

PART 1

The Proton in the East

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Vladimir Chelomey: From the V1 to Proton

Vladimir Nikolayevich Chelomey was born on June 17, 1914 (Julian calendar), or June 30, 1914 (Gregorian calendar) into a family of teachers in Sedletz (Poland). He spent his childhood in Poltava and then moved to Kiev in 1926. At 18 years of age, he finished his studies at the Technicum Automobile of Kiev (Ukraine) and entered the Institut PromEnergetik, studying the internal combustion engine. But the young Vladimir was interested in the then emerging field of aviation. He was accepted into the aerospace faculty at the Kiev Polytechnic Institute (since renamed the National Aerospace University). During his first year, while studying, he also worked as a technician in the subsidiary of the Institute of Civil Aviation.



Figure 1.1. *Vladimir Chelomey (source: rights reserved)*

In 1936, while still a student, he published a paper on vector analysis and taught vibration theory to engineers working at the Zaporozhye aircraft engine factory. This production facility, no. 29 (now Motor Sich), had the manufacturing license for French engines Gnome and Rhône at the time. In 1937, a year ahead of his fellow

students, he successfully received his qualifications from the Institute. He was then accepted to the Institute of Mathematics at The National Academy of Sciences (NAS) of Ukraine where, in July 1939, he presented a PhD proposal in Technical Sciences (“Dynamic Stability of Elements in Aerospace Construction”).

In 1940, he was selected by the NAS to be part of a special group of 50 PhD students, bringing together some of the best doctorate candidates in the country. He then prepared a thesis on the dynamic stability of elastic systems in airplane engines. He submitted the thesis at the beginning of 1941 but was turned down by the administration, and would have to resubmit it at the MVTU in 1951 (“Study of torsional vibrations in aircraft engines”).



Figure 1.2. *The German V-1 (source: rights reserved)*

When war broke out in June 1941 he was evacuated from Kiev to Moscow. He became a member of the Communist Party (CPSU) and joined the Moscow Central Institute of Aviation Motors (TsIAM) where he became head of reaction engines. It was here that he designed a pulsejet engine. In Kazan, in the OKB-16 *charaga* (prison Design Office), B. S. Stechkin designed another pulsejet engine: the US accelerator designed for the Pe-2 aircraft. The US-K model was tested in December 1942 but work was interrupted when Stechkin returned to Moscow in early 1943.

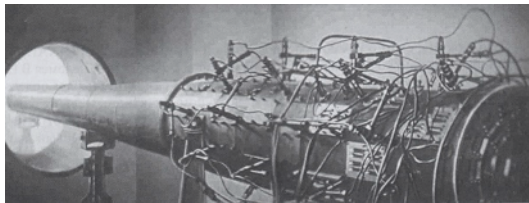


Figure 1.3. *The TsIAM pulsejet engine (source: rights reserved)*

1.1. The Soviet V-1 designer

This type of engine had been used by the Germans on the V-1 cruise missile (Fieseler 103 with Argus 109-014 engine) since December 24, 1942. The first V-1 was fired at London on June 13, 1944. During World War Two, approximately 30,000 missiles were produced, 10,000 of which were directed at London. Moscow decided to produce a similar device. On September 19, Chelomey was appointed Director and Main Designer at production facility no. 51, previously led by aircraft designer N. N. Polikarpov (deceased July 30 1944). Chelomey's appointed deputy was D. L. Tomachevich. Much like Chelomey, he was a graduate from the Kiev Polytechnic Institute and had worked with Polikarpov since 1931. But following an accident that cost the life of pilot V. P. Chkalov, he was sent to the *charaga* from 1938 to 1943. Upon his return, he became Polikarpov's deputy but only until July 1944. He then continued to work with Chelomey but following a deep disagreement about technical solutions, he left in 1947 to go on to develop a national version of the German Hs-293 missile: the RAMT-1400 Schuka (aka KSCh).

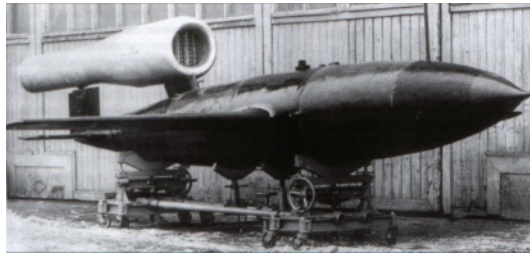


Figure 1.4. *The 10X missile from 1944 (source: all rights reserved)*

On September 23, Chelomey received a V-1 missile recovered in Dembitza, Poland. It was, in fact, the 10X with a D-3 engine. Unlike the V-1, the 10X was launched from an airplane. Consequently, three Pe-8 and two Er-2 aircraft underwent modifications for flight tests. The 10X weighed 2,130 kg and could fly at a speed of 620 km/h across a distance of 240 km. On November 17, the first version was transferred to TsAGI for aerodynamic testing in the T-104 wind tunnel. The engine, with a 270 kg thrust, was tested on a test-bench, then on the test-aircraft Pe-2. On January 18, 1945, by order of decree no. 7350, work began on the construction of 100 missiles, as well as preparations for producing 300 additional units in March. Mass production would be completed by factories no. 456 in Khimki near Moscow, no. 125 in Irkutsk, no. 118 in Moscow (autopilot system) and no. 458 in Savelovo near Dubna (catapult). Following this, on March 20, 1945, the 10X was launched for the very first time in Sjjzak, Uzbekistan. The tests continued until August (63 launches) but the success rate was only 30%. The Commission of Inquiry, led by V. F. Bolkhovitinov, S. A. Lavochkin and N. A. Jemchujin, finally

concluded that the failure was the result of a problem with the fuel supply regulator. Nevertheless, Chelomey received his first Order of Lenin on September 16, 1945.

Around this time, Sergei Korolev was sent to Germany to recover the V-2 and became its main designer on August 9, 1946.



Figure 1.5. *The OKB-51 team in 1944 (source: rights reserved)*



Figure 1.6. *Pulsejet engines D-3 and D14-4 (source: rights reserved)*

In November 1945, Chelomey requested that the Minister of Aviation Industry, A.I. Chakhurin, send specialists from his Design Office (OKB-51) to Germany in order to recover the fuel supply regulator and the Askania autopilot system. One month later, V. I. Tarasov, Chief of the Engine Division, returned with a regulator. By order of decree no. 606-249c, on March 16, 1946 a commission led by A.S. Yakovlev regarding the use of German specialists was initiated. The NKVD General, I. A. Serov, the Aviation General, V. I. Stalin (son of the Head of State) and V. N. Chelomey were also members of the commission. They headed to Germany, where the Sector Chief V. V. Sachkov, at that time visiting Nordhausen, Berlin and other cities, was also present. They returned with autopilot systems and control surfaces from Nordhausen, as well as 129 intact V-1 missiles and three piloted ones from Pulverhof. The autopilot system was copied by production facility no. 118 and renamed AP-4. This gave way to the creation of the PSU-20 pneumatic autopilot system, followed by the AP-52 in 1951. In addition, the electric ESU-1 was also used, followed by the AP-56 in 1952. The ESU-1 was developed by the

Kuibyshev OKB-3 Design Office. There, a group of 61 Germans working for Askania were deported in October 1946. Led by Peter Lertes, the group included specialists such as Waldemar Möller, Helmut Breuninger, Georg Orlamünder, Kurt Kracheel, as well as others. In 1948, the group was placed under the direction of Russian designer P. D. Mitiachin, who manufactured autopilot systems in facility no. 118. But in 1950, the group was transferred to KB-1 in Moscow to contribute to developing the ground-to-air guided missile S-25 Berkut. Here, the group was joined by 13 high-frequency experts from Monino, Johannes Hoch's group from Gorodomlia, and 35 people from Krasnogorsk. Two of them (Bruno Fischer and Wilhelm Fischer) received the Stalin Prize in 1952. They were then transferred to Sukhumi in 1955 before being sent back to Germany.



Figure 1.7. *The D-3 engine on the TU-2 (source: rights reserved)*

In 1946, 180 improved missiles were built and two additional Pe-8 aircrafts underwent improvements. The missile was tested at the Kapustin Yar polygon (73 launches) between December 15, 1947 and July 20, 1948. It was then recommended that the 10X be included in the Army's weaponry, but was refused due to its weak thrust and low speed, lower than other aircraft from that period. But Chelomey continued his tests: 18 launches between late 1948 and October 1949 (11 with the PSU-20 guidance system, five with the PSU-30 and two with the ESU-1).

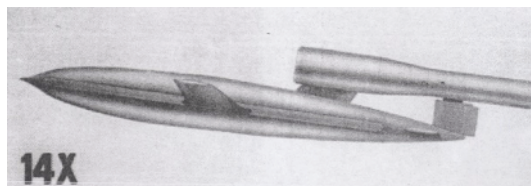


Figure 1.8. *The 14X missile (source: rights reserved)*

At the same time, Chelomey developed the D-5 engine with 400 kg thrust, and the 14X missile with the ability to cruise at 800 km/h. Facility no. 456 went on to

produce 20 missiles. The engine was tested in March 1947 and the 14X flight tests (10 launches) took place in July 1948 using a Pe-8. Four flights allowed for testing of the PSU-20. By the end of 1946, the D-6 engine, with a thrust of 600 kg, successfully passed all flight tests. It was mounted onto the 14XX1 missile the following year, in the first stage of the Kometa program. But once again, the Army refused to integrate it into its weaponry.

Kometa was intended to be a guided anti-ship missile. On September 8, 1947, by order of decree 3140-1026, the special Design Office SB-1 was created and ordered the guidance system to be developed with the assistance of the captured Germans. The Chief of SB-1 was P. N. Kuksenko, and his Deputy was none other than the son of L. P. Beria, Minister of the Interior and Stalin's right-hand man, S. L. Beria (from his real surname Gegechoria). Having just completed the Budyonny Military Academy of Communications, he was now responsible for radio devices on the missile (Kometa-I), on the carrier plane (Kometa-II) as well as on the autopilot system for the missile (Kometa-III). The carrier plane was a Tu-4 (a copy of the B-29). For the missile, several options were possible. Chelomey then proposed a missile equipped with a 900 kg thrust D-7 engine. But in 1947, aircraft designer A. I. Mikoyan opened Department B in his Design Office. Led by M. I. Gourevich, he was in charge of guided missiles. Artem Mikoyan was none other than Anastas' brother, member of the Politbureau and Deputy President of the Ministers Council. In the beginning, Mikoyan proposed a smaller version of the Mig-9, but, in the end, the Mig-15 was finally selected. The KS-1 Kometa, propelled by a RD-500 turbojet, could cruise at more than 1,000 km/h while Chelomey's missile in comparison could only reach 950 km/h. Production for the KS-1 was entrusted to facility no. 256 in Dubna (subsidiary no. 2 of OKB-155). The SB-1 and OKB-155 were awarded with the Stalin Prize in 1953. Among the recipients of the award were S.L. Beria, of course, but also D.L. Tomachevich, who had left the KB-2 in 1949 to become Chief of Sector 32 at SB-1. Tomachevich held a grudge against Chelomey.

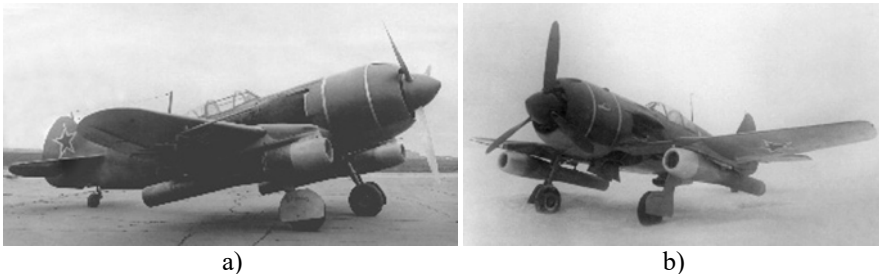


Figure 1.9. a) *La-7 with two D-10* and b) *La-9 with two D-13*
(source: rights reserved)

During this time, the pulsejet engines were used as fighter plane accelerators. The D-10 engine was then mounted onto the Lavochkin-designed La-7 in 1946, and the D-13 engine was mounted onto the La-9 in 1947. Each plane had two engines with a 200 kg unit thrust and were featured in the Tushino Air Show in August 1947.

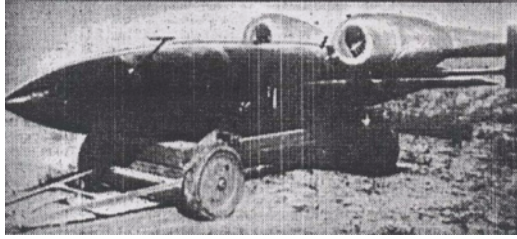


Figure 1.10. *The 16X Priboy missile (source: rights reserved)*

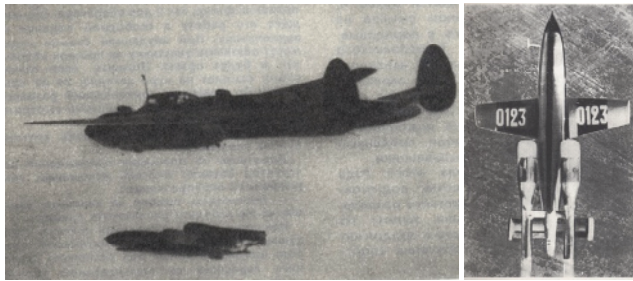


Figure 1.11. *The 16X missile in flight (source: rights reserved)*

On May 7, 1947, by order of decree 1401-370 the airborne missile 16X Priboy was developed (2,557 kg). Likewise, the 15XM was also requested for the Navy. On April 14, 1948, by order of decree no. 1175-440, production of the 15XM (generic program Chtorm) was entrusted to M. R. Bisnovat at facility no. 293 in Khimki. Bisnovat had worked at the NII-1 (Kostikov rocket-aircraft 302 between 1942 and 1944), at factory no. 153 between 1944 and 1946, before working for himself on June 7, 1946 (5 aircraft between 1946 and 1949). The 15XM was propelled by M. M. Bondariuk's ramjet and the Priboy was propelled by two pulsejet engines, namely the D-312 followed by the D-14-4 (251 kg unitary thrust). Following decree no. 1175-440, two variants of the guidance system were planned for production (PSU-20 and ESU-1). From July 22 to December 25, 1948 in Akhtuba (Vladimirovka station in the Kapustin Yar polygon), six missiles underwent flight testing. In 1949, the tests continued over three stages. The first stage involved four launches. The second, with 11 launches, showed that the engine cut off when it

reached 720–775 km/h. To increase speed while maintaining stability, they decided that the nozzle had to be shortened. The D-312 was replaced by the D-14-4, allowing it to reach 1,000 km/h. The new engine could be tested in the third stage with 13 launches: the results showed that the 16X could reach 872 km/h in normal regime and 912 km/h in forced regime. Out of 34 launches, eight were performed from a Tu-2 and 26 from a Pe-8. Twenty-nine of them were equipped with a PSU-20A and five with an ESU-1. A new round of tests (20 missiles, all featuring a PSU-20A) was conducted with a Tu-4 (2 missiles), and a Tu-2 (1 missile) between September 6 and November 4, 1950. The first stage included four launches, the second also had four, and the third had 12. It reached a speed of 900 km/h and a range of 170 km. All launches reached the 10.8×16 km target. The second round of flight tests comprised six launches between June 12 and 17 (with the AP-56 autopilot system), and 22 launches between August 2 and 22, 1952. Regardless of the tests, the Army was persistent in its decision not to integrate it into the weaponry due to a lack of precision and reliability. However, the Army did eventually request additional testing on the 16X in late 1952 (15 missiles), before forming a Tu-4 squadron in 1953 (60 missiles, 20 of which used warheads).

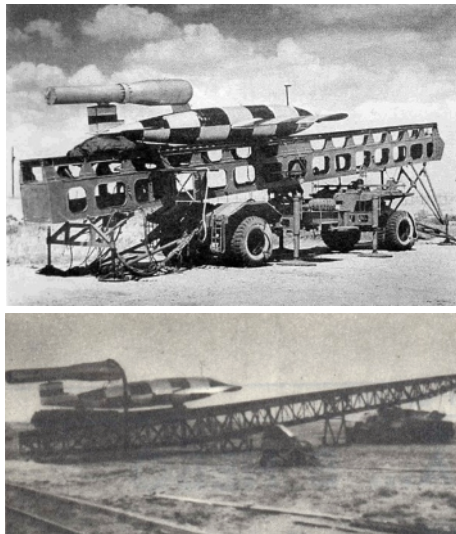


Figure 1.12. *The 10XN missile (source: rights reserved)*

At the same time as the 16X, Chelomey developed the mobile, land-based version of the 10X for the Army, the 10XN (N for *Nazemlie*, meaning *land*). It had been approved by decree no. 4814-2095 of December 4, 1950. It was equipped with

a D-16 engine, reaching a 320 kg thrust from a rail launcher (mobile version on the T-34 tank), using a powder-based accelerator to propel for lift-off. In 1945, the first project used the German accelerator that had been recovered by designer I.V. Chetverikov from facility no. 458, but the project was abandoned due a to lack of materials. In March 1946, a second project was initiated, using an accelerator from the KB of factory no. 81 (now MKB Iskra), with 16 cartridges of M-31 shells. From May 19 to October 19, 1948 at the Sofrino polygon (now NII Geodesia), 12 missiles were launched on rails of 40 m and 30 m length. In 1949 and 1950, five missiles were launched with RBT-700 accelerators. In 1951, the latter was replaced by the SD-10XN, developed by the Krasnoarmeysk KB-3 (now KNIIM). From 23 to 31 July, the 10XN was launched 12 times out of Kapustin Yar (10 with the PSU-30 guidance system and two with the AP-52 autopilot). From May 12 to June 20, 1952, the factory tests were inconclusive: seven out of the 20 launches failed. An additional four launches took place between September 19 and 24. But on February 19, 1953, upon Beria's initiative, Chelomey's OKB-51 was closed down by order of decree 553-271, and his activity was transferred to Mikoyan's OKB-155. OKB-293 was also closed and transferred to KB-1 (former SB-1) to help with the development of ground-to-air missiles from the Third Main Directorate (TGU) of the Ministers Council. It should be noted that the V-1 had been rebuilt by Republic Aircraft (Ford engine) in the United States under the name JB-2 Loon. The first flight had taken place in Eglin in October 1944, and 1,385 models were delivered to USAF. The KGW-1/LTV-N-2 version was developed specifically for the Navy. Tests were carried out on the USS-348 Cusk submarine from February 1947 but, finally, the program was stopped in 1950 much to the advantage of the Regulus missile.

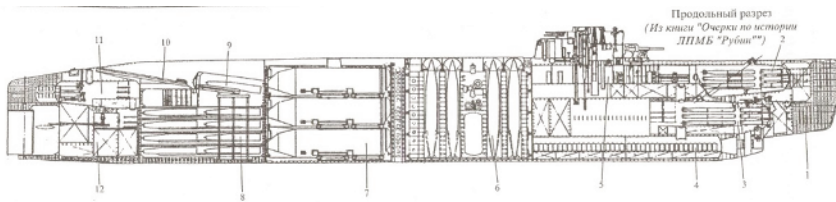


Figure 1.13. *The P-2 submarine project from 1949 fully equipped with the 10XN missile (source: rights reserved)*

However, the 10XN would still be used as a target device. Decree no. 5472 of May 19, 1954 ordered the production of 100 units from facility no. 475 in Smolensk. However, this would be reduced to just 50 units by November 3, 1955. This version was fully equipped with the AP-66 autopilot system and a PRD-15 powder-based accelerator. Six missiles were tested in 1956 and five additional launches for quality control took place in July 1957.

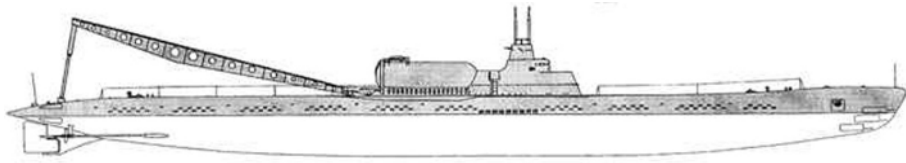


Figure 1.14. *The Pr628 submarine project from 1952 and 1953 with the 10X missile (source: rights reserved)*

In addition, decree no. 4814-2095 of December 4, 1952 required Chelomey to develop a supersonic missile that would be mounted onto a submarine. In 1949, F.A. Kaverin's TsKB-18 started two *Lastochka* projects: the P-2 submarine with 51 10X missiles and the P-4 submarine (Project 624) with Lavochkin's P-40 missiles.

But these projects were quickly abandoned. Chelomey then went on to review the Volna project, which planned to load the 10XN onto a Project 628 submarine. But, once again, in early 1953, the OKB was closed down which put an end to the project.



Figure 1.15. *Missile wing deployment mechanism (source: Christian Lardier)*

When the OKB was shut down, some of Chelomey's colleagues were transferred to Mikoyan's production facility, whereas others preferred to change company altogether. Chelomey's Deputy, V. S. Avduyevsky, went to the NII-1 in G. I. Petrov's laboratory to focus on aerodynamic heating and atmospheric entry. He had studied the centrifuge injector for pulsejet engines at the TsIAM in 1944, then combustion by diffusion at the NII-1 before joining OKB-51. He went on to become Deputy Director of the NII-1 (Keldysh Center) in 1965 until 1973, Vice Deputy of the TsNII Mach between 1973 and 1987, then Vice Deputy of the Institute of Machines at the Academy of Sciences from 1987 to 2003.

1.2. The designer of Soviet naval missiles

However, Stalin died on March 5, 1953 and Sergei, Beria's son, was arrested in July, which greatly changed things. Sergei was eventually liberated and sent to work at the NII-592 in Sverdlovsk from 1954 to 1964. He then went on to work for the NII Kvant in Kiev from 1964 to 1988 and led a department on new physics principles at the Institute for Mechanical Engineering Problems of the Ukrainian Academy from 1988 and 1990. At the end of his career, he was Director of the TsNII Kometa subsidiary in Kiev, from 1990 until 1999.

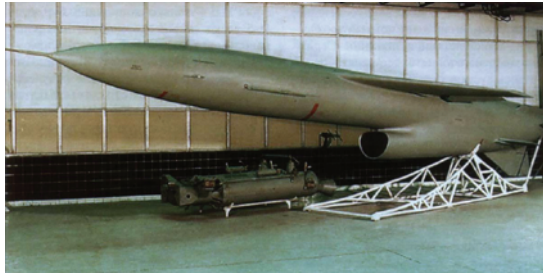


Figure 1.16. *The 1955 P-5 missile (source: NPO Mach)*

OKB-51, which had become a subsidiary of OKB-155, was taken over by designer P. O. Sukhoi in October. Chelomey, who wanted to pursue the development of the Volna program, requested for a new Design Office to be opened. He obtained a special group (SKG-10, with 20 people) located in production facility no. 500 in Tushino (airplane engines) on August 9, 1954. M.I. Livshitz joined Chelomey as deputy, having been responsible for guidance systems in OKB-51.

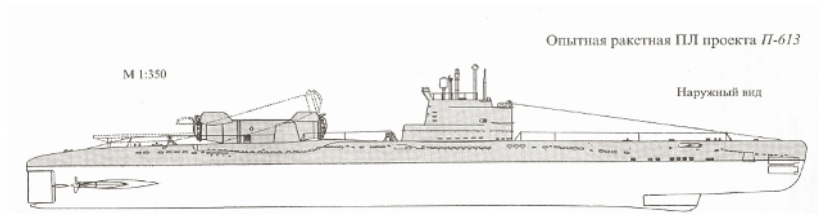


Figure 1.17. *The 1955 Pr613 missile with the P-5 missile (source: rights reserved)*

From then on, he was no longer working for the Air Force but instead for the Navy. On March 5, 1955, he put forward his anti-ship missile MD-1, weighing 3.5 tons. It could reach a speed of 1,500 km/h, with a 400–600 km range depending on

the altitude. The originality of the device was in the deployment of the wings after launch from a tube measuring 1.65 m diameter by 11 m length. He obtained approval from Admiral S. G. Gorshkov who led the Navy from 1956 to 1985, and Vice-Admiral P. G. Kotov from the naval artillery department.

On July 19, 1955, Chelomey moved to the OKB-52 in Reutov (former mechanics factory). His progress here came on rapidly. Decree no. 1457-809 on August 8, 1955 ordered P. P. Pustintsev (TsKB-18) to lead submarine project 613. Chelomey, in OKB-52, was required to design the P-5 missile (4K34), measuring 10.8 m and weighing 5.1 tons. It was ejected from an SM-49 tube (TsKB-34) using a powder-based PRD-34 accelerator developed by I. I. Kartukov (KB of factory no. 81). The wings were deployed by the ARK-5 hydraulics system. It was then propelled at 1,300 km/h by V. N. Sorokin's turbojet KRD-26 (OKB-26 in Ufa). The AP-70A guidance systems made it possible to cruise at a minimum altitude of 400 m. The warhead could be either classic or nuclear (RDS-4, identical to missile R-11FM). The launch management system was developed by S. F. Farmakovsky from NII-303 (TsNII Elektropribor).

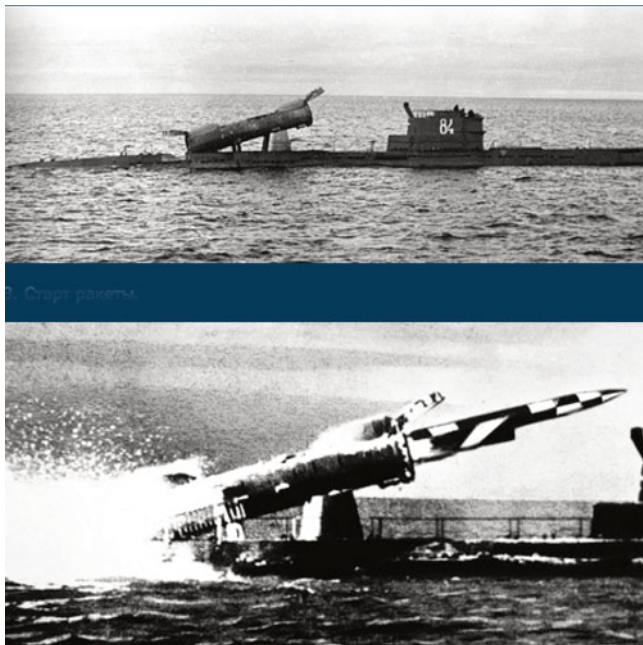


Figure 1.18. *P-5 flight test in 1957 (source: rights reserved)*

The first launch of a prototype took place on March 12, 1957 from the NII-2 base in Belozersky-Faustovo, near Moscow. The NII-2 of aviation industry was established in February 1946 (now named GosNIIAS). From 1951 to 1970, it was led under the direction of V. A. Djaparidze, previous Head of the TsAGI laboratory, who later proposed an air-cushion landing system for one of Chelomey's space shuttles. The P-5 flight tests went ahead in Balaklava from August 1957 to March 1958. The first submarine, Project 613 no. S-146, was built by production facility no. 112 in Krasnoye Sormovo (Gorky). The first launch from the submarine took place on November 22, 1957 in Severodvinsk. In total, 21 launches took place and on June 19, 1959, by order of degree 685-313, the missile was declared operational.



Figure 1.19. *P-5 launch from submarine Pr659*
(source: rights reserved)

The P-5 was deployed on several types of submarine. Project 613 no. S-80 was turned into Project 644, a two-missile carrier, and a salvo of two missiles was carried out in December 1959. Following this, six units of Project 644 were produced (S-44, S-46, S-69, S-80, S-158, S-162). Project 665, a four-missile carrier, was also produced in six units (S-61, S-64, S-142, S-152, S-155, S-164). Finally, Project 659, a nuclear propeller, was equipped with six missiles and produced in six units by production facility no. 199 in Komsomolsk-sur-Amour (K-43, K-59, K-66, K-122, K-151, K-30).

The P-5D version (4K95) was fitted with a Doppler for measuring the speed and drift angle of Zhukovsky's NII-17 to improve accuracy and lower the flight altitude. As such, it reached an accuracy of 4 km/500 km and the altitude decreased from 400 to 200 m. The barometric altimeter was replaced by a RV-5 radio altimeter from OKB-379 in Kamensk-Ural (now UPKB Detal). Between 1959 and 1960, 22 missiles were tested in Kapustin Yar. It was then tested on submarine Project 644D no. S-162 between 1960 and 1961. It was declared operational on March 2, 1962. The P-5SN version was fitted with a RV-5M radio altimeter. Finally, the P-5U was equipped with an inertial guidance system provided by V. I. Kuznetsov from NII-944 (a gyroscopic platform) and E. F. Antipov from OKB-923 (barometric altimeter).



Figure 1.20. *The 1960 S-5 missile (source: rights reserved)*

Chelomey also studied a P-5P for the Army and a P-5N for the Air Force. The S-5 ground version (2K17) was transported by one of V. A. Grachev's ZIL-135K trucks. Seven launches were carried out in 1960, and an additional five launches allowed them to take part in State testing in 1961. It was declared operational on December 30, 1961 and then became the FKR-2 system (frontal cruise-missile). The FKR-1 (or KS-7) had been developed by Mikoyan based on the Kometa missile. The airborne version had not been developed since Mikoyan's X-20 was selected. The S-5L (2K17M) was designed by order of decrees from June 19, 1959 and January 9, 1963. The 9M78 missile was given a 4L44 accelerator, a 4D95 turbojet and a RV-15 radio altimeter. Six launches were fired between August 1 and October 20, 1964. Finally, the S-5V, transportable by Mi-10 helicopter, was reviewed between February 1962 and November 1965.

The P-5 was mass produced in aviation factory no. 292 in Saratov and no. 99 in Ulan-Ude. It cost 1.5 times less than a Mig-21, or half as much as a Su-7B. On the other hand, it cost twice as much as A. Ya. Bereznia's P-15, and six times more than P. D. Gruchin's S-75.

Its two competitors were G. M. Beriev's P-10 and S.V. Ilyushin's P-20. As decided on June 19, 1955, the first had been flight tested in 1956 and abandoned in 1957. Decree no. 1601-892 of August 25, 1955 planned to have it assigned to the Project 642 submarine (replaced by Project 646 in 1956). The second rival, decided in April 1956, had also been abandoned in 1960. Decree no. 1601-892 of August 25, 1955 planned to allocate it to the submarine Project 627A (Project 653 in 1958).

The 1959 Lenin Prize was given to V. N. Chelomey, S. N. Khrushchev, M. I. Livchitz, V. A. Modestov, I. M. Chumilov, V. E. Samoylov, S. B. Purzin, A. I.

Korovkin and V. V. Krylov. In addition, Chelomey also received his first Hero of Socialist Labor medal and became General Designer of the aviation industry. At this time, Korolev was only Main Designer as he was working for the Ministry of Defense Industry which did not yet have general designers. On March 1958, Chelomey hired Khrushchev's son who had just completed his schooling at the Moscow Energy Institute (MEI). As a specialist of anti-ship guidance missiles, he quickly became Deputy of the OKB where he worked up until July 1968. This enabled Chelomey to win the full support of the Head of State until his dismissal in October 1964. He then created his empire, employing 25,000 people, which dominated the aerospace sector for 5 years. During this time, he took over the NII-642 and its production facility on November 6, 1957 (subsidiary no. 2), plant no. 23 and its OKB on October 3, 1960 (subsidiary no. 1), as well as facility no. 301 and its OKB in 1962 (subsidiary no. 3).

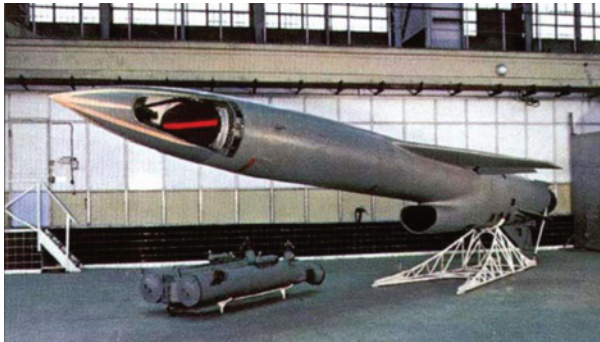


Figure 1.21. *The P-6 (4K48) missile (source: NPO Mach)*



Figure 1.22. *The P-35 (4K44) Redut missile (source: NPO Mach)*

Following the success of P-5, Chelomey went on to design a series of naval cruise missiles: the P-6 (4K48), P-35 Redut (4K44), P-7 (4K77), P-25 (4K70), P-70 Ametist (4K66), P-120 Malakhit (4K85), P-500 Bazalt (4K80), P-700 Granit

(4M45), P-750 Meteorit (3M25), P-800 Yakhont/Onyx (3M55) and P-1000 Vulcan (3M70).

The corresponding NATO codes are SSN-3 Shaddock (P-5, P-6, P-35, P-7), SSN-7 Starbright (P-70), SSN-9 Siren (P-120), SSN-12 Sandbox (P-500), SSN-19 Shipwreck (P-700), SSN-24 Scorpion (P-750), SSN-26 Strobile (P-800) and SSN-27 (P-1000).



Figure 1.23. *Mobile version of coastal defense Redut*
(source: rights reserved)

Decree no. 1149-592 of August 17, 1956 required the development of the P-6 (4K48) submarine-launched missile and P-35 (4K44), which was launched from the surface. Produced in Reutov, the first missile was equipped with a guidance system taken from NII-49 (now NPO Granit), and the second developed by the NII-10 subsidiary (now NPO Altair). They were 10 m in length and weighed 6 tons. The P-6 was propelled by a KRDF-26 (4D48) turbojet designed in the Ufa OKB-26-300 (where V. N. Sorokin was replaced by S. A. Gavrilov in 1962). The SM-77 launcher was provided by TsKB-34 and the Leningrad Bolshevik facility.

The first stage in the P-6 tests began in December 1959 and ran until July 1960 in Kapustin Yar (five launches). The second stage, in Nenoksa, ran from July until October 1960 (six launches). But the guidance system was causing problems. A series of launches took place from August to December 1961 (seven launches). The launches from swing bench started in May until December 1962 (seven successful launches out of 13). This was followed by tests from a Pr-675U submarine between July and October 1963 (five launches). The last stage, from October to December 1963, consisted of three launches from a 651 submarine and nine launches from a Pr-675. On July 23, 1964, the State commission, led by Vice-Admiral V.A. Sitchev, declared the P-6 operational after 46 launches. This was then mass produced by facility no. 292 in Saratov and no. 126 in Komsomolsk from 1962 to 1967. It was deployed on the 16 diesel Pr-651 submarines (four missiles) and the 26 nuclear Pr-675 submarines (eight missiles). The submarines were designed by the TsKb-18 in Leningrad (now the TsKB MT Rubin).

The P-35 flew for the first time on October 21, 1959. It was propelled by S.K. Tumansky's KR-7-300 turbojet (OKB-300). The launch accelerator was a SPRD-38 by I. I. Kartukov. The TsKB-34 along with the TsNII-173 developed the launchers: SM-70 (four tubes) for the Pr-58 Grozny cruiser, SM-82 (four tubes) for the ground tests and SME-142 (one tube) for the tests on ship OS-15. From October to March 1960, five launches took place with no radio-technical systems. Between July and August 1960, seven launches were fired with the APLI-1 autopilot system but the results were not encouraging. After some improvements, another 10 launches took place in 1961, six of which were successful. Following this, five launches took place from Grozny between June and July 1962. The missile was incorporated into the weaponry on August 7, 1962. The production facility no. 292 in Saratov was entrusted with mass producing the missile. It was deployed on four Pr-58 ships (eight tubes) between 1962 and 1964, and on four Pr-1134 ships (four tubes) between 1967 and 1969. Decree 903-378 of August 16, 1960 ordered for a coastal defense version of the P-35B Redut to be designed, transported by a ZIL-135K truck. Flight tests began in 1963 and the system was declared operational on August 11, 1966. After this, 52 units were deployed.

The P-6 and the P-35 were awarded the Lenin Prize in 1967 (A. I. Eidis, A. S. Mironov).

On July 16, 1961, a decree ordered the coastal defense missiles S-2 Sopka (Mikoyan's Kometa missile) to be replaced by P-35B missiles. The guidance system was produced by the NII-303 (now TsNII Elektropribor). The first launch took place on May 30, 1971. The fixed Utes installation was declared operational on April 28, 1973. Twelve further installations were launched in three divisions in Balaklava in Crimea (object 100) and on Kildin Island near Murmansk (object 101).



Figure 1.24. *The 3M44 Progress (source: Christian Lardier)*

It was improved and developed into the 3M44 Progress in 1973. The flight tests took place between October 1976 and October 1977 in Severodvinsk. It was announced operational in 1982 and then mass produced. It was deployed on the Pr58 and Pr1134 ships, as well as on the Redut and Utes systems.

The P-6 and P-35 were the first to use the new Uspekh-U Naval Reconnaissance and Target Designation System (MRSTs) by Main Designer I. V. Kudriavtsev from the Kiev NPO Kvant. The system was mounted onto the Tu-16 and Tu-95 planes, as well as onto the Air Force's Ka-25 helicopters. With this system, it was possible to attack targets outside the visibility zone. This led to the development of Chelomey's space MKRTs.



Figure 1.25. *The P-7 missile from 1959 to 1965 (source: rights reserved)*

The decree on June 19, 1959 ordered the development of the P-7 missile with a 900–1,000 km range, with the mass increased from 1.2 to 6.6 tons. The engine was a KR-21-26 designed by S.A. Gavrilov and the launch accelerator was a PRD-94 by Kartukov. The guidance system was completed by the NII-923 (V. V. Drabkin). It had an NII-17 Doppler system by V. A. Granovsky. The subsidiary of OKB-52 in production facility no. 256, Dubna, was in charge of mass production. The first launch from a SM-49 tube took place on April 21 1961 at Kapustin Yar (10 launches). The submarine tests (S-158) took place from October 1962 to 1963 in Severodvinsk (11 launches). Two additional launches took place in November 1964, reaching a total 23 launches. On August 2, 1965, the program was closed down.



Figure 1.26. *The P-70 (4K46) missile Ametist (source: rights reserved)*

The P-25 (4K70) missile was designed following decree no. 926-386 of August 26, 1960. With a solid propellant engine, it was meant to replace the Bereznik P-15 on the Pr205 torpedo. Production began in facility no. 642 between 1961 and 1962, but the program was transferred to the Lavotchkina facility on December 18, 1962.

On April 1, 1959, decree no. 363-170 ordered the development of the P-70 Ametist, the world's first anti-ship missile with a submerged launch. With a mass of 3.7 tons, it had a 70 km range and flew at 60 m altitude. It had a 293-P solid propellant engine from KB-2 (I. I. Kartukov). The guidance system was provided by the NII-49 (B. A. Mitrofanov). It included an autopilot system, a radio altimeter, a calculator and a radar seeker. The TsKB-34 produced four types of launch tubes: SM-101 for ground tests, SM-107 for the Pr613A submarine, SM-97 for the Pr661 atomic submarine and SM-7A for the Pr670A atomic submarine. The first stage in the tests included 10 launches from SM-101 in Balaklava (first underwater launch on June 24, 1961). On December 12, 1962, the first launch of the Pr613A submarine failed. The flight tests started once again in Feodosi in 1963 with 10 launches, but on December 17, a decision was taken to stop the tests in order to make modifications to the submarine. The third stage took place from July to December 1964 with six launches in the White Sea. The combined tests took place from March 1965 to September 1966 with 13 launches, and the control tests during October–November 1967 (10 launches with salvos). The missile was declared operational on June 3, 1968 after 50 launches. It was then mass produced in facility no. 126 in Komsomolsky-sur-Amour (KnAPO) and in facility no. 301 in Khimki (Lavotchkina). It was deployed on 10 Pr670 submarines (eight missiles) between 1967 and 1972 and on a Pr661 (10 missiles) between 1969 and 1970.

The Ametist was awarded the Lenin Prize in 1970 (V. I. Patruchev, N. M. Tkachev).



Figure 1.27. *The P-120 (4K85) missile, Malakhit (source: rights reserved)*

The P-120 Malakhit missile was developed by order of decree 250-89 from February 28, 1963. It was the first missile to use two radar and thermal (infrared) guidance systems. This system, Delfin, designed with the NII-10 (V.E. Krasnov),

included the Dvina radar, the infrared seeker Drofa and the APLI-5 Dniepr autopilot system. The solid propellant engine 4D85 (I. I. Kartukov) was more efficient. With a mass of 3.8 tons, it had a 150 km range and flew at 900 km/h. It was launched from the SM-156 tube from atomic submarine Pr670M and from Pr1234 torpedoes. The first round of flight tests began on September 25, 1968 until February 1969 in the Black Sea. From July to October 1969, three launches were carried out from a depth of 50 m, and four launches took place from a coastal installation. From March to August 1970, six launches took place from the Pr1234 Buria. Altogether, the combined tests took place between September 1970 to 1972 (14 launches). On March 17 1972, the missile was declared operational on the Pr1234. From April to December 1974, the tests were combined with the Pr670M submarine (eight launches). On November 21 1977, the Malakhit was also declared operational on the Pr670M. There were 44 launches between 1968 and 1975. Mass production commenced at production facility no. 301 in Khimki and at facility no. 47 in Orenburg. It was deployed on 33 Pr1234 (six missiles) and on six Pr670M (eight missiles). It was also scheduled to be deployed on the Pr705 submarine (12 missiles).



Figure 1.28. *The P-500 (4K80) Bazalt missile (source: rights reserved)*

The P-500 Bazalt missile was initiated under the same decree as the Malakhit. It was propelled by a KR-17-300 Ufa engine, allowing it to fly a Mach 2 and have a 550 km range. It had a mass of 4.8 kg and was 11.7 m long. The NII-49 Argon (TsNII Granit) guidance system was, for the first time, equipped with an onboard computer. The first round of flight tests started on October 1969 until October 1970 in Nenoska. Afterwards, the tests continued up until 1974. On August 11, 1975, the missile was declared operational. It was produced in the no. 292 Saratov facilities, as well as no. 1 in Kuybichev and no. 47 in Orenburg. It was then deployed on 10 Pr675MK submarines (eight missiles), on the four Pr1143 aircraft carriers Kiev, Minsk and Novosibirsk with eight missiles, and on Admiral Gorchkov/Baku with 12 missiles between 1975 and 1987. It was further deployed on the three Slava Pr1164 class cruisers Moskva, Marshal Ustinov and Variag (16 missiles) between 1983 and 1989. The MRSTs Uspekh (Ka-25RTs, Tu-95RTs) and Legend (satellites US-A and US-P) controlled the target identification.



Figure 1.29. *The P-1000 Vulcan (source: Christian Lardier)*

The decree of May 15, 1979 required the Bazalt to be modified into the P-1000 Vulcan. Because of the use of modern materials, it allegedly weighed 1–2 tons, which enabled an increased range reaching 700 km. The flight tests started in July 1982. The first launch from a Pr675MKV submarine took place on December 22, 1983. On December 18, 1987, the State Commission, led by Rear Admiral O. D. Bobyrev from the Nenoska polygon (GTsMP-21) declared it operational. Five submarines were equipped with eight missiles. The decree of October 13, 1987 requested that the three Pr1164 cruisers be equipped with 16 missiles, which took place between 1983 and 1989.



Figure 1.30. *The P-700 (4M45) Granit missile (source: rights reserved)*

The development of the P-700 Granit missile, a 7-ton device able to fly at 2.5 Mach across a distance of 550 km, was authorized by decree on July 10, 1969. It was launched underwater from a tube of TsKB-34 (V.V. Chernetsky) with an accelerator. Two versions were developed, one using liquid propellant with the RD-0231 engine from KB Khimavtomatiki in Voronej, and another using solid propellant and an engine from the KB Mach in Perm (L. N. Lavrov). The second was finally chosen. The cruise missile engine was a KR-21-300 from Ufa (S.A. Gavrilov). For the very first time, it used a solid propellant ignition and an electronic regulator in operating regime (ERRD-21). The guidance system was produced by the TsNII Granit (V. V. Pavlov, I. Yu. Krivtsov, V. V. Golovanov). The flight tests took place from November 1975 to August 1983, with the first underwater launch on February 26, 1976 and the first launch from a Pr949 submarine in December 1980. The State Commission led by Rear Admiral K. K. Frantz from NII-28 declared it operational on March 12, 1983. Production was entrusted to facility no. 47 in Orenburg. It was deployed on four nuclear cruisers: Pr1144 Admiral Uchakov, Admiral Lazarev, Admiral Nakhimov and Piotyr Velikiy (20 missiles), as well as the aircraft carrier Pr1143.5 Admiral Kuznetsov in 1990 (12 missiles), and finally, three Pr949 atomic submarines between 1980 and 1996, and nine Pr949A from the TsKBMT Rubin (24 missiles) between 1980 and 1996. The Granit was awarded the Lenin Prize in 1984.



Figure 1.31. *The P-750 (3M25) Meteorit cruise missile*
(source: Christian Lardier)

The intercontinental strategic missile P-750 Meteorit was authorized on December 9, 1976. Three versions were meant to be developed: land-based variants (Meteorit-N, aka SSC-5), sea-based variants (Meteorit-M, aka SSN-24 Scorpio) and air-based variants (Meteorit-A, aka ASX-19 Koala). It weighed 6.3 tons, measured 12.8 m in length and 5 m in width. It was a tube-launched cruise missile, propelled by a KR-93 ramjet from OKB-26 in Ufa (mass produced at the Tyumen engine

facility). It flew at 2.3–3.0 Mach across a distance of 5,000 km at an altitude of 22–24 km. The high-precision guidance system operated and adapted according to ground conditions. The map of the zone surrounding the target was introduced into the onboard computer. The trajectory could be corrected during flight and the missile could make a return flight across several thousand kilometers (Kapustin Yar to Balkhash and back again). It was equipped with an anti-jamming protector and a stealth system (it was covered by a film, making it practically invisible). As a strategic missile, the warhead was therefore a nuclear one. The land and sea variants were launched using a 6,270 kg liquid propellant accelerator. It was propelled by two RD-0242 engines with 12.6-ton thrust power (KB Khimavtomatiki), which could operate for 32 s.

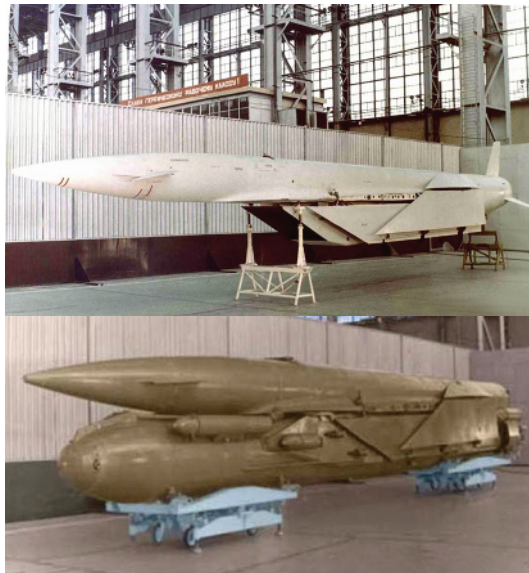


Figure 1.32. *The space (top) and naval (bottom) Meteorit (source: rights reserved)*

The sea-based variant was ready in December 1978 and the air-based variant in January 1979. Facility no. 23 Khrunichev was responsible for production. The first ground stand flight took place on May 20, 1980 but the rocket did not leave the tube. The three following launches also failed. On December 12, 1981, it flew 50 km. Initially, the sea version was meant to be deployed on the Pr949M submarines. Eventually, the Pr667 no. K420 was changed into Pr667M (12 missiles) in Severodvinsk. It was launched from a depth of 40 m. The first launch from a submerged tube took place on January 29, 1982. The first launch from the Pr667A in the White Sea was performed on December 26, 1983. As for the air-based variant,

which was dropped in flight (no tube, no accelerators), a Tu-95MS plane was transformed into a Tu-95MA by the Taganrog facility. The first flight was carried out in January 1984. The flight tests continued up until the end of the 1980s. The State Commission was led by Captain E. M. Kutovoy from the Kuznetsov Academy for the sea variant and by Major General L. V. Kozlov from the NII-8 for the air-based version. By the program's definitive end in 1992, there had been 70 flights, 50 of which were land launches (ground stand and submarine), and 20 from the plane. One of these innovations received a government award in 2001.

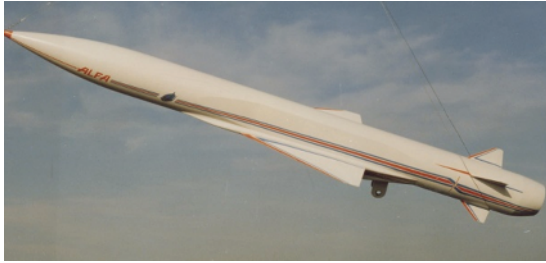


Figure 1.33. *The Alpha project missile (early 1990) (source: NPO Mach)*

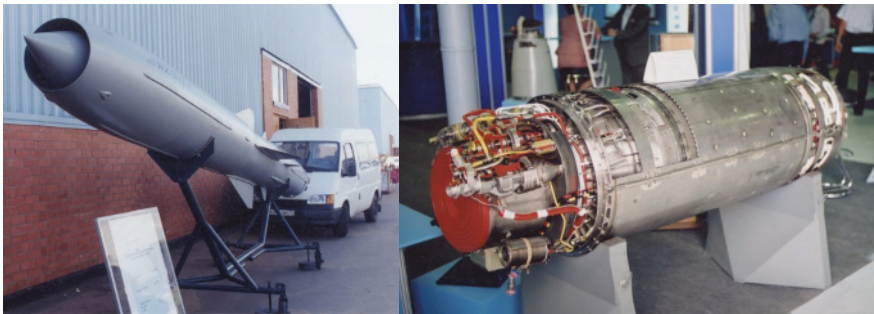


Figure 1.34. *The P-800 Onyx/Yakhont missile and the Plamyia ramjet (source: Christian Lardier)*

The P-800 Onyx/Yakhont was being developed from March 1982 onwards, to replace the Malakhit. Weighing 3.0 tons, it was put into a tube measuring 8.9 m in length and 0.71 m in diameter, designed by the TsKB-34 (V. F. Potapov). It was propelled by a 3D55 supersonic ramjet by the company Plamya (I. B. Levanov), spun off from the KB Soyuz in Turaevo, located in the Keldysh Center from 1978 to 1991. After a few years of operating independently, it was integrated into the Zvezda-Strela holding between 1998 and 2004 before later closing. A solid propellant engine located in the ramjet nozzle enabled lift-off. The missile flew at

2.8 Mach with a 300 km range. The guidance system was produced by the TsNII Granit (inertial navigation and radar seeker). The first mock-up flew on April 26 and July 19, 1985. The first flight from a ground launcher in the Black Sea took place on December 29, 1986. The missile was launched from the Pr1234.7 Nakat ship (12 missiles) in September 1987. Following this, the Pr670M no. 452 (24 missiles) was transformed to launch the Onyx, the first launch taking place on December 14, 1990. From 1985 to 2000, there were 61 flight tests and the missile was declared operational on September 23, 2002. The missile and the engine were manufactured by facility no. 47 in Orenburg. The missile was fully multifunctional, with sea (surface ship and submarine), air-based (Alpha system), and coastal defense (Bastion system using the Maz-543 vehicle) variants. Thirty units of nuclear submarine Pr885 Yassen were to be produced. The first model, the Severodvinsk, has been in the sea since 2010. It carried eight vertical SM-346 tubes for the Onyx missile. 20 of the frigate Pr22350 were also to be produced. The first, Admiral Gorshkov, has been at sea since October 2010. It carried 16 tubes for the Onyx. Finally, 30 models of the Pr12300 Scorpio were produced and carried four tubes for the Onyx.



Figure 1.35. *Air-based variant of the Yakhont (source: Christian Lardier)*



Figure 1.36. *Indian version, Brahmos (source: Christian Lardier)*

In exported markets, it is known as Yakhont, and Brahmos is the version sold under licence to India.



Figure 1.37. From left to right: G. A. Efremov, S. N. Khrushchev, A. I. Eidis, I. M. Chumilov, M. I. Lifchitz, V. A. Modestov and V. V. Satchkov (source: rights reserved)

Several people were awarded the Socialist Labor Hero medal for their work on the navy missiles: V. N. Chelomey, G. A. Efremov, M. I. Lifchitz, V. F. Malikov, V. A. Modestov, V. V. Satchkov, S. N. Khrushchev, I. M. Chumilov from OKB-52, as well as A. A. Kobzarev (Deputy Minister of the Aviation Industry), V. A. Kazakov (Head of NII-923 who was Minister of the Aviation Industry between 1977 and 1981) and others.



Figure 1.38. Socialist Labor Hero medalists in 1963: (from left to right) I. M. Chumilov, V. A. Kazakov, M. I. Lifchitz, A. A. Kobarev, V. N. Chelomey, V. F. Malikov, S. N. Khrushchev, V. V. Satchkov, G. A. Efremov and V. A. Modestov (source: rights reserved)