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Chapter 3

Liquid Propellant Engines in the Soviet Union*

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The history of the liquid rocket engine (LRE) in the Soviet Union began with the theoretical works of Konstantin Tsiolkovsky, the father of cosmonautics. Initially, his rocket projects were to use liquid oxygen and hydrogen. But later, he proposed the use of other propellants like hydrocarbons and recommended another type of rocket using radium disintegration.

In 1924, Friedrich Tsander (1887-1933) elaborated upon a project of a rocket-plane and built his first rocket engine, the OR-1, in 1930. Tsander also helped create the Group for Study of Reactive Motion of Moscow (MosGIRD) of Osoaviakhim in the beginning of 1931. Their first project was the rocket glider RP-1 that was to be equipped with the OR-2 engine using liquid oxygen and gasoline.

The first liquid rocket engines, also known as ORMs, of rocket engine designer Valentin P. Glushko, had also been tested at the GDL (Gas Dynamics Laboratory) in 1931. In May 1932, Sergei P. Korolev (1906-1966) [the future Chief Designer of rocket vehicles in the USSR—ED.], replaced Tsander as the head of GIRD. The GIRD-8 rocket, launched in August 1933, actually used a hybrid engine (gasoline solidified into a colophane gel), The second rocket, the GIRD-10, was launched in November 1933 and used an LRE (liquid oxygen and gasoline).

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Then in 1933, the GIRD (Group for Study of Reactive Motion) merged into the RNII (Institute for Reaction) that equipped practically all the Soviet liquid fuel rockets developed up to 1946. Their thrusts reached up to 300 kg for the ORM-52 (one chamber), 500 kg for ORM-57 (one chamber), and 600 kg for the ORM-58 (two chambers). Then, Glushko worked on nitric acid-kerosene engines and L.S. Dushkin on liquid oxygen-kerosene engines.

In 1938, however, Glushko went into prison in Kazan [due to the Stalinist purges—ED.] and Dushkin took over the nitric acid-kerosene engines. The last ones developed by Glushko were the combined KRD-600 (1,278 kg thrust) and D1-A-1100 (1,100 kg thrust) engines which were modified by A.M. Isayev in 1943 as the RD-1 engine. During this time, Glushko tested in flight the RD-1KhZ (300 kg thrust) at Kazan.

In 1944, Glushko, Dushkin, and Isayev became chief designers of the NII-1. They went to Germany in 1945 and Glushko took over the German engine of the V-2 that was rebuilt in plant No. 456 at Khimki in 1946 as the Soviet RD-100 [the Soviet version—ED.] with a thrust of 25 tons). Dushkin produced the RD-2MZV engine with a thrust of 1.4 tons for the I-270 rocket plane of Mikoyan and RM-1 of Moskalev. He became chief of the OKB-1 at NII-1 in 1952-1957.

Isayev took over the head of sector No. 9 at NII-88 in 1948 (producing the 9TN engine with a thrust of nine tons). But it was N.L. Ournansky (1908-1967), Chief of Sector No. 8 in 1946-1948, who received the order to develop engines for the R101 anti-aircraft missile (based on the WW II German Wasserfall), made by E.V. Sinilshikov, and the R-102 (based on the German WW II Schmetterling), made by S.E. Rachkov.

The Wasserfall (3.5 tons) was smaller than the V-2 at a scale of 1/3 and was equipped with an engine of eight tons of thrust (nitric acid, or "Tonka" as propellant). The tank's pressurization was ensured by a gas pressure accumulator (VAD). About 30 flights were conducted between October 1949 and January 1950. The speed was 300 m/sec and the range was 5 km. Sinilshikov, A.P. Eliseiev [probably A.S. Yeliseyev—ED.], I.N. Sadovsky, V.A. Goviadinov, N.N. Cheremetievsky, G.N. Babakin, and N.L. Oumansky, *et al.*, took part in these flights.

The Schmetterling (420-445 kg) was equipped with the 109-558 engine of 375 kg thrust and two solid propellant boosters. Flight tests were conducted in January 1950. The speed was 250 m/sec and the range was 13 km.

The R110 missile (based on the WW II German Taifun) was developed as a liquid propellant version (using nitric acid-kerosene) by P.I. Kostine (Chertok missile). A PAD replaced the Wasserfall's VAD. But the results were not good and this work was transferred at the end 1952 to the OKB-3 of D.D. Sevruk (mis-

sile 3R7/Korchoun), whereas a solid propellant variant was transferred to the NII-642 of A.D. Nadiradze (missile Strij). I.N Sadovsky and Isayev modified the Wasserfall further. The VAD (gas) was replaced by a PAD (powder). The engine was a 9TN whose first ground test failed on 9 Feb. 1948. These tests continued, but without success because there were combustion instabilities.

In May 1949, Isayev decided to replace the 9TN with an S-09-29 using four chambers with two tons of thrust. Then, on 23 Sept. 1950, [Semyon A.—ED.] Lavotchkin decided to use it on the 205/V-300/R-113 anti-aircraft missile of the S-25/Berkut system (or SA-1 Guild). The 205 (3.5 ton) missile made its first flight at Kapustin Yar on 25 July 1951. Later, there were 2,313 produced between April 1952 and 1954.

In 1950, Isayev decided to divide the combustion chamber into four parts. For this purpose, he placed a cross of 100-mm height (as an anti-pulsation dividing wall) inside the injection head. The first ground test on 15 Aug. 1950 was a success. In 1951, Isayev realized that the S2-145 one chamber engine with a PAD for the R-1 1 rocket of [Sergei P.—ED.] Korolev would replace the R-1 (270-km range).

At the same time, this engine was installed on the 206 missile, but combustion instability of the solid propellant appeared during flight tests and the program was canceled. In 1952, an S09-2.9 using only two of the four chambers was installed on the 207 missile to increase the duration of the active part of flight, but during flight tests, the new propellant damaged the chamber walls. The engine was then replaced by an S2-145 on the 207A missile. Flight tests were conducted during 1953-1954 and the missile was mass produced. The 208 was developed with an engine equipped with a PAD. Flight tests were conducted in 1953, but the program was abandoned for the benefit of the 207A at the beginning of 1954.

In March 1952, Isayev's sector became OKB-2 and D.D. Sevruk, Glushko's deputy, took over as the head of OKB-3 at NII-88. The mass production of the S09-29 began at plant No. 66 at Zlatoust in 1953 before it was moved to plant No. 586 at Dniepropetrovsk in 1954. In May 1955, the S-25 system was declared operational. About 3,200 fixed launching sites were deployed around Moscow until 1958. For the S-25M system, missiles were equipped with turbopump engines of 17 tons thrust. The 217 missile received an S3-42A of Sevruk, whereas 217M and 218 versions were equipped with the S-5-1 engine of Isavev. The last one used a spherical chamber with goffered red walls. Flight tests were conducted during 1958-1962.

In 1955-1958, S.A. Kosberg (OKB-J54/KBKhA) developed the RD-0200/R01-154 engine for the 400 (5V11) missile that Lavotchkin had designed

for the DAL system (SA-5 Griffon) which was to be deployed around Leningrad. Flight tests were conducted at Sary-Shagan during 1958-1962 but all interceptions failed. In June 1961, the three stage 420 missile was developed for the DA system with a non-nuclear ABM capacity. Tests were made at Sary-Shagan in 1962. But work was abandoned in 1964 in favor of the V-360 missile built by P.D. Groushin (the S-200 system). Lavotchkin had also studied the 425 missile, a derivative of the DAL system, for the ABM A-35 system. The latest was abandoned in lieu of the A-350 Grushin missile.

In 1950, Lavotchkin realized the 210 missile, a derivative of the 205 for the air-to-air G-300 system. In 1952, the 211 version was equipped with an Isayev engine of two thrust levels allowing the suppression of the initial booster and the increase of the ballistic characteristics. Flight tests were conducted at Kapustin Yar at the end of 1952 but the program was canceled. Another air-to-air missile, the K-7 with the Kosberg D-7 engine and semi-active guidance, was developed by L.I. Toropov for the E-150 fighter in 1956-1958. But it too was abandoned.

In 1955-1962, Dushkin realized the A6-12 engine with two thrust levels (4,000-1,500 kg) and the KRR-300 engine with three thrust levels (ten tons, 3,000 kg, and 100 kg) for V-600 and G-300 anti-aircraft missiles of Lavotchkin.

In 1954, Isayev realized the engine of 3.1 tons thrust for the V750 missile that Grushin designed for the S-75/Dvina anti-aircraft system that was declared operational in 1957. The missile was then modified into V-750V (1ID), V-750VN (13D), V-755 (17D), V-758, V-760, 5Ya23 and the 5V29 versions. In 1961, Grushin developed the V-860 (5V21) missile for the S-200 system (SA-5 Gammon). It was tested at Sary-Shagan in 1962 and came to be deployed around Tallin [Estonia—ED.] in 1963. But it was operational only in 1967. The V-850 missile served in 5V28 and 5V28M versions.

In 1956, Grushin developed the V-1000 rocket from the V-750 for the A system at Sary-Shagan. The first flight was on 24 November 1960. But there were five failures to intercept R-5 rockets.

Each failure had different origins. On 31 December 1960, it was the sixth failure of that type. On 13 January 1961, the V-1000 failed at 39 seconds into the flight. The next four flights were also failures. The first successful non-nuclear interception was on 4 March 1961. On 26 March 1961, a R-5 warhead filled with 500 kg of trotyl exploded during interception. Then, an R-12 warhead was destroyed on 9 June 1961. In total, there were to be 11 hits in flight. In 1959, Grushin studied the V-1100 missile equipped with the RD-020J Kosberg engine. Then, in 1962, he built up the A-350 (Galosh-IA) for the A-35 system. It was a vehicle of 32 tons with three stages (solid propellant booster and LRE). It was expected to receive the first Russian rocket engine with a movable nozzle that

had already been tested on the missile when the test bench in Nijny-Selda had been commissioned for the UR100 missile of [Vladimir N.—ED.] Chelomei in 1963. There was no more place for a new bench and the LRE with movable nozzle was abandoned in place in 1963 of the engine for the UR-100's second stage. The latter was designed by OKB-117 of S.P. Izotov and produced by A.S. Mevius (1910-1969) at plant No. 466 at Krasny Oktiabr in Saint-Petersburg. The missile was seen on Red Square in a demonstration parade in October 1964. But it was to be tested with the experimental Aldan system of Sary-Shagan only after 1965. An interception succeeded on 29 November 1969. Moreover, the A-35 system A-35 was declared operational only in 1977.

On his side, Isayev realized an LRE with 10.5 tons of thrust for a Grushin missile in 1956. It was original because the turbopump's axis was coincident with the chamber's axis, one of the turbine's covers serving as the chamber's bottom. But this model of linear engine was transferred to Mevius for further development. From 1963 to 1969, Isayev also produced engines of 17 and 18 tons of thrust for the 5Ya24 and 5Ya25 missiles (the 5Ya26 of Lyulev and 5Ya27 of Grushin—both with solid propellants—were part of the S-225 system studied between 1966 and 1978).

In 1950-1951, Isayev created a liquid pressure accumulator (JAD) for the S2-253 engine of 8.3 tons thrust used on the R-11 rocket in 1953. The last was launched from a submarine in 1955. From this time, Isayev made nearly all the LREs used on [Viktor P.—ED.] Makeyev's SLBMs. Thus, the R-13 was equipped with a main chamber and four verniers with 25 tons of thrust and the R-21's engine of 40 tons of thrust with four combustion chambers. Isayev realized the first fully welded engine in 1957. This permitted them to be plunged inside the tanks of the R-27 (one stage), the R-29 (two stages), the R-29R (two stages) and the R-29RM (three stages). The first stage of the R-29RM was equipped with an RD0243 engine of 83 tons thrust and was made by OKB-154. It had the highest pressure with 275 atmospheres in a normal regime (or 325 atmospheres maximum). Only the RD-701 of Energo-Mash was to be equivalent with a pressure of 300 atmospheres in a tri-propellant regime.

In 1958, Isayev modernized the R-11 with a new engine of 13.38 tons thrust and equipped with a turbopump. The missile became the famous R-17, or Scud-B.

During this time, Glushko developed engines derived from the one in the V-2. This scheme of combustion chamber with double wall welded point-by-point for regenerative cooling was used for the following engines: in 1949, the RD-101 of 35 tons thrust, and, in 1953, the RD-103 of 44 tons of thrust. In parallel, he studied the RD-110 engine of 120 tons thrust (with pressure of 60 atmos-

pheres) for the R-3 rocket during 1947 to 1951. (On his side, A.I. Polyarny of NII-I did not succeed in developing his engine due to too many innovations.). Glushko produced a spherical welded chamber in which the cooling was assured by water circulation in a closed loop. But it was not a success. In 1949-1951, a new experimental ED-140 chamber of seven tons thrust was built with a cylindrical chamber of 240 mm in diameter and regenerative cooling (double wall) and, for the first time, a cooling with tangential swirling of coolant on the internal wall of the chamber (film cooling). In 1952-1956, a chamber of 600 mm in diameter was built in many examples with different variants of elements made to mitigate high frequency instabilities that appeared when the chamber diameter was increased. This was done for the RD-105 engine of 55 tons thrust that was designed for the four boosters of Buran's missile designed by V.M. Myasishchev. Tests were carried out with an engine using elements borrowed from the RD-103.

But the firing test did not give the expected results. It was needed to resolve the problem of combustion stability inside the chamber. For this reason, chambers with smaller dimension had to be built. Thus, in 1954, Glushko proposed the RD-107 engine with four chambers of 25 tons thrust to equip the R-7 rocket of Korolev. The chamber diameter was then 430 mm. This time, everything was all right. However, Glushko refused to develop the R-7's vernier engines and OKB-1 had to make them. For this reason, the engine sector of M.V. Melnikov was created in Korolev's OKB. At take off, the R-7 ignited its 20 main chambers and 12 verniers (32 nozzles in all). In 1960, it was equipped with a third stage engine (the RD-0110) and a fourth stage engine (the S1-5400).

Since 1952, Glushko developed engines of 55 tons of thrust using nitric acid-kerosene propellant under the arrangement of four chambers. The RD-214 version with four chambers of 18.5 tons (pressure of 44 atmospheres) was developed during 1955-1957 for the R-12 rocket of [Mikhail K.—ED.] Yangel. In this period, Isayev developed the S-2-1150 engine with four chambers of 17 tons thrust for the two boosters of the Buria missile designed by Lavotchkin. Plant No. 500, "Tchernychev" of Tushino, made the serial production of this engine. The Buria missile flew 18 times between June 1957 and December 1960, but the work was stopped when the R-7 was declared operational. The S-2-1150 served as the basis for the 11D49 engine of the Cosmos rocket (11K65) second stage.

Since 1958, Glushko started encouraging storable propellants instead of liquid oxygen favored by Korolev. Moreover, he refused to develop liquid hydrogen engines. Thus, he realized the following engines: the RD-215 (two chambers of 44 tons), the RD-216 (two RD-215s), the RD-217 (two chambers of 37.5 tons), the RD-218 (three RD-217s), and the RD-219 (two chambers of 45 tons). However, the RD-217 presented high frequency instabilities during flight tests in

1961. This chronic problem was resolved by modifying the hydraulic canal of injectors in the stage of serial production.

During this time, Glushko was delaying the development of the RD-111 and RD-119 engines for Korolev. The latter was working on three versions of the R-9 rocket. One used liquid oxygen (the 8K75) with the RD-111 engines of Glushko and the RD-0 106 of Kosberg. The second, with nitric acid (the 8K76) had a first stage with four engines of 40 tons thrust of Isayev. Then, the third one (the 8K77) was using four NK-9 engines of N.D. Kuznetsov (of 40 tons thrust each) and four S1-5400 engines of Melnikov (6.8 tons of thrust each). During ground tests, the RD-111, with four chambers of 35-tons of thrust each, also presented high frequency instabilities. But despite this, the engine was chosen for the R-9 that was to be declared operational only in 1965.

The RD-119, of 10 tons of thrust, had been requested for use in the Block-E version of the R-7 in 1958. The R-7 finally received the RD-0105 developed by Kosberg in eight months when the RD-119 was to be finished at the end of 1961 It was to be used for the second stage of the Cosmos rocket (I 1K63). The problems between Korolev and Glushko then became very serious. In 1962, Korolev decided to work only with Kuznetsov for his GR-1 and N-1 rockets.

The OKB-276 of Kuznetsov had been formed from the plant No. 2 of Kuybychev in May 1949. Some 1,901 Germans were transferred to this engine plant in October 1946 (then factory No. 145), whereas 1,703 others were assigned to plant No. 1 at Podberezie near Doubna, 492 to Gorodomlia (a subsidiary of NII-88), 157 to plant No. 500 in Tushino, 67 to OKB-456 of Glushko, and 16 to plant No. 16 in Kazan.

In 1959, Premier Nikita S. Khruschev, who did not trust anyone in aviation, transferred a part of the Soviet aeronautical industry into the rocket sector. Thus, beside Kuznetsov, other engine designers began to make LREs. The OKB-300 of A.A. Mikoulin and S.K. Turmansky developed the R201-300 engine for the X-22 missile, the R209-300 for an unknown vehicle, the R203-300 for the US satellite, and the R204-300 for the IS satellite. In 1964, the subsidiary of Touraievo at Lytkarino near Moscow became the TMKB Soyuz that was to be headed by V.G. Stepanov, D.D. Guilevitch and V.G. Komissarov. The TMKB produced many orientation and stabilization engines for satellites. The OKB-117 of V. Ya. Klimov and S.P. Izotov, developed the 15D13 second stage engine for the UR-100 missile of Chelomei and the A-350 of Grushin. Finally, the OKB-165 of A.M. Liyulka was to work in the field of cryotechnic propulsion.

In 1962, three global rocket FOBS (Fractional Orbital Bombing Systems) projects were in competition. These were the GR-1 (R-9M with the third stage/8K713) of Korolev, the GR-2 (UR-200B/8K83) of Chelomei, and the GR-3

(R-360rb/8K69) of Yangel. Two versions of the GR-1 were foreseen. The first stage was to be equipped with four NK-9 engines of 37 tons thrust each. But the second stage could be furnished with an NK-9V engines or four S1-5400s. Then, the third stage was to be equipped with an 8D726 or another Kosberg engine. The 8D726 of Melnikov began ground tests in 1963 (Some 230 engines were built and 5,000 ground tests were made). But the project was abandoned and the GR-3 chosen instead.

For the N-1, Korolev was to use 150-ton thrust engines (using liquid and kerosene) whereas Glushko developed a 680-ton thrust engine (N204-UDMH) for the competitive UR-700 project of Chelomei. The first stage of the N-1 was to be equipped with 30 NK-15/NK-33 engines each of 154 tons thrust (six in the center and 24 peripherals). For the guidance, four roll engines (11D121) were developed by Melnikov. The second stage had eight engines (NK-15V/NK-43) each of 179 tons thrust. The third stage had four engines (NK-19/NK-39) each of 41 tons thrust. Then, the Block-G was to be equipped with one NK-21/NK-31 of 41 tons thrust. All these engines were using closed cycle ("gas-liquid" scheme) where the gas generator becomes a pre-burner rich in fuel or oxidizer). The Block-D was to be equipped with a re-ignitable 11D58 engine of Melnikov. This engine, built in 1964, was tested at NII-229 in 1966.

The first flight was with the 7K-LI /Zond spacecraft in 1967. During the flight of Cosmos-382 in 1970, seven re-starts were made to repeat the lunar N1-L3 mission. In 1968, Lavotchkin proposed his own stage equipped with a Glushko engine of ten tons thrust (LOX-UDMH) to replace the Block-D. But it was not accepted.

The first closed cycle engine was tested by NIT-1 in 1958 and the first to fly was the S1-5400 of Melnikov (fourth stage of the R-7) in 1960. In 1961, the NK-9 of Kuznetsov (37 tons thrust). RD0202 of Kosberg (57 tons) and the RD-253 of Glushko (150 tons) followed. The first chambers of 150 tons thrust were those of the RD-253 and NK-15. The pressure then went to 150 atmospheres. The RD-253, in which the chamber diameter was identical to the RD-107, was used on the first stage of the UR-500/Proton of Chelomei (the first stage had six engines). Another liquid oxygen-kerosene version was proposed as back-up for the NK-15. On the same basis, the NK-9 served as a back-up for the RD-111. In Russia, all closed cycle engines were rich in oxidizer except the RD-301 with fluorine-ammonia, the cryogenic KVD-1 and RD-0120 engines, as well as the RD-857 and the RD-862 with N204-UDMH.

For the UR-700, Glushko developed the RD-270 engine with a "gas-gas" arrangement (two pre-burners were fed the main combustion chamber). It was ground tested at 27 times from October 1967 to July 1969 with nine nominal tests

(pressure up to 255 atmospheres). But this was equivalent to the U.S. F-1 engine that was last used in 1971. An experimental RD-280 engine was developed during 1965 to 1968 with the same arrangement but with a different propellant.

The R-56 (8K68) of Yangel was designed as a cluster of four R-46s (for an ICBM with a warhead of 100 megatons). Each R-46 was equipped with four RD-253s on the first stage and one RD254 (altitude variant of the RD-253) on the second stage. The third stage, based on the second stage of the R-46, used only one RD-254, and the fourth was equipped with a four chamber re-ignitable engine. All these engines, designed by Glushko, were of 150 tons thrust, like Kuznetsov's engines. But in 1962, another version of the R-56 was made with an RD-270 instead of four RD-253s on the first stage.

After four failures between February 1969 and November 1972, the N-I was abandoned. At this time, an improved version was already in development. The 2e, 3e, 4e, and 5e stages had to be equipped with cryogenic engines. The second stage had to be fitted with eight NK-35 of 200 tons thrust. The third stage was designed for six to eight 11D54 engines with fixed nozzles and of 40 tons thrust each. The fourth (Block-S) was equipped with one 11D57 engine with an extendable nozzle and of 40 tons thrust. Finally, the fifth (Block-R) had one 11D56 of 7.5 tons of thrust.

The use of liquid hydrogen in LREs was studied in the Soviet Union since 1960 (by the NII-1, NII-229, NII Mach, GIPKh, the VNII Kriogen-Mach, the State Institute of Nitrogen, *et al.*). Melnikov proposed their use on upper stages of the R-7. The NK-35 of Kuznetsov was never tested. But the 11D54/11D57 of Lyulka and the 11D56 of Isayev were built. The test bench at NII-229 was ready in 1966 for a test and the first test of the 11D56 was made in June 1967. The 11D56 was tested on the Block-R stage during 1976 to 1977, whereas tests of the 11D57 were also completed in 1977. However, these engines were never to fly.

In 1978, Glushko designed Energya and Vulkan rocket engine projects. He ordered the RD-0120 cryogenic engine at the OKB-154. This equivalent of the American SSME [Space Shuttle Main Engine—Ed.], had a thrust of 146 tons on the ground or 190 tons in a vacuum. The work done on the RD-02 15 was incorporated into the development of the RD-0215 that had a closed cycle of 250 tons of thrust had been under research during 1962-1965 for a Chelomei rocket.

The Energya, that was to fly twice during 1987-1988, consisted of four boosters equipped with RD-170 engines each of 740 tons thrust and a central stage equipped with four RD-01 20 engines. The payload had to go into orbit with its own engine (one 17D12 of Melnikov for the Buran Shuttle). In the case of the Vulkan, there were eight boosters and a third stage equipped with an

llD57M engine. The boosters, produced by NPO Youjnoe, were to serve in the first stage of the Zenith rocket (using the RD 171).

The RD-170, with four chambers, was difficult to produce. The thrust had to be increased up to 185 tons and the pressure up to 1,250 atmospheres. On 26 June 1982, the first static test at the NII-229 was unsatisfactory. An expert commission worked on the problem between September 1982 and May 1983. It was necessary to wait until December 1984 for the second static test. A third one in December was finally successful and the first flight occurred in April 1985 on the Zenith (the second stage was powered by an RD-120). For Energya, Glushko built a special bench for the first stage propulsion test at Baikonour, those that were not made for the unfortunate N-I.

In 1969-1972, the engines for the second generation missiles, the MR-UR-100/SS-17 of Yangel, the R-36M/SS-18 of Yangel, and the UR-100N/SS-19 of Chelomei, were developed by Glushko and [Aleksandr D.—ED.] Konopatov (Kosberg's successor at OKB-154). The MR-UR-I00 was equipped with one RD-268 in the first stage and one RD862 in the second stage (derivative of the RD-857 built for the combined RT-20/SS-15) rocket. The RD-268 of 126 tons thrust was an augmented thrust version of the RD-263 and a cluster of four units formed the RD-264 used on the first stage of the R-36M missile. As for the second stage of the R-36M, the engine was an RD-0228 (consisting of RD-0229 and RD-0230 engines) that would be replaced by an RD-0255 (consisting of the RD-0256 and RD~0257) on the latest version of the R-36M2 that was equipped with an RD274 (four R.D-273s) on the first stage. As for the UR-1OON/SS-19, the engines were the RD-0233/234 on the first stage, an RD-0235/236 on the second, and an RD-0237 on the third.

The OKB-154 also made engines to accelerate naval missiles. The RD0231 was built in 1968-1970 for the Granit missile of Chelomei. Then, the RD-0242 was tested in 1977-1983 on 3M25/Meteorit strategic missiles (SSC-X5, SSN-24 Scorpion, and ASX-19 Koala). But this was abandoned. Finally, the OKB was responsible for the development of the solid phase nuclear engine RD0410. The first one was tested three times in Semipalatinsk in 1978 (70 seconds at 24 MW on 27 March, 93 seconds at 33 MW on 3 July, and 90 seconds at 42 MW on 11 September), whereas the second one was tested on 26 January 1981 for 175 seconds at 22 MW, then 38 seconds at 63 MW. The third one served as a trial unit with gaseous nitrogen between 25 October 1983 and 4 November 1984.

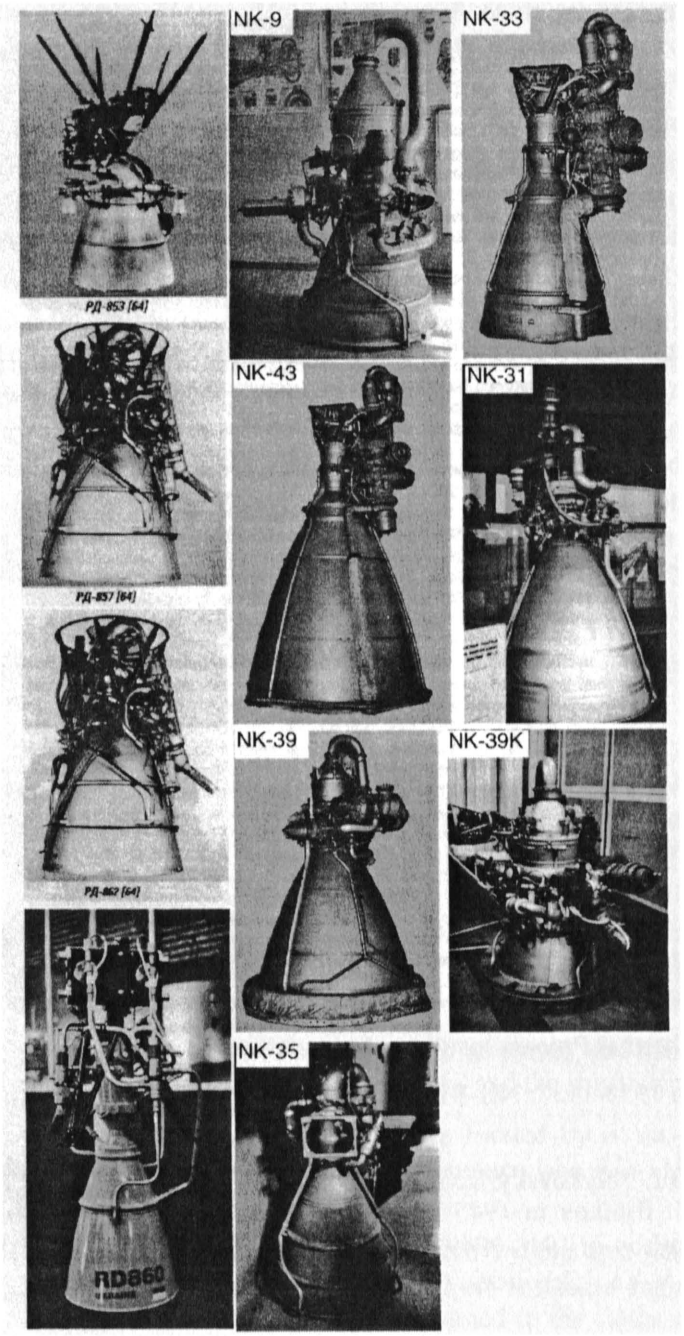

Figure 1: Representative large-scale Russian liquid fuel rocket engines. Left to right: RD-853, NK-9, NK-33, RD-857, NK-43, NK-31, RD-862, NK-39, NK-39K, RD-860 and NK-35 (Photos from the Christian Lardier Collection).

During his long career, Glushko had to finesse the cryogenics of liquid hydrogen and oxygen. But on the other hand, he worked on flourine-ammonia engines (RD-300), nuclear engines (RD-400), hydrogen peroxide engines (RD-500), chemical lasers (RD-600) and tri-propellant engines (RD-700). In July 1962, he made a study to find the optimal scheme for a one chamber engine of 1,000 tons thrust. The RD-301 was made for an upper stage designed by M.F. Rechetnev for the Proton rocket. It was developed in 1969-1976 but cancelled in 1977. In 1958, Glushko proposed a solid phase nuclear engine using liquid hydrogen. But in July 1963, this work was stopped and moved to a gaseous phase nuclear engine until 1983. However, neither the solid phase nor the gaseous phase came into reality. In 1960-1966, Glushko tested hydrogen peroxide with pentaborane on the RD-502 and in 1965-1971, he tested hydrogen peroxide with hydride of berillium on the RD-560. The last work that he made with his deputies S.P. Agafanov and B.L Katorgin was the development of a continuous chemical laser using fluoride as propellant. More than 1,100 tests at 30 kW were made in 1974 and 520 tests at 400 kW in 1979. Since 1979, Energo-Mash is the Russian leader in this field.

Annex:
Organizations and Biographies

Note: HTS = Hero of Socialist Labor.
PL = Lenin prize
PE = State Prize (ex Stalin)
MAI = Moscow Aviation Institute
MVTU = Moscow High Technical University
MGU = Moscow State University

(I.) NII-1/Thermal Process Institute of Moscow:

(II.) RNII in 1933-1937; NII-3 in 1937-1944; NII-1 in 1944-1965; then NIITP of Moscow

Directors: B.I. Polykovsky from 18 Feb. to 29 May 1944; P.I. Fedorov in 1944-1945; Ya. I. Bibikov in 1945-1946; M.V. Keldysh (1911-1978) in 1946-1948; V.D. Vladimirov in 1948-1949; V.A. Okoulov in 1949-1951; A.T. Toumanov in 1951-1955; V.Ya. Likhouchin (1918-1992) in 1955-1987; then A.S. Koroteiev in 1987.

Deputies: G.I. Petrov (1912-1987) in 1944-1965; V.S. Avduyevskiy in 1947-1973; A.P. Vanitchev (1916-1993) in 1955-1990; V.M. Ievlev (1926-1990); and A.M. Gubertov, etc. The subsidiary of Nijnv-Selda was created in 1958 and became NII Khim-Mash in 1981.

(III.) NII-229/NII Khim-Mash of Zagorsk/Sergei-Possad: subsidiary of NII-88 in 1948 which became NII-229 in 1959 (village of Krasnozavodsk/Novostroïka)

Directors: G.M. Tabakov in 1948-1949; V.S. Chatkin in 1949-1950; Poletaiev in 1950-1953; F.G. Soukhomlinov in 1953-1955; A.L Bykovsky in 1955-1957; G.M. Tabakov in 1957-1965; V.P. Beliakov in 1965-1972; N.V. Filine in 1972; V.P. Poukhov; Yur. A. Kornelv; then A.A. Makarov.

(IV.) NPO Energo-Mash of Khimki

The aircraft factory No. 84 where the DC-3/Li-2 of Lissounov was in serial production became factory No. 456 in 1942. The OKB of V.P. Glushko came here in November-December 1946. The factory was headed by A.G. Ploskinny in 1946; L.A. Grichin from 1946-1952; V.A. Kolytchev from 1952-1955; A.A. Evteiev from 1955-1960; Yu. D. Soloviev in1960-1968; S.P. Bogdanovsky from 1968-1992; and G.G. Derkatch from 1992 until now. The OKB developed engines for the following rockets: Cosmos (R-214, RD-119, RD-216), Cyclone (RD-218, RD-219, RD-251, RD-252, RD-261, RD-262), Soyuz (RD-107, RD-108), Proton (RD-253), Zenith/Energya (RD-170, RD-120), SS-17 (RD-268), SS-18 (RD-264), etc. that were produced in factory Nos. 586 Youj-Mach at Dniepropetrovk, No. 24 imeni Frunze at Kouybichev; No. 19 imeni Sverdlov at Perm; No. 29 imeni Baranov at Omsk; No. 1001 Kras-Mach at Krasnoylarsk; and No. 166 Polyot at Omsk, etc. These factories had subsidiaries.

Since 1951, the subsidiary of Dniepropetrovk was headed by N.S. Chniakin. The design bureau KB-4, formed in July 1958, has been headed by: I.I. Ivanov, A.V. Klimov, then Vladimir Chniakin. Since 1958, the subsidiary of Kuybichev was headed by Yu..D. Soloviev. He was replaced by R.I. Zelenev in 1960-1975; A.F. Oudalov in 1975-1978; and A.A. Ganin in 1978.

Since 1958, the subsidiary of Perm was headed by R.I. Zelenev. He was replaced by Yu. D. Plaskin in 1959-1980, N.V.Niksotov in 1980-1992, and D.P. Juravlev in 1992.

Since 1958, the subsidiary of the Baranov Plant in Omsk was headed by V.F. Khomratchev. The production was stopped in 1968 and the subsidiary closed.

Since 1959, the subsidiary of Krasnoyarsk was headed by A.Ya. Kitayev. In 1968, the plant became specialized in SLBM engines (the RD-119 was transferred to Khimki and RD-216M to Youj-Mach).

Since 1958, the subsidiary of Primorsk (50 km from Vyborg near Leningrad) was headed by E.N. Kuzmin and began work on fluorine-ammonia engines. It was a part of NPO Energia in 1974-1989 and then returned to the status of autonomy (undertaking work on chemical lasers with GIPKh).

[The following are some key people with leading Russian liquid fuel rocket organizations.—ED.]

(1) **Valentin Petrovitch Glushko** (1908-1989)

HTS, 1956-1961; PL, 1957; PE, 1967. Completed his studies at Leningrad University in 1929; then worked at GDL-OKB in 1929-1933; RNII in 1933-1938; OKB-82-NKVD in 1938-1941; OKB-16-NKVD in 1941-1946; Main Designer of OKB-456 in 1946-1974; and General Designer of NPO Energya in 1974-1989.

(2) **Victor Petrovitch Radovsky** (born 1920)

HTS, 1976; PL, 1960; PE, 1985; Director and Main Designer of Energo-Mash from 1974-1991.

(3) **Boris Ivanovitch Katorgin**

Deputy from 1986-1991; Director and Main Designer of Energo-Mash in 1991-1999

(4) **Dominik Dominikovitch Sevruk** (born 1908)

Worked at TsIAM in 1934; OKB-16 in 1941-1946; Deputy of OKB-456 in 1946-1952; Chief of OKB-3 at NII-88 in 1952-1959; returned to OKB-456 in 1959-1961; Chief of OKB Zaria in 1962, working on electric propulsion); returned to NII-88 in 1965-1972; then worked as a professor at MAI in 1972-1988.

(5) **Vladimir Andreyevitch Vitka** (1901-1989)

HTS, 1957; Deputy for Construction in 1946-1954; First Deputy in 1954-1961.

(6) **Georgii Frolovitch Firsov** (1917-1960)

Deputy for Flight Tests (died during the R-16 catastrophy at Baikonour).

(7) **V.S. Radoutny**

PL; Deputy for Flight Tests.

(8) **Vladimir Ivanovitch Kurbatov**

HTS, 1957, PL; First Deputy during 1961-1974.

(9) **V.L. Chabransky**

HTS, 1961; PL, 1967; Deputy

(10) **V.I. Lavrenetz-Semenyuk**

HTS, 1961; PL, 1960; Deputy

(11) **Sergei Petrovitch Agafonov** (1918-1993)

HTS, 196l; completed studies at the Polytechnic Institute of Leningrad in 1941; worked at OKB-456 on turbopumps during 1942-1960; then became Deputy advanced engines (nuclear engines and chemical lasers in 1960-1985).

(12) **Yu. D. Soloviev**

HTS, 1961; PL, worked at OKB-456; Chief of Kyubichev's subsidiary during 1958-1960; then head of Khimki's factory from 1960-1968.

(13) **V. F. Trofimov**

First Deputy during 1974-1993.

(14) **Yu. N. Tkatchenko**

PL, 1976; First Deputy.

(15) **V.K. Chvanov**

PE, 1988; First Deputy 1993.

(16) **V.F. Rakhmanin**

PE, 1988; First Deputy.

(V.) KB Khim-Mash at Podlipki/Kaliningrad/[Sergei P.] Korolev

Sector No. 9 of NII-88 in 1948; OKB-2 in March 1952; and became autonomous on 16 January 1959; renamed KB Khim-Mash in 1974.

(1) **Alexei Mikhailovitch Isayev** (1908-1971)

HTS, 1956; PL, 1958; PE, 1948-1968

Completed studies at the Mine Institute in 1932; worked at OKB-293 of Bolkhovitinov in 1934-1944; Main Designer at NII-1 in 1944-1948; then at NII-88 in 1948-1959; then at OKB-2 in 1959-1971.

(2) **A.P. Eliseyev**

First Deputy in 1948-1952.

(3) **G.M. Tabakov**

Deputy in 1950-1957.

(4) **Vladislav Nikolaievitch Bogomolov** (1919-1997)

HTS, 1961; PL, 1958; Completed studies MAT in 1946; worked at NII-1 NII-88 in 1948; Deputy of Isayev in 1952; First Deputy in 1959-1971; Main Designer in 1971-1985.

(5) **Nikolai Ivanovitch Leontie'v** (born 1928)

PL, 74; completed studies at the Automechanical Institute of Moscow in 1951; worked at the NII-88; Komsomol Secretary in 1951-1953; Chief Constructor at OKB-3 for the 217 rocket of Lavotchkin in 1954-1958; then went to OKB-2 in December 1958 (worked on engines for the 217A and 218 rockets, verniers of the 11D49, and engines for the SLBM from the first stage of the RSM-40 to the second stage of the RSM54) at Kras-Mash; First Deputy in 1971; Main Designer in 1985; General Designer in 1996.

(VI.) OKB-154/KB KhimAvtomatiki of Voronej:

OKB-296 imeni Dzerzhinsky of Kharkov created on 13 October 1941 from a group of the carburetor factory No. 33 of Moscow. Evacuated to Berdsk near Novossibirsk, 1941-1946. Transferred to factory No. 265 of Voronej in March 1946. Became OKB-154 in May 1946 (renamed KB Khim-Automatiki of the Mechanical Factory of Voronej). It produced injectors, pumps, regulation aggregates, and solid and liquid propellant starters during 1941-1954.

(1) **Semyon Arievitch Kosberg** (1903-1965)

HTS, 1961; PL, 1960

Completed his studies at MAI in 1931; worked at TSIAM in 1931-1965.

(2) **Alexandre Dmitrievitch Kononatov** (born 1922)

HTS, 1966; PL, 1976; PE, 1970

Completed studies at the Aeronautical Technology Institute of Moscow in 1945, then worked at OKB-154; Main Designer in 1965-1993.

(3) **A.S. Ratchuk**

General Designer in 1993.

(4) **A.A. Golyubev**

First Deputy

(5) **G.I. Tchoursine**

First Deputy, Mechanical Factory of Voronei

Directors: L.L. Abramov in 1957-1965 and 1969-1976; B.A.Tchevela in 1969-1976; V.F. Soloviev in 1976-1981; G.V. Kostin in 1981-1993; and A.I. Tchassovskikh in 1993.

(VII.) OKB-IJNPO Energia at Podlipki

(1.) **Mikhail Vassilyevitch Meinikov**

HTS, 1961; PL, 1960

Worked with Isayev in 1946; Chief of Sector No. 12 at OKB-I in 1951; then Deputy of Korolev: Chief of Complex No. 5 of TsKBEM in 1966. Now, B.A. Sokolov; I.I. Rayekov; and V.G. Borzdyko; realized the LRE of NPO Energia.

(VIII.) KB-4 of NPO Youjnoe at Dniepropetrovk (Ukraine)

(1.) **N.S. Chniakin**

PL

Deputy of Boudnik for engines in 1951; main designer from April to July 1954;

Deputy of Yangel in 1954-1956; then returned as Deputy of Glushko in 1956.

(2) **Ivan Ivanovitch Ivanov** (born 1918)

HTS, 1961; PL, 1964; PE, 1977

Completed studies at Aviation Institute of Kazan in 1946; worked at OKB-456 in 1946-1952; then SKB-586 (Main Designer of KB-4 in July 1958).

(3) **A.V. Klimov**

Main Designer

(4) **Vladimir Chniakin**

Main Designer

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Table 1
LIQUID ROCKET ENGINES IN RUSSIA

Design Office	Production	Engines
NPO Energya Of Podlipki/Korolev	Mechanical factory of Voronej	11D58M, 17D12
NPO EnergoMash Of Khimki	Factory of Khimki	RD-268, RD-170/171
	YoujMash/Dniepropetrovsk	RD-101/103
		RD-261/262
		RD-264
		RD-120
	PO Motorostroitel/Samara	RD-107/108
	PO KrasMach/Krasnoïarsk	RD-119/RD-216
	PO Motorostroitel/Perm	RD-214/253/275
	PO Baranov/Omsk	RD-218/219
KB KhimAvtomatiki Of Voronej	Mechanical factory of Voronej	RD-0110/RD-0124
		RD-0120
		RD-0255
		RD-0410
	PO Motorostroitel/Perm	RD-0216/RD-0217
	Factory of Oust-Katav	RD-0237
	Krasnaya Oktiabr factory of St-Petersburg	RD-0235/RD-0236
	PO KrasMach/Krasnoïarsk	RD-0243
KB KhimMash Podlipki/Korolev	factory of Zlatoust	missiles engines
	factory of Oust-Katav	space engines
	PO KrasMach/Krasnoïarsk	SLBM engines
	Krasnaya Oktiabr factory of St-Petersburg	SAM/ABM engines
NPO Youjnoe (KB-4)	YoujMash Of Dniepropetrovsk	RD-861
NII Mash Of Nijny-Selda	ex subsidiary of NII-1	small engines
TMKB Soyuz Of Touraievo	ex subsidiary of OKB-300	small engines
RIAME Moscow	MAI department	Electric propulsion
OKB Fakel Kaliningrad/Konigsberg		Electric propulsion
TsIAM Moscow	TMKB Soyuz	Scramjet

Table 2
LIQUID PROPELLANT ENGINES OF NPO ENERGOMASH

Engine	Rocket	Year	Thrust (vacuum)	Pressure (atm)	Isp (s)	Observations
Liquid oxygen-kerosene/oxygen-UDMH/oxygen-sintin [synthetic kerosene—ED.]						
RD-100	R-1	1945-1948	31 t	16	237	developed
RD-101	R-2	1947-1949	41 t	21	237	developed
RD-110	R-3	1947-1951	120 t	60	243	project
RD-103	R-5	1952-1953	51 t	24	248	developed
RD-103M	R-5M	1952-1955	51 t	24	248	developed
RD-105	1st stage R-6	1952-1954	65 t	60	302	project
RD-106	2nd stage R-6	1952-1954	65 t	60	310	project
RD-107	1st stage R-7	1954-1957	102 t	60	313	developed
RD-108	2nd stage R-7	1954-1957	96 t	52	315	developed
RD-109	2nd stage R-9	1957-1958	10 t	80	334	project
RD-111	1st stage R-9	1958-1961	166 t	80	317	developed
RD-112	1st stage R-20	1960	111 t	147	344	project
RD-113	2nd stage R-20	1960	116 t	147	360	project
RD-114	1st stage N-1	1960-1961	168 t	147	341	project
RD-115	2nd stage N-1	1960-1961	176 t	147	357	project
RD-116	UR-700M	1970	645 t	200	333	project
RD-117	1st stage Soyuz	1969-1975	69 t	54,2	316	developed
RD-118	2nd stage Soyuz	1969-1975	94 t	59,7	314	developed
RD-119	11K63	1958-1962	11 t	80	352	developed
RD-120	11K77	1974-1985	85 t	166	350	in production
RD-120K	1st stage	1986	87 t	179,8	330	in development
RD-120M	Sea Launch	1985-2003	93 t			in production
RD-121	1st stage	1972	200 t	200	334	project
RD-123	1st stage 11K77	1975	666 t	250	340	project
RD-124	1st stage 11K77	1974	127 t	225	340	project
RD-124A	3 x RD-124	?				project
RD-124B	roll engine	?				project
RD-125	2st stage 11K77	1974	130.2 t	225	350	project
RD-126	2nd & 3rd stage	1974	264 t	225	357.5	project
RD-127	2nd & 3rd stage	1974	261 t	225	350	project
RD-128	1st stage	1974	251 t	212	340	project
RD-129	1st stage	1974	251 t	212	340	project
RD-130	2nd stage	1973	200 t	200	450	Lox-LH_2
RD-133	2nd stage 11K55	1987	35 t	170	352.4	project
RD-134	2nd stage 11K55	1993	35 t	170	357	project
RD-135	2nd stage RLA	1974	250 t	210	450	Lox-LH_2
RD-136	2nd stage 11K77	1984-1988	90 t	174	357	project
RD-137	2nd stage 11K77	?				project
RD-138	2nd stage 11K77	?				project
RD-141	2nd stage 11K37	1978	214 t	250	361	project
RD-142	2nd stage 11K37	1983	90 t	175.7	350	project
RD-143	3 x RD-144	1983	270	175.7	350	project

RD-144	2nd stage 11K37	1983	85 t			project
RD-144K	2nd stage Angara	?	85 t			project
RD-146	2nd stage Ienissei	1992	90 t	167	350	project
RD-150	1st stage	1974	1,136 t	212	340	project
RD-161	3rd stage	1995	2 t	120	365	in development
RD-161A	stage Proryv	?				project
RD-161B	stage Yamal	?				project
RD-161V	stage Taymir	?				project
RD-162	2nd stage Ienisseï	?				project
RD-170	11K25	1974-1987	806 t	250	337	developed
RD-171	11K77	1974-1985	806 t	250	337	in production
RD-171M	Sea Launch					in development
RD-172	Vulkan	1988-1991	848 t	262	337	abandoned
RD-173	?	?				project
RD-179	Vulkan	?	937 t	?	?	project
RD-180	Atlas-3A	1995	423 t	262	337	in production
RD-191	Angara	1998	212 t	262	337	in development
Liquid oxygen-methane						
RD-167	2nd stage	?	35 t	196	383	abandoned
RD-169	Rikcha	1995	15 t	147	309	abandoned
RD-182	Air Launch	1995	80 t	166	351	RD-120K derivative
RD-183	Rikcha	1995	1 t	?	?	kick stage
RD-184	Rikcha	1995	1.5 kg	?	?	orientation engine
RD-185	Rikcha	1995	18 t	147	375	RD-169 for 2nd stage
RD-190	Rikcha	1995	102 t	147	351	6 x RD-169
RD-192	?	1996	207 t	245	356	RD-191 derivative
RD-192S	?	1998	217 t	245	371	RD-192 for 2nd stage
N_2O_4-UDMH						
RD-200	?	1954	3 t	23.5	241	project
RD-210	?	1951-1954	3 t	23.5	241	project
RD-211	IRBM	1953-1955	65.5 t	40	262	project
RD-212	Buran	1954-1956	63.5 t	40	253	project
RD-213	Buran	1956-1957	76.4 t	46.6	254	project
RD-214	R-12	1952-1957	74 t	44	264	developed
RD-215	R-14	1958-1960	88.7 t	75	289	developed
RD-216	R-14	1958-1960	176 t	75	289	2 x RD-215
RD-217	R-16	1958-1960	88.6 t	75	289	developed
RD-218	R-16	1958-1960	266 t	75	289	3 x RD-217
RD-219	R-16	1958-1960	90 t	75	293	1 x RD-219
RD-220	1st stage N-1	1960-1961	109.5 t	147	306	project
RD-221	2nd stage N-1	1960-1961	114 t	147	318	project
RD-222	1st stage N-1	1960-1961	166.6 t	147	302	project

RD-223	2nd stage N-1	1960-1961	173 t	147	314	project
RD-224	1st stage R-26	1960-1962	181 t	83.3	294	2 x RD-225
RD-225	R-26	1960-1962	90.5 t	83.3	294	project
RD-250	R-36	1961-1965	90 t	85	301	developed
RD-251	R-36	1961-1965	270 t	85	301	3 x RD-250
RD-252	R-36	1961-1965	92 t	91	317	1 x RD-252
RD-253	N-1/R-56	1961	166 t	150	316	project
	UR-500	1962-1965	166 t	150	316	in production
RD-254	N-1/R-56	1961	175 t	150	328	project
	UR-700	1961-1966	175 t	150	328	project
RD-261	Cyclone-2	1966-1969	303 t	85	301	in production
RD-262	Cyclone-2	1966-1969	101 t	91	318	in production
RD-263	R-36M	1969-1973	106 t	210	318	developed
RD-264	R-36M	1969-1973	461 t	210	318	4 x RD-263
RD-268	MR-UR-100	1969-1973	126 t	230	319	1 x RD-263
RD-270	UR-700	1962-1969	685 t	255	301	project
RD-273	R-36M2	1982-1988	126.2 t	226	318	developed
RD-274	R-36M2	1983-1986	505 t	230	318	4 x RD-273
RD-275	Proton-M	1987-1993	178 t	157	316	modernization of RD-253
RD-280	2nd stage	1963-1965	11.9 t	147	350	RD-270 derivative
Fluorine-ammonia						
RD-301	4th stage UR-500	1969-1976	10 t	117	400	project
RD-302	Yangel	1965-1968	10 t	117	400	project
RD-303	Yangel	1960-1965	10 t	120	400	project
LH2						
RD-350	2nd stage	1961-1967	10 t	78.4	464	project
RD-351	?	1967- ?	25 t	?	?	project
RD-352	?	? -1976	10 t	?	?	project
Hydrogen peroxide						
RD-502	pentaborane	1960-1969	10 t	147	380	Experimental engine
RD-510	kerosene	1969-1974	12 t	150	331	project for the lunar module of the N1-L-3M program
RD-511	kerosene	1970-1974	8 t	200	329	Project of braking engine
RD-512	pentaborane	1970-1974	8 t	150	380	Project of braking engine
RD-530	diborane	?	1,5 t	?	?	Project of braking engine for the manned spacecraft Zarya

-RD-531	pentaborane	1988	?	?	?	Project of engine for a Jupiter and Saturn probe of Lavotchkin
-RD-532	?	1989	3 t	?	?	Project for the shuttle Maks of NPO Molnya
-RD-550	hydride of berillium	1963-1968	10 t	147	400	
-RD-560	hydride of berillium	1965-1971	?	?	?	project
-RD-161P	kerosene	1993	2.5	124.75	319	Project for an upper stage of rocket
Pentafluorurine of chlorinate						
-hydrazine gel with aluminium suspension						
4D75M***	1st stage 4K75M	1970/71	85 t	220	325	project
4D76M	2nd stage 4K75M	1970/71	32 t	?	?	project
Tri-propellant engines (hydrogen-oxygen-kerosene)						
RD-701	Maks	1987	408 t	294	415	abandoned
RD-704	?	1990-1991	204 t	300	415	in development
Nuclear engines						
RD-401	2nd stage	1956-1958	168 t	100	428	project
RD-402	2nd stage	1956-1958	168 t	100	428	project
RD-403	Experimental	?	?	?	?	project
RD-404	2nd stage	1962	200 t	?	950	project
RD-405	Experimental	1963	40-50 t	?	?	project
RD-600	Interpl. Spacecrt.	1962-1968	600 t	500	2000	project
RD-610	Experimental	?	60-70 t	?	?	project
Nuclear generators						
EU-610	Experimental	?	?	1000	?	YaRD : 60-70 t/2000 s
YaEUsm	Experimental	?	150 MW	?	?	ERD : + 300 kg/5000s
BEU-620	Experimental	?	175 MW	?	?	project
YaDEU	Experimental	?	200 MW	?	?	engine of 17 tons thrust
Continuous chemical laser using fluoride						
?	Experimental	1974	30 kW	?	?	+1100 tests
?	Experimental	1979	400 kW	?	?	520 tests

*** also called RD-503

Table 3
ENGINES OF CADB

Engine	Propellant	Thrust (vacuum) (t)	specific impulse (s)	Chamber pressure (atm)	Year	Utilization
D-154	monergol	4.0	185	21	1954	E-50A
D-7	monergol	1.2	200	30	1956	missile K-7
RD-0101[1]	LOX-alcohol	2-4.0	255	43,5	1956	E-50A
RD-0102[2]	LOX-Kerosene	1.5-4.0	260	42	1957	Yak-27V
RD-0103[3]	LOX-Kerosene	1.4-3.53	277	38	1957	T-3 and P-1
RD-0105[4]	LOX-Kerosene	5	316	45,9	1958	Luna
RD-0106[5]	LOX-Kerosene	30	?	?	1958-1960	R-9
RD-0107	LOX-Kerosene	30.38	326	?	1958-1960	Molnya
RD-0108	LOX-Kerosene	30	?	?	1963	Voskhod
RD-0109[6]	LOX-Kerosene	5.56	323	51	1959-1960	Vostok
RD-0110	LOX-Kerosene	30.38	326	70	1964	Soyuz
RD-0120	LOX-LH_2	200	455	223	1974-1987	Energia
RD-0122	LOX-LH_2	232.9	?	?	1990	project
RD-0124	LOX-Kerosene	30	359	160	1996	In development
RD-0125	?	?	?	?	?	Aerospaceplane, Aerojet
RD-0126	LOX-LH_2	4,0	476	73	1998	Yastreb
RD-0126A	LOX-LH_2	10	476	123	?	project
RD-0128	LOX-LH_2	10	474	123	?	project
RD-0129	LOX-Methane	?	?	?	?	In development
RD-0131	LOX-LH_2	10	467	128	?	project
RD-0132	LOX-LH_2	10	469	102	?	project
RD-0133	LOX-LH_2	10	467	86	?	project
RD-0139	LOX-Methane					project
RD-0140	LOX-Methane					project
RD-0141	LOX-Methane					project
RD-0142	LOX-Methane					project
RD-0143	LOX-Methane	30	?	?	?	Air Launch (RD-0124 derivative)
RD-0144	LOX-Methane					project
RD-0145	LOX-Methane					project
RD-0146	LOX-LH_2					
RD-0148	LOX-LH_2					

RD-0149	LOX-Methane					project
RD-0151	LOX-Kerosene	5.0	?	?	?	monochamber (RD-0124 derivative)
RD-0200[7]	NH_3-Kerosene	0.6-6.0	230	67,4	1957-1962	5V11/400/DAL
RD-0201	NH_3-Kerosene	3.0-6.0	?	?	1959-1962	V-1100 of Grushin
RD-0202	N_2O_4-UDMH	4 x 57.0	316	144	1961-1963	UR-200 (3xRD-0203+1xRD-0204)
RD-0205	N_2O_4-UDMH	57.0	?	?	1961-1963	UR-200 (RD-0206+verniers RD-0207)
2nd stage	N_2O_4-UDMH	4 x 60.0	?	?	1962-1965	UR-500 (3xRD-0208+1xRD-0209)
2nd stage	N_2O_4-UDMH	4 x 60.0	326	144	1965-1967	UR-500 (3xRD-0210+1xRD-0211)
RD-0212[8]	N_2O_4-UDMH	60.0	324	144	1965-1967	UR-500 (RD-0213+verniers RD-0214)
RD-0215	N_2O_4-UDMH	250.0	?	?	1962-1965	1st stage of Chelomei rocket
1st stage	N_2O_4-UDMH	4 x 22.3	?	?	1963-1966	UR-100 (3xRD-0216+1xRD-0217)
RD-0221	N_2O_4-UDMH	?	?	?	1965-1974	upper stage of N1-L3
RD-0225	N_2O_4-UDMH	0.4	287	9	1966-1971	Almaz (Salyut-2/3/5)
RD-0228	N_2O_4-UDMH				1967-1974	R-36M (RD-0229+verniers RD-0230)
RD-0231	N_2O_4-UDMH				1968-1970	Granit missile of Chelomei
1st stage	N_2O_4-UDMH	4 x 51.9			1969-1974	UR-100N (3xRD-0233+1xRD-0234)
2nd stage	N_2O_4-UDMH	?			1969-1974	UR-100N (RD-0235+verniers RD-0236)
RD-0237	N_2O_4-UDMH				1969-1974	3rd stage UR-100N
RD-0242	N_2O_4-UDMH	12.6	302,6	200	1977-1983	missile of Chelomei
RD-0242M	N_2O_4-UDMH	10	335,6	156	1998	project
RD-0243	N_2O_4-UDMH	83	?	275 (325)	1977-1985	RSM-54 (RD-0244+verniers RD-0245)
2nd stage	N_2O_4-UDMH				?	project (RD-0250+verniers RD-0251)
RD-0255	N_2O_4-UDMH				1983-1987	R-36M2 (RD-0256+verniers RD-0257)
RD-0410	nuclear	3.6	910	?	1965-1988	project
RD-0411	nuclear	40			1965-1988	project
RD-0600	laser GDL				1972-1985	module SKIF
RD-0750	Tri-ergols	79-175	450-417	85-190	1996	project

Note: 1-SK-1, 2-SK-1K, 3-SK-2, 4-RO-5, 5-RO-9/RD-461, 6-RO-7/RD-448, 7-R01-154, 8-RD-473

Table 4

ENGINES OF DUSHKIN, SEVRUK, MELNIKOV, KUZNETSOV, TUMANSKY AND IZOTOV

	Year	Thrust (t)	Isp (s)	Pressure (atm)	Utilization
L.S. Dushkin -V.A. Chtokolov - S.A.Doubinetz					
D1A-1100	1941-1944	1.1			rocket plane BI-1
RD-2MZV	1944-1948	0.3-2.0			rocket plane I-270
RDKS-1	1945-1947	0.3-1.5			
S-155	1947-1955	1.3			aircraft E-50/Mig-19
RU-V	1947-1955	1.3			aircraft Yak-27
A6-12	1955-1962	4.0-1.5			missile G-300
KRR-300	1955-1962	10,.3-0.1			missile V-600
	1957/59 (OKB-165)				
?	1960-1961	12			2nd stage A-350
5I43 (BIP)	1962-1967				missile 5V21/S-200
5I47 (BIP)	1962-1967				missile 5V28/S-200M
5I48 (BIP)					
4E60 (BIP)	1962-1967				missile V-611/4K60/Chtorm
R-200	1964-1967	200			
BIP-Nuclear	1967/72 (OKB-670)				
D.D.Sevruk (Nitric acid-kerosene)					
S3-892	1952-1957	?			Tchirok-Korchoun
?	1955	32.0			Experimental engine
RU-01	1958	3.0			aircraft SM-12 (U-19D)
RU-013	1959	3.0			aircraft SM-50 (U-19D)
S3-20M5A	1960	3.0			aircraft E-66 (U-21)
S3-40	1955	?			project for R-12
S3-41	1955	?			project for R-12
S3-42A	1954-1958	17.0			missile 217
?	?	?			missile 208
S3-46	1955	?			project for R-16

S3-50	1955	?			project for R-16
S3-52	1955-1957	8 chambers			R-15 (D-3) of OKB-586
S3-54	1955-1957	4 chambers			R-15 (D-3) of OKB-586
S3-55	1955	?			project for R-16
S3-56	1955	?			project for R-16
S3-61	1955	?			project for R-16
?	?	?			missile V-750
?	?	?			missile V-1000
M.V.Melnikov (liquid oxygen-kerosene)					
S1-35800	1954-1957	3.0	?	?	vernier-engine of R-7
S1-5400	1958-1960	6.8	340	54.5	Block-L of R-7
8D726	1962-1965	6.8	?	?	3rd stage GR-1
11D58	1965-1967	8.5	354	79	5th stage N-1/Block-D
11D121	1962-1974	7.0	313	73	vernier-engine of N-1
17D11	1976-1988	?	?	?	ODU of Buran
17D12	1976-1988	8.8	362	79	Buran engine
17D15	1976-1988	0.4	295	?	Buran engine
11B97	1978/	?	3000	?	Electronuclear engine
N.D. Kuznetsov (liquid oxygen-kerosene)					
NK-9	1959-1962	37.0	?		1st stage R-9/GR-1
NK-9V	1959-1962	40.0	?		2nd stage R-9/GR-1
NK-15	1962-1969	154.0	331	148.3	1st stage N-1
NK-15V	1962-1969	179.0	346	148.3	2nd stage N-1
NK-19	1962-1969	41.0	352		3rd stage N-1
NK-21	1962-1969	41.0	352		4th stage N-1
NK-35	1962-1976	200.0	?		2nd stage N-1
NK-31	1969-1974	41.0	352		4th stage N-1
NK-33	1969-1974	154.0	331		1st stage N-1
NK-39	1969-1974	41.0	352	93.8	3rd stage N-1
NK-43	1969-1974	179.0	346		2nd stage N-1

S.K. Tumansky (OKB-300)-V.G. Stepanov (TMKB Soyuz of Touralevo)

R201-300	1959-1964	1.4-8.3		X-22 of Berezniak
R203-300	?	?		US satellites
R204-300	?	?		IS satellites
R209-300	?	0.65-3.3		missile KSR-2
210A/210B	1962-1964	?		Polyot satellites (obj. 93 and 94)
R210E-300	1962-1966	1.3 kg	micromotors	Cosmos-102/125/138/185
R210D-300	1962-1966	16.5 kg	micromotors	Soyuz/Zond/Luna/etc.
11D78	?	?		satellites Gran/Raduga
11D79	?	?		stage Block-D & DM

S.P. Izotov-A.S.Mevius-P.D.Gavra (OKB-466)

5D12	1958-1961	3.2-10.0 t	V-860/5V21/S-200
5D16	1960-1961	2.0-16.0	2nd stage A-350
5I27 (BIP)	1962		
5D67	1967/ ?		V-880/5V28/S-200M
?	1962/ ?	12	lunar module Block-L/UR-700
15D13	1963-1967		2nd stage UR-100
15D14	1963-1967		roll engine UR-100
R1-117	1960-1963		3rd stage UR-200A
R2-117	1962-1963		warhead UR-500
R5-117/5D22	1964-1967	13.4	2nd stage A-350
5A18	1964	2.0-3.2	roll engine A-350
5I28 (BIP)	1964		

Table 5
CODIFICATION OF RUSSIAN LREs (LIQUID ROCKET ENGINES)

RD-100	8D51	1945-1948	
RD-101	8D52	1946-1950	
RD-103	8D54	1952-1953	
RD-103M	8D71	1952-1955	
RD-105	8D56	1952-1954	
RD-106	8D60	1952-1954	
RD-107	8D74	1954-1957	8D728/11D511/14D21
RD-108	8D75	1954-1957	8D727/11D512/14D22
RD-109	8D711	1958-1960	
RD-110	8D55	1947-1951	
RD-111	8D716	1958-1961	
RD-112		1960	
RD-113		1960	
RD-114	11D31	1960-1961	
RD-115	11D32	1960-1961	
RD-116	11D120	1970	
RD-117	11D511	1969-1975	
RD-118	11D512	1969-1975	
RD-119	8D710	1960-1963	
RD-120	11D123	1976-1985	
RD-121		1972	
RD-123		1975	
RD-124		1974	
RD-125		1974	
RD-126		1974	
RD-127		1974	
RD-128		1974	
RD-129		1974	
RD-130		1973	
RD-133		1987	
RD-134		1993	
RD-135		1974	
RD-136	14D11	1984-1988	
RD-141	17D18	1978	
RD-142		1983	
RD-143		1983	
RD-146		1992	
RD-150		1974	
RD-161		1995	
RD-161P		1993	
RD-170	11D521	1976-1985	
RD-171	11D520	1976-1985	
RD-172	14D20	1988-1991	
RD-180		1994-1999	
RD-191		1999/ -	

RD-210		1951-1954
RD-211	8D57	1953-1955
RD-212	D-41	1954-1956
RD-213	D-13	1956-1957
RD-214	8D59	1955-1959
RD-215	8D513	1958-1960
RD-216	8D514	1958-1960
RD-216M	11D614	1966-1968
RD-217	8D515	1958-1961
RD-218	8D712	1958-1960
RD-219	8D713	1958-1960
RD-220		1960
RD-221		1960
RD-222	11D41	1960-1961
RD-223	11D42	1960-1961
RD-224	8D720	1960-1962
RD-225	8D721	1960-1962
RD-250	8D518	1962-1966
RD-251	8D723	1961-1963
RD-252	8D724	1961-1963
RD-253	11D43	1961-1965
RD-254	11D44	1961-1963
RD-261	11D69	1966-1969
RD-262	11D26	1966-1969
RD-263	15D117	1969-1975
RD-264	15D119	1969-1973
RD-268	15D168	1970-1976
RD-270	8D420	1962-1971
RD-273	15D286	1982-1988
RD-274	15D285	1982-1988
RD-275	14D14	1987-1993
RD-280	8D725	1963-1965
RD-303	8D21	1960-1965
RD-302	11D13F	1965-1969
RD-301	11D14	1969-1976
RD-350		1961-1967
RD-401		1956-1958
RD-404		1962
RD-502	11D11	1960-1969
RD-503	8D75M	1970
RD-510	11D217	1969-1974
RD-511		1970-1974
RD-512		1970-1974
RD-550		1970-1974
RD-600		1962-1968
RD-701		1988-1991
RD-704		1990-1991
RD-851	8D63U	1958-1963

RD-852	8D64U	1958-1963	
RD-853	8D722	1960-1963	
RD-854	8D612	1962-1967	
RD-855	8D68M	1962-1965	
RD-856	8D69M	1962-1965	
RD-857	15D12	1963-1967	
RD-858	11D411	1965-1972	
RD-859	11D412	1965-1972	
RD-861	11D25	1968-1972	
RD-862	15D169	1969-1972	
RD-863	15D167	1970-1973	
RD-864	15D177	1976-1978	
RD-866	15D264	1980-1983	
RD-868	17D40	1983-1985	
RD-869	15D300	1983-1985	
RD-8	11D513	1976-1985	
?	11D49	1960-1964	
KVD-1	11D56	1960/	
S5-51	11D68	1964/	
?	17D61	?	Yantar-1KFT/Kometa
RD-0105	8D714	1958	RO-05
RD-0106	8D715	1960	RO-09/RD-461
RD-0107	?	?	
RD-0108	?	?	
RD-0109	8D719	1960	RO-07/RD-448
RD-0110	11D55	1964	
RD-0120	11D122	1976-1987	
RD-0205	8D47	1961-1963	
RD-0210	8D411	1962-1965	RD-465
RD-0211	8D412	1962-1965	RD-468
RD-0212	8D49	1962-1965	8D48+verniers 8D811
RD-0213	8D48	1965-1967	RD-473
RD-0214	8D811	1965-1967	
RD-0216	15D2	1963-1965	
RD-0233	15D96	1969-1974	
RD-0235	15D113	1969-1974	
RD-0236	15D114	1969-1974	
S1-5400	11D33	1958-1960	
?	8D726	1962-1965	
?	11D58	1965-1967	
?	11D121	1962-1974	vernier of N-1
?	17D11	1985-1988	ODU of Buran
?	17D12	1985-1988	Buran engine
NK-9	8D517	1959-1963	
NK-15	11D51	1962-1967	
NK-15V	11D52	1962-1967	
NK-19	11D53	1962-1967	
NK-21	11D59	1962-1967	

NK-31	11D114	1968-1972	
NK-33	11D111	1968-1972	
NK-39	11D113	1968-1972	
NK-43	11D112	1968-1972	
?	11D54	?	Liyulka
?	11D57	?	Liyulka (N-1/3rd stage Vulkan)
?	11D57M	?	Liyulka
?	15D13	?	Izotov (UR-100/A-350)
?	15D14	?	Izotov

Table 6
KB KHIMMACH ENGINES

Engine		Year	Thrust (t) (in vacuum)	Isp (s)	Utilization
RD-1/RD-1M		1943-1945	1.1		BI-7/4302
U-1250		1945-1946	1.25		
U-400-10		1946	0.4		Bisnovat missile
SU-1500		1946-1948	1.5		aircraft Il-28/Tu-14
U-2000		1947	2.0		project for ground-to-air missile
U-400-2		1947	0.4		project for air-to-sea missile
?		1955-1957	0.5-1.2		P-15 of Berezniak
Ground-to-air missiles (SAMs)					
9TN	VAD	1948	8.0		R-101/Wasserfall
S09-29A	4 x ch/VAD	1950	9.0		R-113/V-300/205
S09-29D	4 x ch/JAD	1950-1952	9.0		V-300K3
S2-260	4 x ch/VAD	1952	9.0		207
S2-168B		1950-1951	9.0		ChB-32 (abandoned)
S2-145	1 x ch/PAD	1950-1951	9.0		206 (abandoned)
S2-751V	1 x ch/VAD	1953-1954	9.0		V-303/207A/215
S5-1A		1954-1958	17.0	218	217A/217M/218
S5-41		1958-1961	17.0	218	217M
5D25		1963-1969	5.0-17.0		5Ya24/5Ya25/44N6
S2-711V		1954-1957	3.4	233	V-750
S2-720		1955	2.3-3.8		V-755
S2-726		1957-1959	10.5		V-1000/geophysical rocket
Ground-to-ground missiles					
S2-253	JAD	1952-1957	8.3-9.7	220-257	R-11/R-11M/R-11FM
S5-2 (9D21)		1958-1962	13.38	218	R-17 of Makeyev
S2-1100	4 x17 t	1953-1957	68.0		Buria of Lavotchkin
S2-1150	4 x17 t	1953-1957	68.0		Buria

Air-to-ground missiles

S2-711V		1956	3.1-3.4		K-16
S2-722V		1957-1960			K-12B of Beriev
S2-721V		1957			KSR of Berezniak
S5-6.000		1957-1962			KSR-2
?		1957			KSR-11
S5-33		1963-1969			KSR-5
S5-44		1960			X-22
?		?			X-32
?		1969			X-45

Naval missiles (SLBM) of Makeyev

S2-713	1956-1958	25.0		R-13
?	1958-1962	40.0	4 x 10 t.	R-21
4D10	1962-1968	23.0	plunged	R-27
			plunged	1st stage R-29
			plunged	2nd stage R-29
			plunged	1st stage R-29R
			plunged	2nd stage R-29R
			plunged	2nd stage R-29RM
			plunged	3rd stage R-29RM

Space engines

?	? /11D49	1960-1964	16.0	303	11K65M/Cosmos-3M
S5-4	TDU-1	1958-1960	1.614	266	Vostok
S5-45	?	1958-1960	0.2	267	Venera-2 to 8
S5-19	KDU-414/11D414	1958-1960	0.2	272	Mars-1/Venera-1/Molnya
S5-5	KTDU-5A	1960-1963	4.64	277	Luna-4 to 14
?	?	1960-1963	?	?	Polyot
S5-35	KTDU-35/main	1963-1967	0.415	282	Soyuz/Salyut-4
S5-60	KTDU-35/back-up				
S5-53	KTDU-53	1964-1967	0.415	282	7K-L1/Zond
?	KVD-1/11D56	1962-1976	7.0	463	Block-R of N-1

S5-51	? /11D68	1962-1974	0.417-3.38	314	LOK
?	KTDU-417/11D417	1968-1970	0.75-1.9	314	Luna-15 to 24
S5-61	KRD-61	1968-1970	1.9	313	Luna-15 to 24
?	KTDU-425/11D425	1969-1971	1.0-1.9	315	Mars-2 to 7/Venera-9 to 14
S5-66	KTDU-66	1969-1971	0.415	282	Salyut-1
?	KTDU-426/11D426	1968-1974	0.315	292	Soyuz-T
?	KRD-442/11D442	1970-1977	0.447	?	TKS modules
?	? /17D61	1974-1981	0.3	?	Kometa/Ikar
S5-80	KTDU-80	1978-1986	0.3	302	Soyuz-TM/Progress-M
S5-79	KRD-79	1978-1986	0.315	?	Mir
S5-92	?	1978-1988	2.0	327	Phobos/Breeze-M/Fregat
?	? /14D30	1990	2.0	326	stage, Breeze

Table 7

ENGINES OF KB-4 OF NPO YOUJNOE

Engine	Year	Thrust (t) (vacuum)	specific (s) impulse	pressure (atm)	Utilization
N_2O_4-UDMH					
RD-851	1958-1963	28.8	243	67	vernier 1st stage R-36
RD-852	1958-1963	4.9	255	67	vernier 2nd stage R-36
RD-853	196-1963	47.6	300	85.2	8K66/R-26 (2nd stage)
RD-854	1962-1967	7.7	312	87	8K69/R-36Orb (FOBS)
RD-855	1962-1965	29.1	254	67	vernier 1st stage Cyclone-2
RD-856	1962-1965	5.5	280	73	vernier 2nd stage Cyclone-2
RD-857	1963-1967	14.0	329	130	8K99/RT-20P (2nd stage)
RD-858	1965-1972	2.0	315	80	LK (main engine)
RD-859	1965-1972	2.0	312	80	LK (back-up engine)
RD-860	?	2-6 kN	310-323	?	to 15 re-starts
RD-861	1968-1972	8.0	317	90	11K68/Cyclone-3 (3rd stage)
RD-862	1969-1972	14.5	331	135	15A15/MR-UR100 (2nd stage)
RD-863	1970-1973	28.2	259	90	vernier 1st stage R-36M
RD-864	1976-1978	2.0	309	?	4 verniers (AVUM)
RD-865	?	?	?	?	?
RD-866	1980-1983	0.5	305	41.5	1 chamber + 16 verniers
RD-867	?	?	?	?	?
RD-868	1983/?	2.3	325	93.3	1 chamber + 10 verniers
RD-869	1983-1985	2.0	313	?	4 verniers (AVUM)
RD-8	1976-1985	8.0	342	78	4 verniers 2nd stage Zenith-2