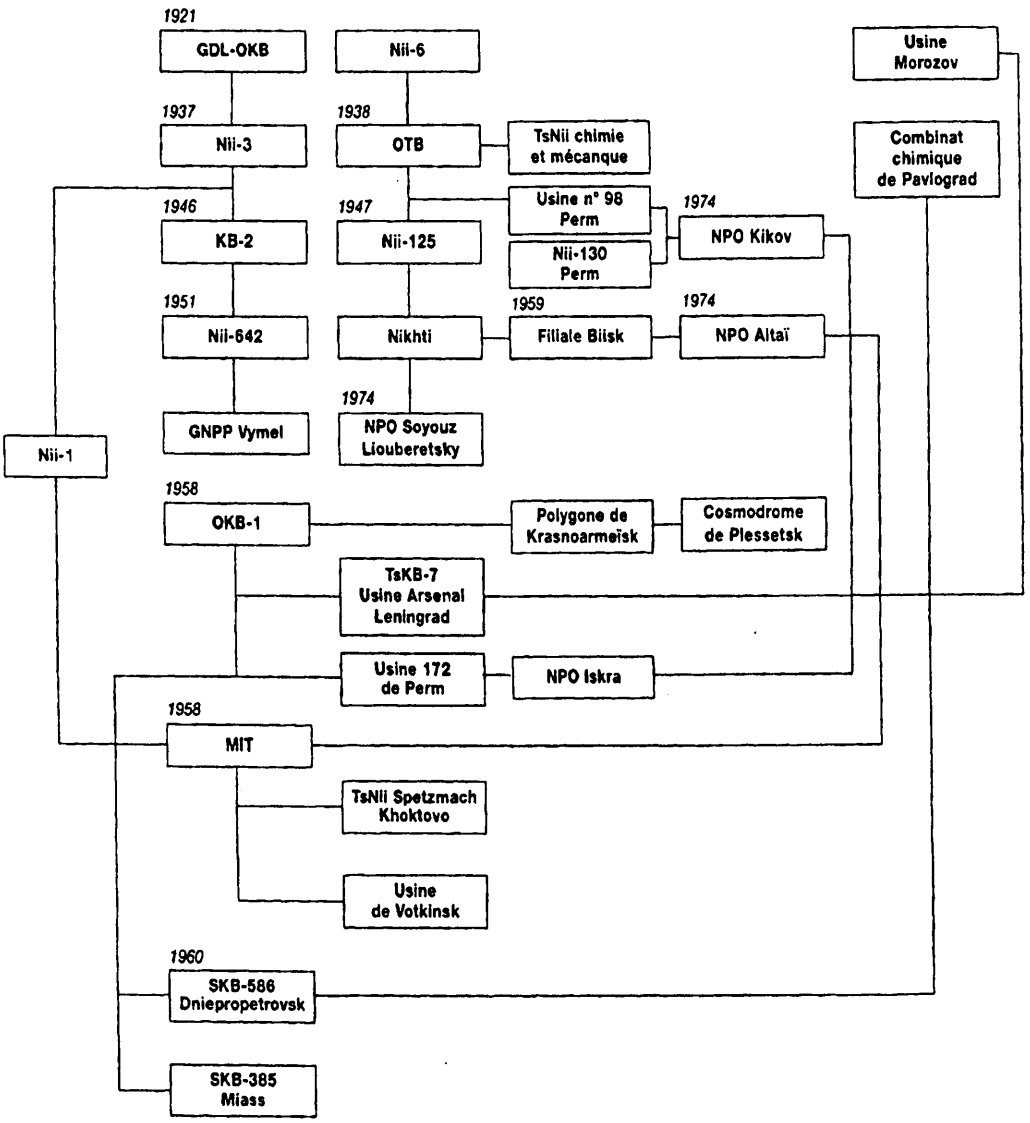


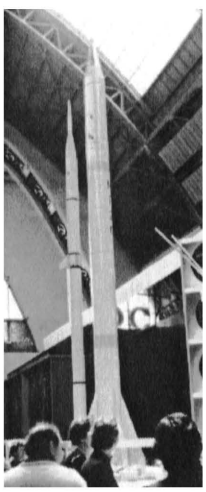
Diagram showing the relationships of Soviet factories and design offices involved in the development of solid propellant rockets.

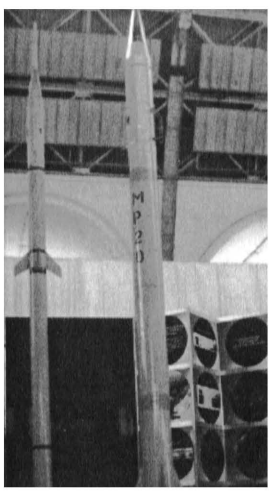
Russian Solid Rocket Motors

Design	Production	Deployed
MIT Moscow	Mechanics Factory of Votkinsk (Izhevsk)	SS-25 SS-27
KB Mach Kolomna	Mechanics Factory of Votkinsk (Izhevsk)	SS-26
KB Mach Miass (Chyelabinsk)	Chemical Complex of Pavlograd NPO Altai (Biisk) NPO Iskra (Perm)	1st stage SSN-20 1st stage SSNX-28 2nd and 3rd stages
NPO Yuzhnoye Dnicpropetrovsk	Chemical Complex of Pavlograd NPO Iskra (Perm)	1st stage SS-24 2nd and 3rd stages
OKB Novator Sverdlovsk	Kalinin Factory at Sverdlovsk	SA-12/SH-08
OKB Fakel Khimki	Sever Factory at St. Petersburg	SA-10/SH-11
NPO Mach Reutov	NPO Iskra (Perm)	Sea-sea missiles
OKB Raduga	MKB Iskra (Moscow)	Air-ground missiles
OKB Molniya	MKB Iskra (Moscow)	Air-air missiles
OKB Vympel	MKB Iskra (Moscow)	Air-air missiles
OKB Zvezda	MKB Iskra (Moscow)	Air-ground missiles

Missile	RT-15 8K96	RT-25 8K97	RT-2 8K98	RT-2P 8K98P	R-31 3M17
First stage thrust design office	15D27 42 t TsKB-7	15D23 91 t KBM/Perm	15D23 91 t KBM/Perm	15D23P 100 t KBM/Perm	3D17 59 t TsKB-7
Second stage thrust design office	15D92 22 t TsKB-7	15D25 ? KBM/Perm	15D24 44 t TsKB-7	15D24P 44 t TsKB-7	? 23,8 t KBM/Perm
Third stage thrust design office			15D25 ? KBM/Perm	15D94 18 t KBM/Perm	

Rocket/ missile	Russian code name	NATO-code name	Type	Develop-ment	Tests	Remarks
RT-20P (30 t)	8K99	SS-15 Scrooge	Mobile (silo-launched in 1965)	1964/70	10/67 to 10/69 (12 fir-ings)	Solid-fuel first stage Liquid-fuel second stage
RT-21 (42 t)	15J41		Rail	1963	Aban-doned	
RT-22					Aban-doned	
RT-23 (80 t)	15J43		Rail	1969	Aban-doned	
RT-23 (80 t)	15J44	SS-24	Silo	1976	1982/83	
RT-23 (104 t)	15J52	SS-24	Rail	1980	1983/85	Experimental project
RT-23UTTX Molodetz	15J61	SS-24	Rail (Selina-2 mo-bile launcher)	1983	1985/87 (32 fir-ings)	Deployed until 2003
RT-23UTTX	15J60	SS-24	Silo (More power-ful than the rail version)	1983	1986/88 (28 fir-ings)	Deployed until 2003





MR-12 **MR-20** **M-100 to M-130**

Soviet solid-fuel meteorological rockets. MR-12 and M-100 were designed by N.P. Mazurov, also responsible for the Luna rocket series.

Frog-0

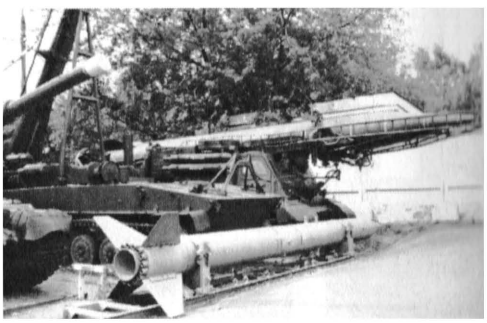
Пусковая установка комплекса "Филин" (FROG-1).

Frog-1

Frog-2

Frog-3

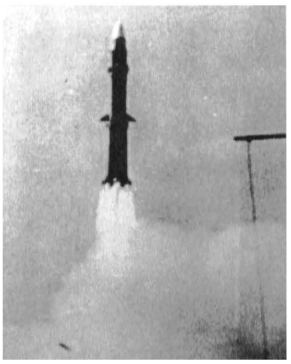
Frog-7



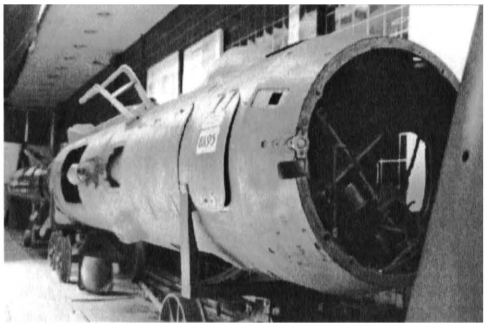
Frog Scud

Frog Series

"Frog" series of missiles (also known as Luna-M), a product of the NII-1 institute (later MIT). Designed by N. P. Mazurov



RT-1



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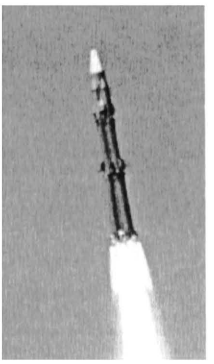
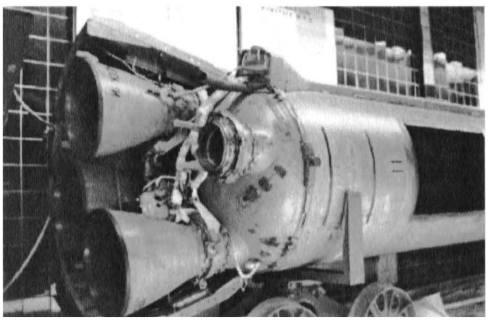
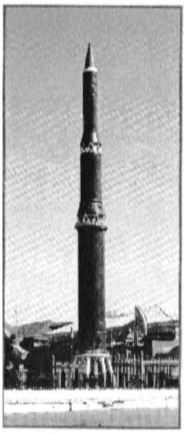


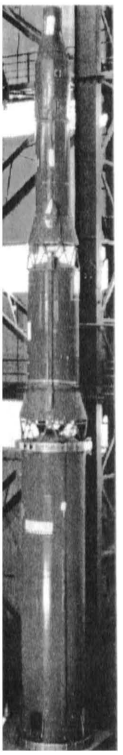
RT-1



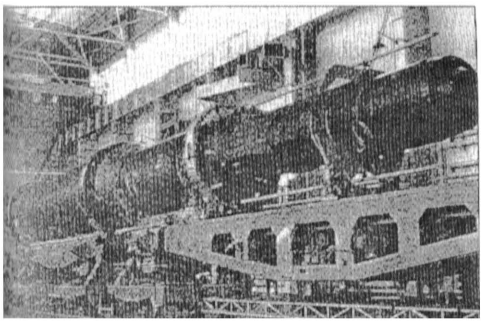
RT-1



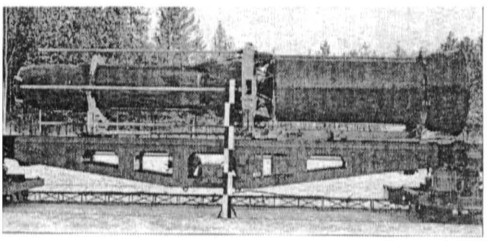
RT-2



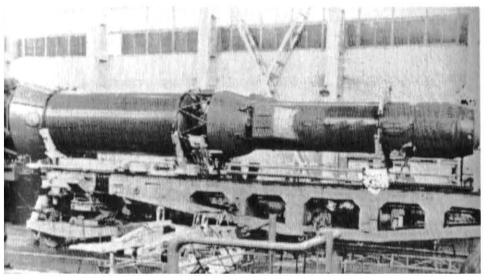
RT-2



RT-2

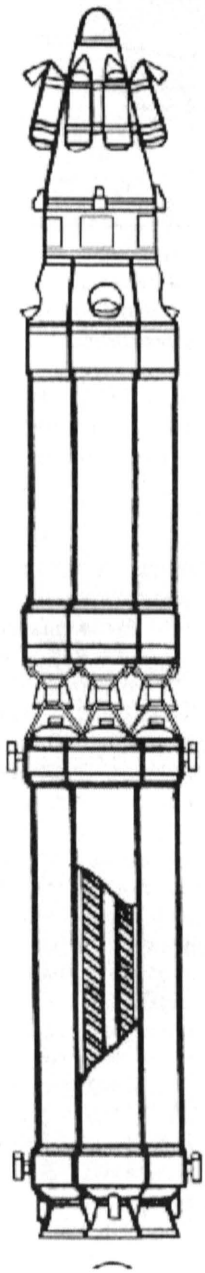


RT-2

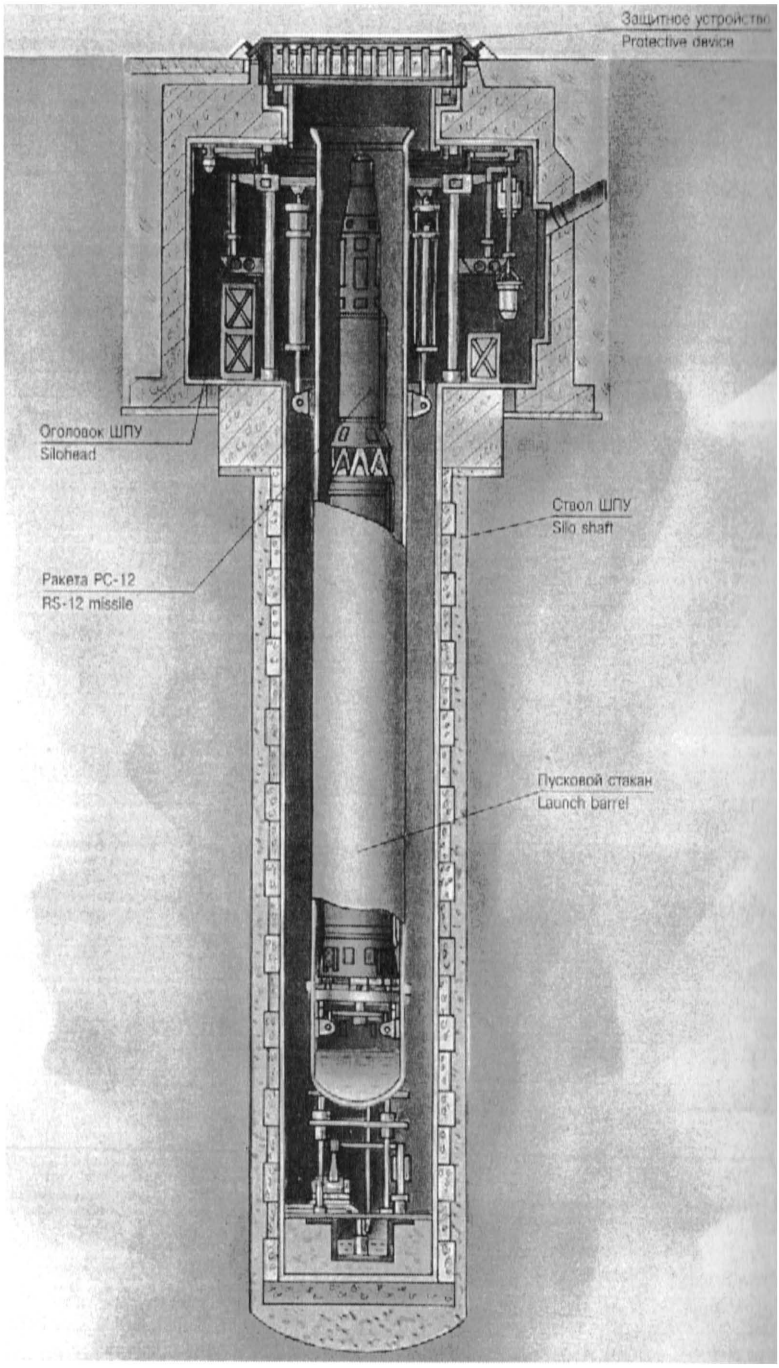


RT-2

Products of Sergei Korolev's OKB-1. The RT-1 was the first large Soviet solid propellant ballistic missile. Developed and tested in 1959-63, it did not go into production. Its successor, RT-2 (SS-13 Savage) was the first Soviet solid propellant ICBM, first deployed in 1968. It had mobile and silo-launched versions.

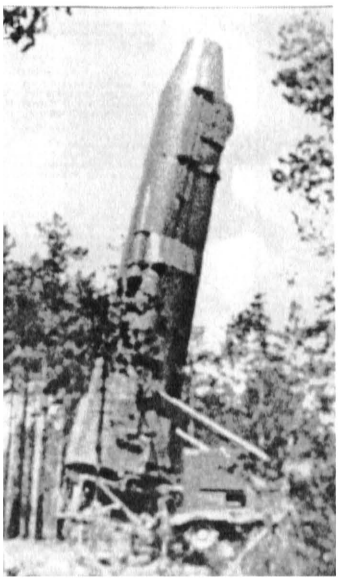


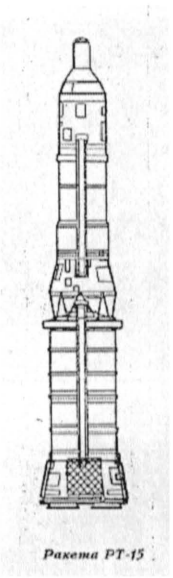
D-6

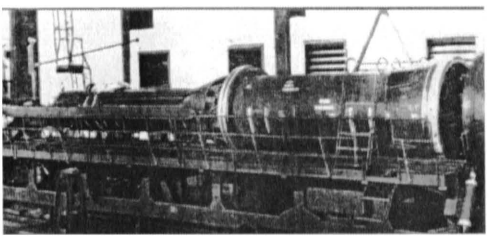


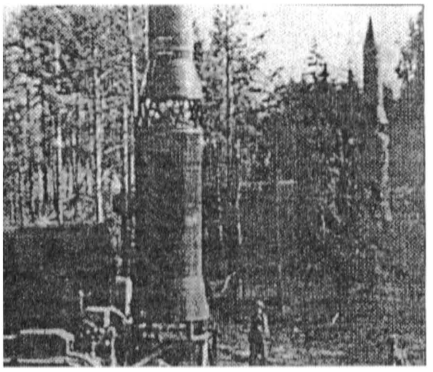
RT-2

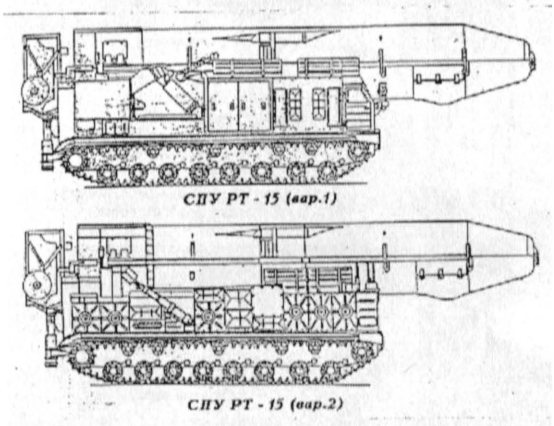
(left) D-6, an unsuccessful submarine launched ballistic missile design developed in the early 1960s by TsKB-7. (right) Diagram of the silo-launched variant of the RT-2. RT-2 missiles were initially deployed in 1968, in 60 silos at Yoshkar-Ola.

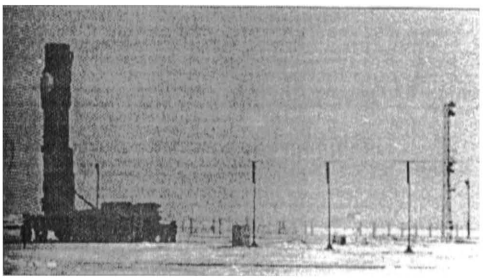


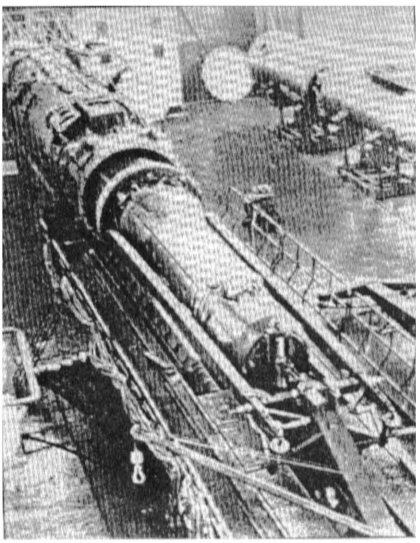






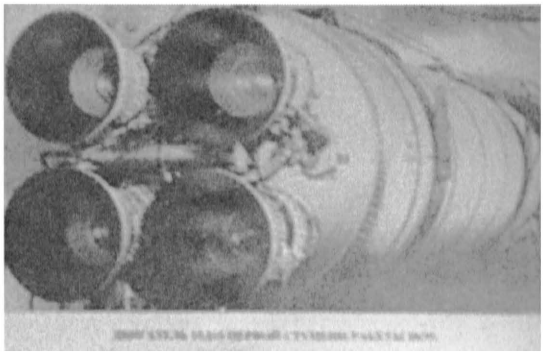




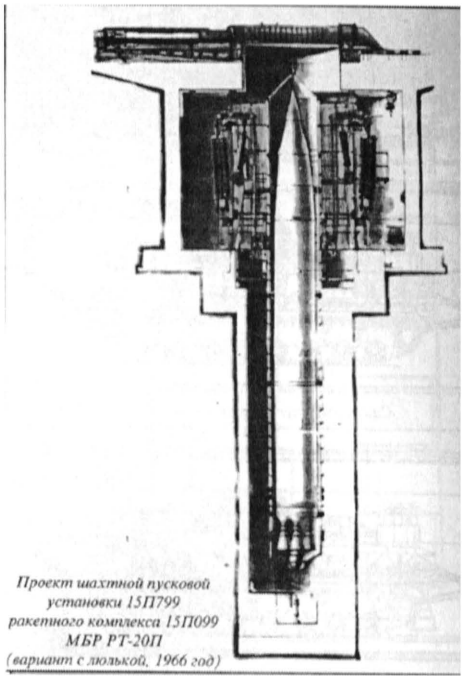


RT-15 Photos: The RT-15 (SS-14 Scamp) IRBM utilized the TsKB-7 2nd and 3rd stages of the RT-2 in its design. After a lengthy development period, only a limited number were ever deployed.

8K99



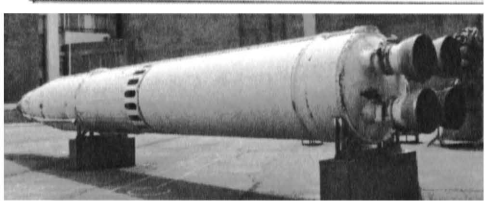
8K99



Проект шахтной пусковой установки 15П799 ракетного комплекса 15П099 МБР РТ-20П (вариант с люлькой, 1966 год)

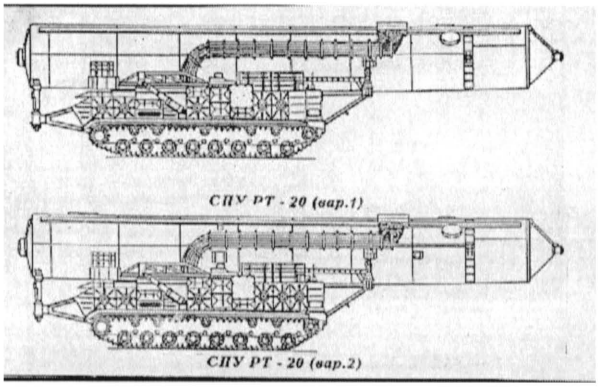
Рис. 3.8.
Межконтинентальная баллистическая ракета РТ - 20 (в транспортно-пусковом контейнере)

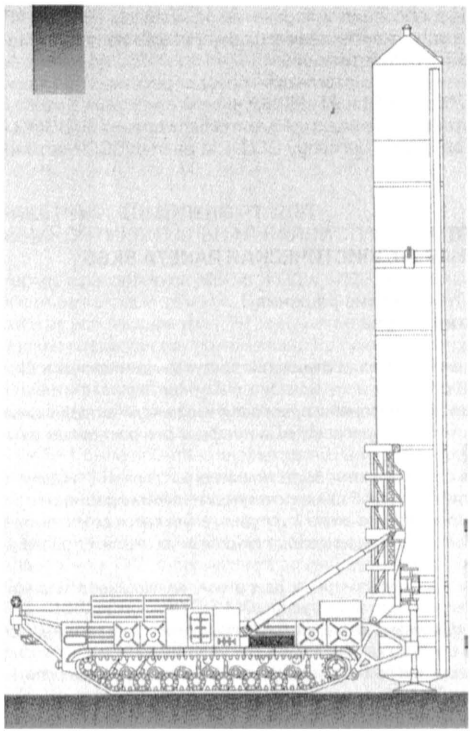
1 - транспортно-пусковой контейнер;
2 - сбрасываемый наконечник головной части;
3 - головная часть;
4 - приборный отсек;
5 - демпфирующий конус;
6 - бак окислителя II ступени;
7 - демпфирующая перегородка;
8 - бак горючего II ступени;
9 - маршевый ЖРД II ступени;
10 - переходник с газозащитным экраном;
11 - пороховой двигатель конечн ступени тяги;
12 - маршевый РДТТ I ступени;
13 - поворотные сопла РДТТ I ступени;
14 - стартовый пороховой аккумулятор давления.

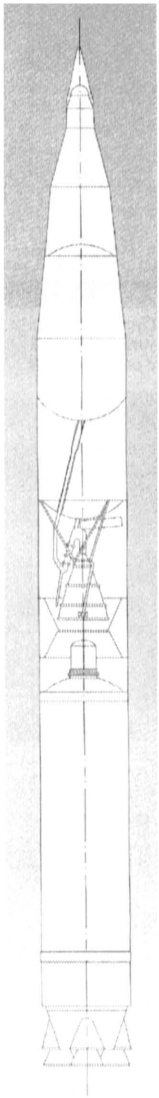


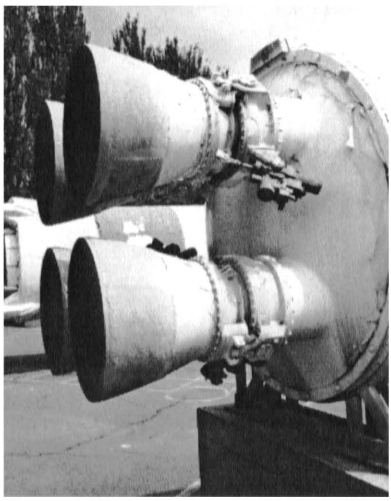
RT-20 Photos

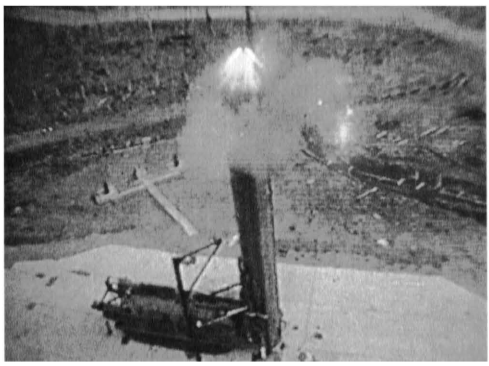
SKB-586/NPO Yuzhnoye headed by M.K. Yangel produced its first solid rocket , the RT-20P (Soviet designation 8K99; NATO code name SS-15 Scrooge), in 1964. Designed for mobile launching, there were also plans for a silo-launched version.

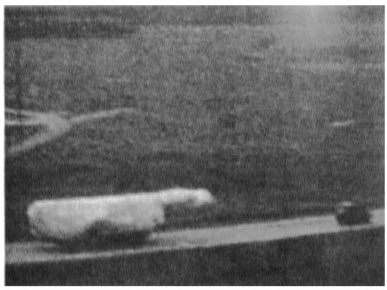


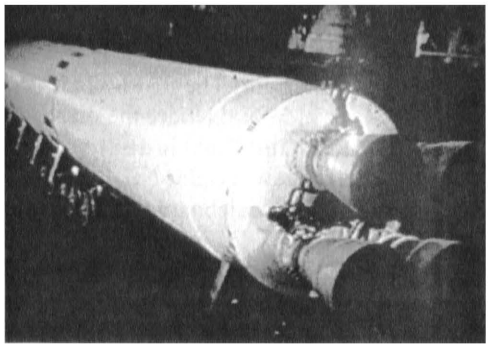






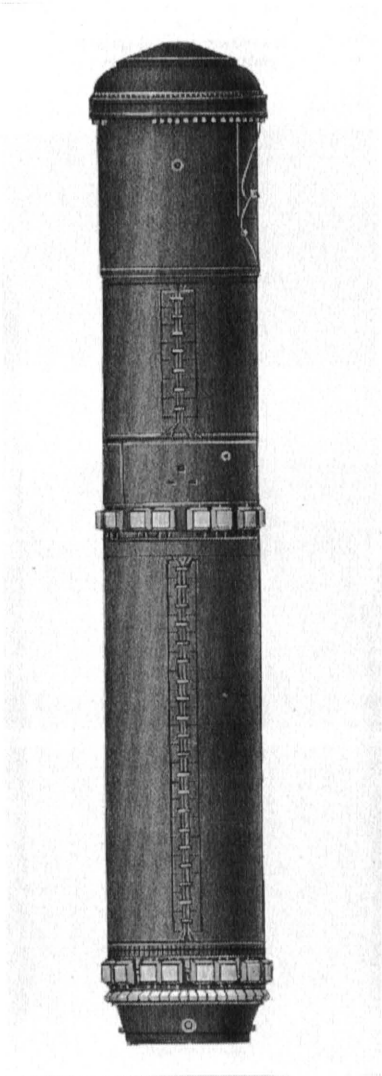




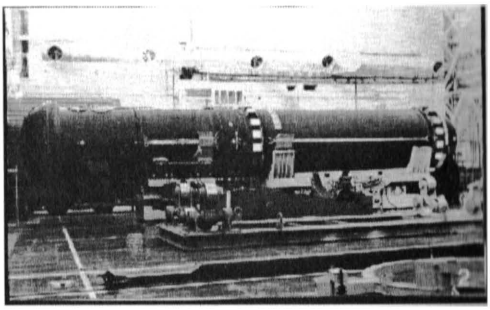


The two-stage RT-20 combined a solid-propellant 1st stage motor with a liquid-propellant second stage. After 8 test flights, between 1967-69, this contemporary of the RT-15 was abandoned.

RT-20 Photos

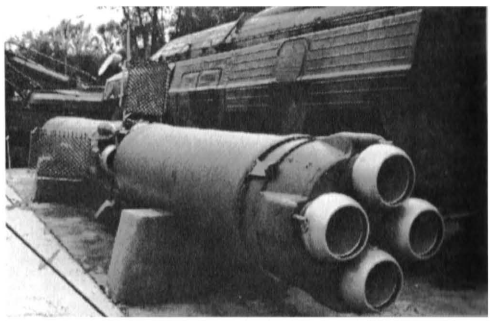


SSN-20



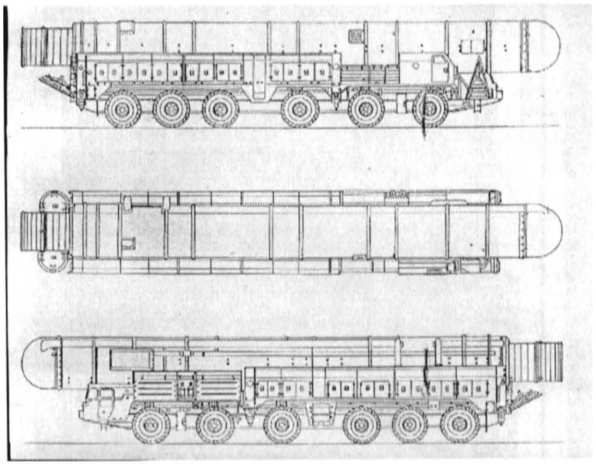
SSN-20

SS-12

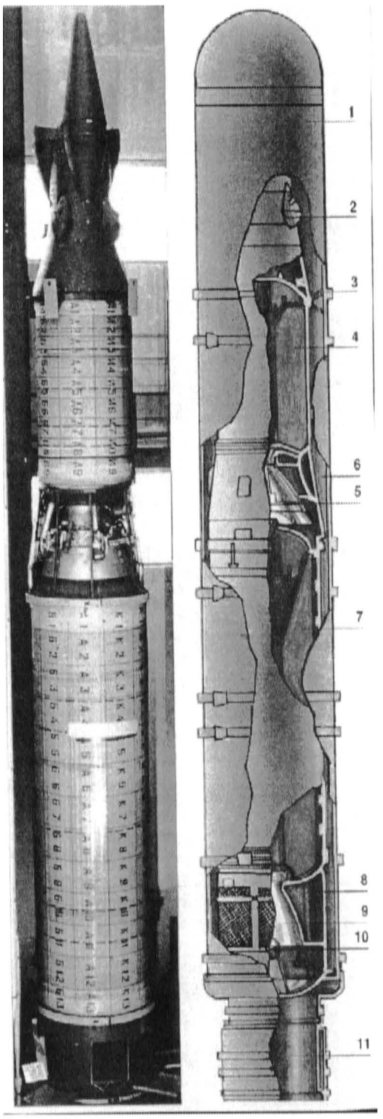


SS-12

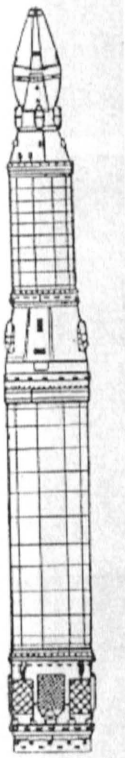
(left and top right) The RSM-52 (SSN-20, Sturgeon) SLBM was developed by SKB-385/ KB Mach in Miass. Under the direction of V.P. Makeyev, development began in 1971, with the first test flight in 1981.
(middle and lower right) NII-1, under A.D. Nadiradze, designed the nuclear-equipped 9K76 (SS-12, Scaleboard), which had a 900km range.



SS-20



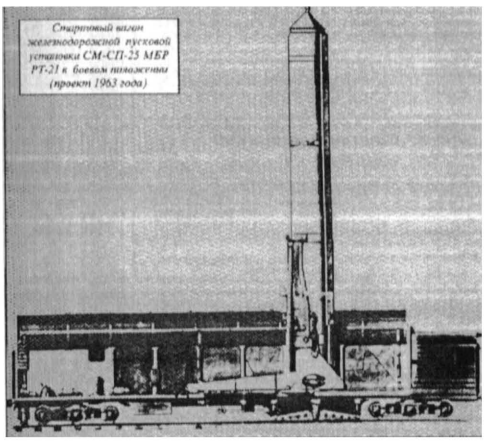
SS-20



Внешний вид БРСД "Пионер"

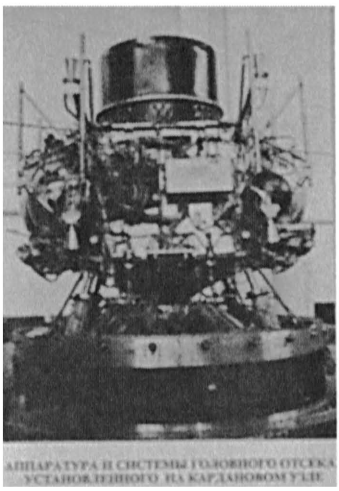
SS-20

SS-20



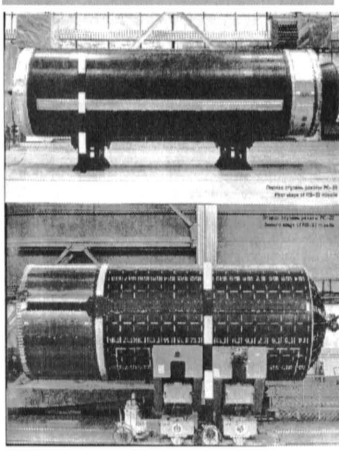
RT-21

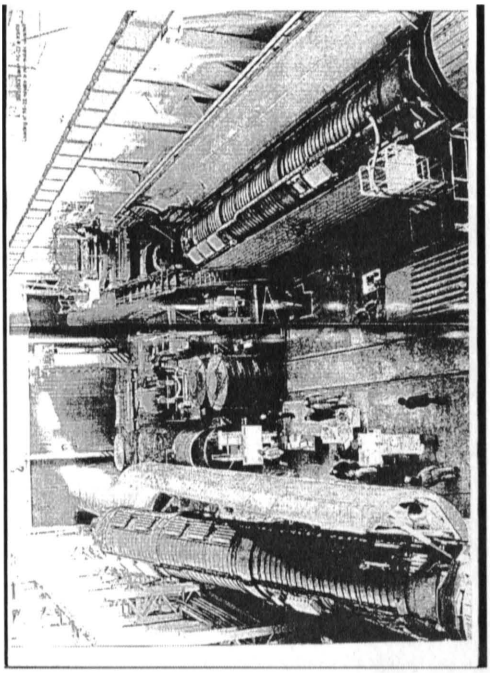
The RT-21 Pioneer (SS-20 Saber) was another product of Nadiradze's NII-1/MIT design bureau, built by the Votkinsk factory, near Izhevsk. Tested between 1974-76, it was deployed in August 1976.

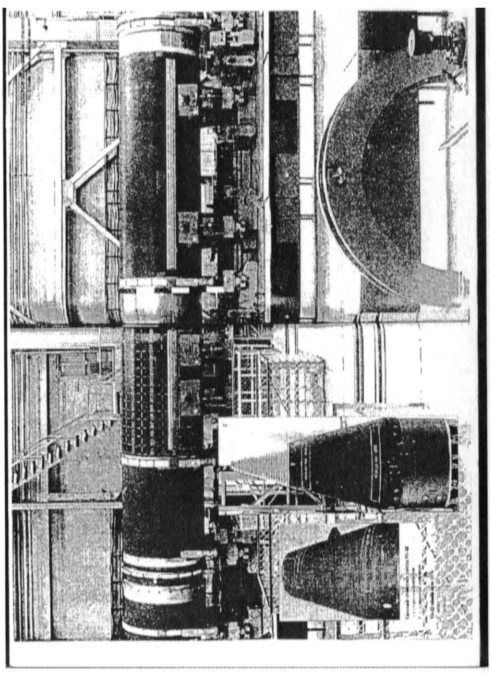


АППАРАТУРА И СИСТЕМЫ ГОЛОВНОГО ОТСЕКА, УСТАНОВЛЕННОГО НА КАРДАНОВОМ УЗЛЕ

НА РАКЕТЕ 15Ж60 ПРИМЕНЕН ОБТЕКАТЕЛЬ ИЗМЕНЯЕМОЙ ГЕОМЕТРИИ

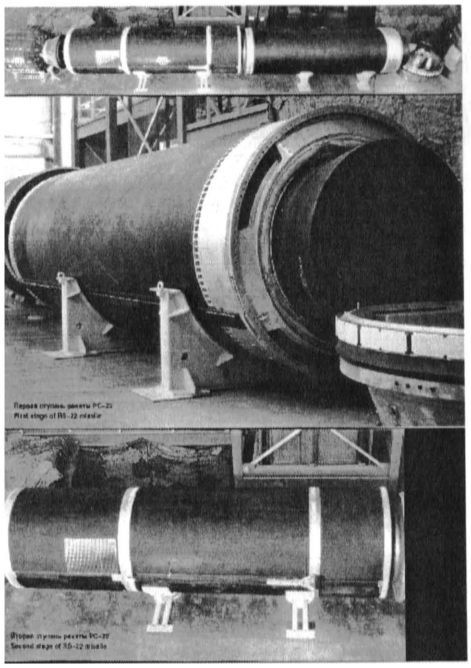


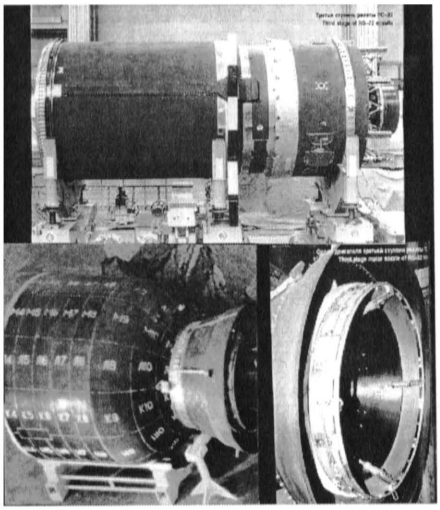


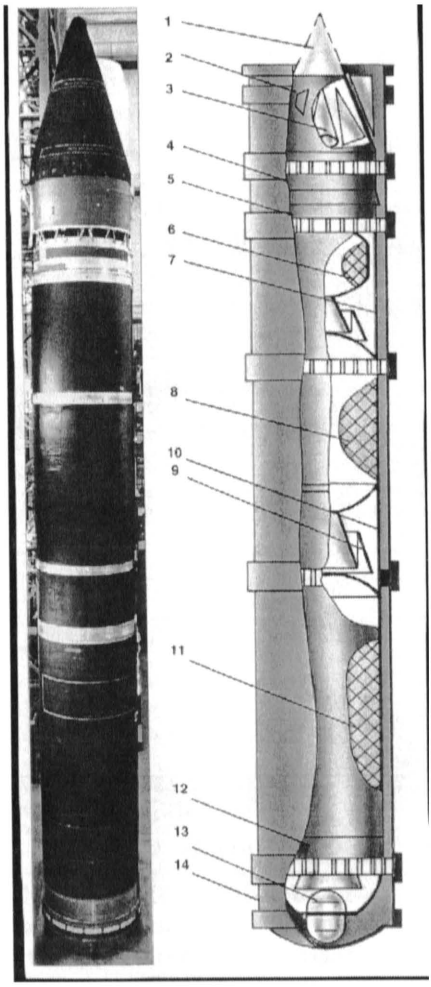


SS-24 Photos

The RT-23 (SS-24, Scalpel) was a 3-stage missile with silo and rail-launched variants, designed by Yangel's 586/NPO Yuzhnoye in the Ukraine. The missile carried 10 MIRVed warheads.

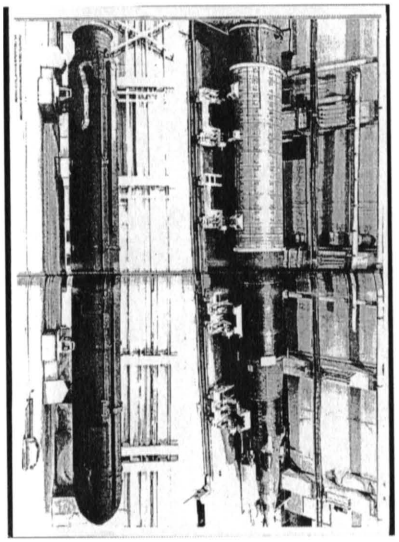


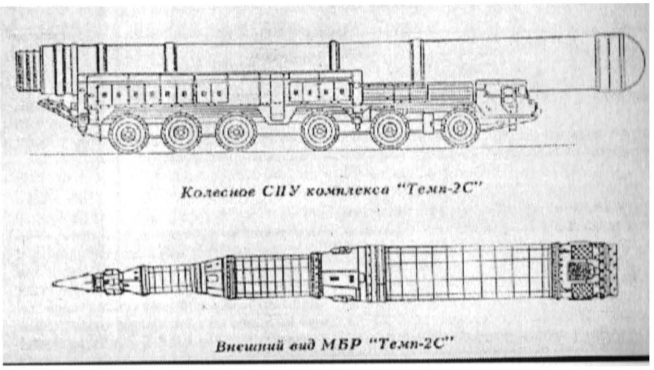


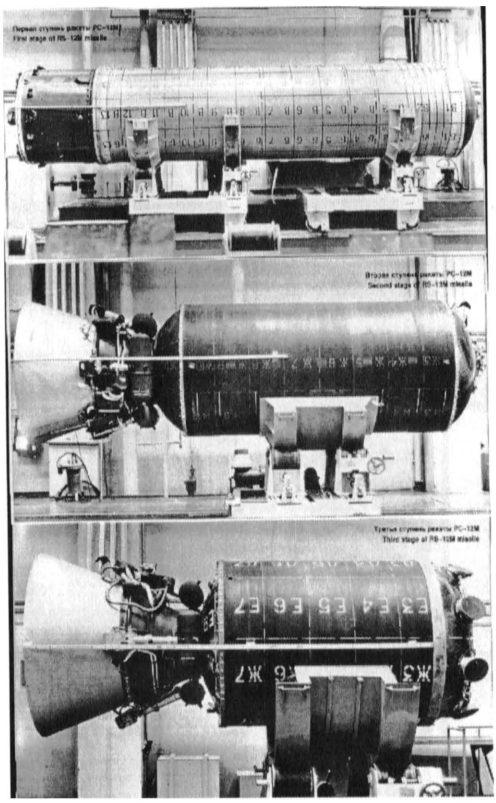


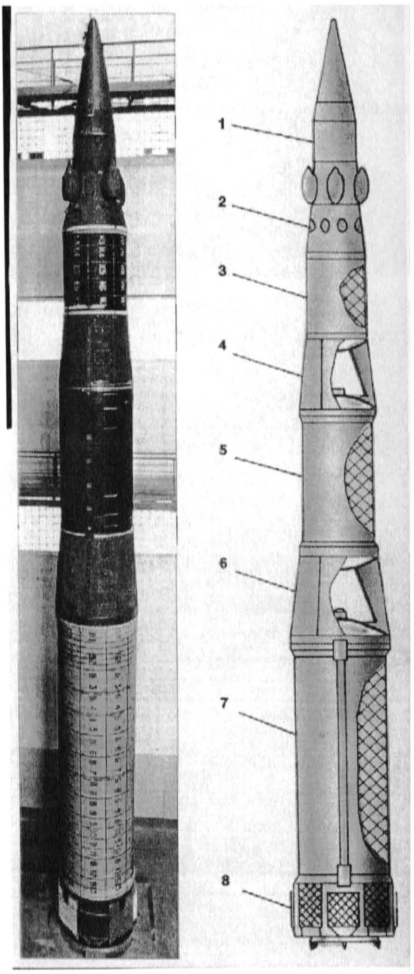
SS-24 Photos

The rail-launched version of the RT-23 was the first rail-launched ICBM to be operationally deployed.



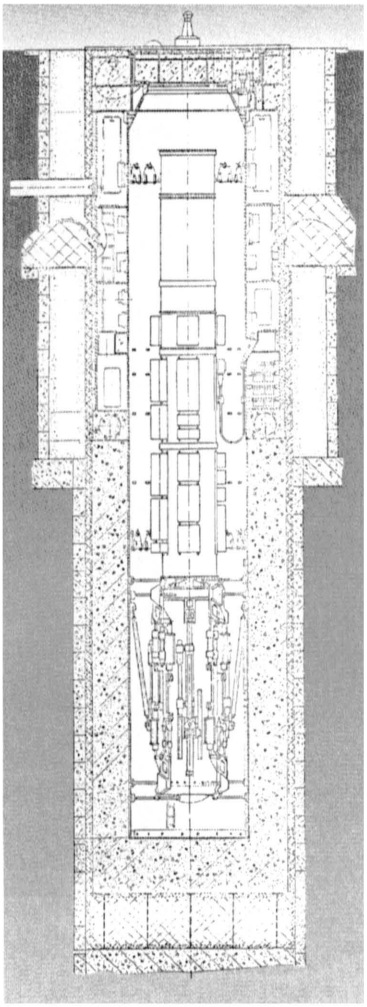




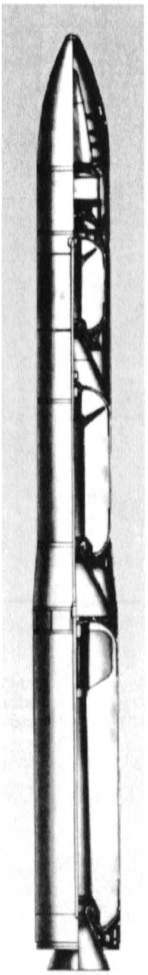


SS-25 Photos

Nadiradze's MIT design office (formerly NII-1) developed the RT-2PM Topol (SS-25, Sickle) mobile ICBM, which became operational in 1988. The missile carried a warhead of 1.0 t. There was also a silo-based variant.



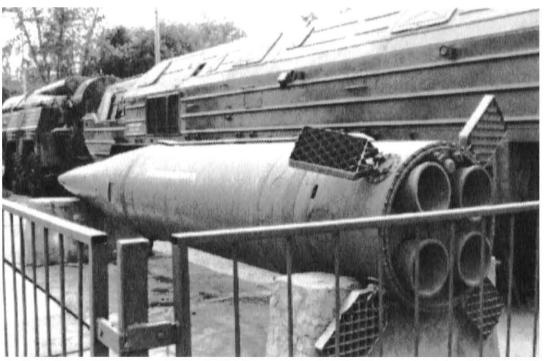
SS-27



SS-27

Totchka-U

(top left) First deployed in 1997, the Topol-M (SS-27) is the advanced version of the RT-2PM Topol. (upper and right) The Totchka (SS-21 Scarab) is a short-range tactical ballistic missile designed by KB Mach as a replacement for the earlier Frog missile. The 9K714 Oka (SS-23 Spider) was a KB Mach stable mate to the Totchka, with a range of 450 km.



Oka