THE SOYUZ LAUNCH VEHICLE

The Two Lives of an Engineering Triumph

Christian Lardier & Stefan Barensky

Translator Tim Bowler

Springer

PRAXIS

The Soyuz Launch Vehicle

The Two Lives of an Engineering Triumph

Christian Lardier and Stefan Barensky

Translator: Tim Bowler

The Soyuz Launch Vehicle

The Two Lives of an Engineering Triumph

Springer

Published in association with
Praxis Publishing
Chichester, UK

PRAXIS

Christian Lardier
Space Editor
Air & Cosmos
Paris
France

Stefan Barensky
Space Editor
Science & Vie and *European Voice*
Jaillans
France

Original French edition: *Les Deux vies de Soyouz* © Éditions Édite 2010

SPRINGER–PRAXIS BOOKS IN SPACE EXPLORATION

ISBN 978-1-4614-5458-8 ISBN 978-1-4614-5459-5 (eBook)
DOI 10.1007/978-1-4614-5459-5
Springer New York Heidelberg Dordrecht London

Library of Congress Control Number: 2012944347

Cover design: Jim Wilkie
Project copy editor: David M. Harland
Typesetting: BookEns, Royston, Herts., UK

Printed on acid-free paper

Springer is part of Springer Science+Business Media (www.springer.com)

Contents

Foreword

Since October 4, 1957, with the launch of Sputnik, the planet's first artificial satellite, the Soyuz rocket has been an integral part of the history of space conquest and thus of the history of humanity.

More than fifty years and 1,750 launches later, Soyuz is still here and its recent introduction to French Guiana, South America, far from its birthplace on the Kazakh steppe has given the legendary rocket a second life.

The value of this remarkable book, co-authored by Christian Lardier and Stefan Barensky, lies in its complete and accurate description of the two lives of Soyuz, thus becoming a reference book chronicling the cooperative space endeavor of Europe and Russia.

The first chapters take us back to the early days of astronautics, at a time when technology was at the service of politics. From archives found in the Soviet Union and impressive documentation work the authors show the difficulty of designing a rocket in the immediate post-war period and the heavy price that Eastern engineers had to pay to get there.

That period was followed by the golden age of Soyuz, with the multiplication of launch pads at Baikonur and at Plesetsk and the numerous missions Soyuz carried out. On the one hand, scientific missions and manned flights were publicized worldwide and used as a powerful propaganda tool. On the other hand, the much more numerous military missions were kept highly confidential!

Then came the fall of the Soviet Union with all its consequences for Russian astronautics. That collapse raised the issue of relations with the West and the sometimes tortuous path that led to unexpected cooperation with Europe, now seen as exemplary, while the United States salvaged for their sole benefit almost all of the ex-Soviet space resources.

After that, Soyuz began its second life. The role of a few visionaries in Russia and in Europe, who decided to leave their respective isolation behind and bring Soyuz and Ariane together, is recalled in detail and cannot leave the reader indifferent. The authors analyze all phases of the implementation of this unprecedented cooperation, from the political agreements to the decision to launch Soyuz from Guiana, and of course the creation of Starsem.

But in the final analysis, what the book describes most profoundly is a formidable human adventure, with its political, technical and commercial ramifications. At a time when a new order was taking shape in the space sector, the players being the United States, Russia, Europe, and Asia, and when economic difficulties sometimes made it tempting to withdraw, this book reminds us that, in the global space sector, nothing is set in stone. That is the overall lesson to be learned from the two lives of the Soyuz rocket.

Jean-Yves Le Gall
Chief Executive Officer
Arianespace – Starsem

Introduction

Throughout history mankind has built a number of machines which stand out from the rest. In the field of power plants, these include the steam engine, the first internal combustion engine, Frank Whittle's turbojet, and Robert Goddard's liquid-propellant rocket. In the field of transport vehicles we think of the first automobile built by engineer Nicolas-Joseph Cugnot, the locomotive by Richard Trevithick, the Wright brothers' first aircraft, Wernher von Braun's long range V-2 rocket, etc. Among automobiles, some have enjoyed a greater career than others, including the very popular VW Beetle (21,529,500 built) or the Citroen 2 CV (5,115,000 built). Among combat aircraft, we can point to the Ilyushin Il-2 "Sturmovik" (more than 36,000 built) or the MiG-21 (over 11,000).

In the realm of space launch vehicles, the most remarkable machine is without a doubt the rocket known today as the Soyuz (meaning "Union" in Russian). Developed after the Second World War, it became the first intercontinental ballistic missile in August 1957. It carried Earth's first artificial satellite aloft in October of that year. It enabled Yuri Gagarin to be the first man in space, in April 1961. It has become the "workhorse of space", launching all kinds of satellites and interplanetary probes, and all the cosmonauts. It is still in use, launching crews to the International Space Station.

In fact, this rocket has had several names: R-7, also known as Semyorka ("little seventh" in Russian), Sputnik, Luna, Vostok, Voskhod, Soyuz, Molniya, etc. In total, more than 1,750 units were produced and launched in the first 53 years of operations from the Baikonur and Plesetsk cosmodromes, while only 603 units of the American equivalent, the Atlas, were launched during the same period (including the new Atlas 5 version which has no technical relationship to the original Atlas missile). But the career of the extraordinary machine that is the Soyuz launcher – not to be confused with the piloted spacecraft of the same name – did not end there, since it began a second life at the Guiana Space Centre (CSG), Europe's space port, with the inaugural flight on October 21, 2011 carrying a pair of European navigation satellites into medium Earth orbit. This marked the starting point of an equatorial operation which should last for 20 years. At the same time, the manufacturer – the Samara Space Center (formerly TsSKB-Progress) – still envisages improving the launcher for new uses: the Soyuz-1 and Soyuz-2-3 versions were exhibited for the first time at the Paris Air Show in June 2007. At the current rate of about 15 launches per year, the number of launched units will one day pass the 2,000 mark!

This book is presented in two parts: Christian Lardier has chronicled the "first life" in Russia and Stefan Barensky has explored its "second life", covering Starsem, the Franco-Russian company and implementation by ESA at the French Guiana Space Centre.

Part one has been developed, with a maximum of historical rigor, from Russian sources. It provides a rather descriptive approach to purely technical issues. This is a first, as no single work, dedicated solely to this rocket, has been published before, including in Russia.

The second part tells a contemporary story gathered more from Western sources and interviews with key protagonists (Jean-Yves Le Gall, Victor Nikolaiev, Jérome Paolini, Michel Delaye, Charles Bigot, Jean-Marie Luton, Jean-Jacques Dordain). This part is more narrative and addresses the sensitive issue of the strategic choices that led to the establishment of the Soyuz in Guiana.

Finally, we wish to thank Mrs. Lucette Calaque, Jean-Marc Astorg, Philippe Clerc, Stéphane Corvaja, Patrick Eymar, Michel Guérin, François Maroquène, Pierre Marx, Boris Melioransky, Jacob Terweij, Jacques Tiziou, Timothy Varfolomeiev, Alexandre Chliadisky, and Jean-Charles Vincent.

October 21, 2011

This is a unique sighting, in this remote launch pad on the edge of the Amazonian rain forest. A Russian-built launch vehicle, derived from a former Soviet nuclear weapon carrier, is standing on its launch table. Although no launcher has been seen more often on a launch pad, this one is different. Its flanks are covered with logos for Roskosmos, TsENKI, TsSKB-Progress and NPO Lavochkin, as well as those of the European Space Agency (ESA) and CNES, the French space agency, but these have been seen before on previous commercial flights. The white 4-m diameter fairing is reminiscent of the long-gone Ariane 4 launchers. It features large logos for Galileo, the European global navigation satellite system, and for Arianespace, the operator of the Ariane vehicles. There is also a commemorative marking for the Ariane Cities Community with the name of its nearest member – "City of Sinnamary". But what most amazes the observer is the thick cloud of condensation vapor that shrouds the vehicle, like cotton, while its tanks are filled with liquid oxygen. For the first time, on this morning of October 21, 2011, a Soyuz launch vehicle will lift-off in a 100% hygrometry environment, from a new launch pad within the premises of the Guiana Space Centre, Europe's spaceport in French Guiana.

It is a Soyuz-2.1b brought to the European ST-B standard by the addition of a Belgian-built "safety kit" to provide secured telemetry links capable of enabling the range safety officer to shut down the propulsion in case the vehicle veers off course and the onboard system fails to order flight termination. Only two months ago, on August 24, a more traditional Soyuz-U launched from Baikonur in Kazakhstan suffered an engine failure on its Block I stage and crashed into the Altai with its payload, a Progress-M freighter carrying supplies for the International Space Station. This was the first failure after 80 consecutive successes of the Soyuz-U and Soyuz-FG, so the international space community is holding its breath because the Soyuz launcher is the last remaining man-rated vehicle available to maintain the lifeline with the ISS and ensure crew rotation. It will eventually return to flight with success on October 30, and the ISS crew will be renewed before Christmas, but as the first Guianese Soyuz awaits launch on its equatorial pad, everybody is still anxious about the future of the largest manned orbital outpost in history. The Europeans authorized their own Soyuz launch to proceed only after a similar Soyuz 2-1.b vehicle was successfully launched from Plesetsk in northern Russia on October 2, carrying a Russian Glonass global positioning satellite. The Soyuz-2.1b features a different engine (RD-0124) on its modified Block I than the model that caused the Progress launch failure (RD-0110).

It is baptism of fire for the new Soyuz launch complex (ELS, for "Ensemble de Lancement Soyouz" in French). The facility was completed, tested and qualified by CNES in the first months of 2011. On March 31, after at the end of an acceptance review, it was handed over to ESA, which immediately turned it over to Arianespace to start its qualification process for launch operations. A dry rehearsal was conducted from April 29 through May 5, with the very first erection of a Soyuz vehicle on pad. The handover ceremony was replayed with Jean-Jacques Dordain, director general of ESA, Jean-Yves Le Gall, chairman and CEO of Arianespace, Yannick d'Escatha, president of CNES, and Vladimir Popovkin, head of Roskosmos on May 7.

In July, the Launcher Flight Readiness Review gave its green light to start the launch campaign for the first Soyuz mission from Guiana, to be designated VS01,[1] on August 16. The final assembly of the vehicle began on September 12, and the rollout from the MIK assembly building was performed on October 14. That same day, the vehicle was erected in upright position, enclosed in the new mobile gantry, and integrated vertically with its payload composite in preparation for a launch on October 20. Later the launch had to be postponed when a propellant line accidentally disconnected from the launcher during the very first fuelling operations. The joint European-Russian team was able to restore the vehicle to launch-ready configuration within 24 hours.

And here we are, on this foggy Guianese morning of October 21, 2011. Right on time, the very first Soyuz to be launched from South America lights the 32 chambers of its five main engines and their 12 vernier thrusters. The counterweights open the petals of the Tyulpan system that has supported the vehicle on pad, and the launcher rises in the cloudy sky. Some 3 hours 49 minutes later, the new Fregat-MT upgraded upper stage, with 900 kg of additional propellant, releases "Thijs" and "Natalia", the first pair of satellites for the Galileo constellation, into a circular orbit at an altitude of 23,222 km.

This textbook mission will be followed by a second one on December 16, this time into sun-synchronous orbit carrying the Pleiades 1 dual high-resolution remote sensing satellite for CNES, a quartet of French Elisa military electronic intelligence satellites, and the SSOT military observation satellite for Chile. The launch manifest is filling up rapidly, mostly with science and Earth observation missions, but it could also accommodate some small geostationary satellites that are unable to find a timely slot on the larger Ariane 5.

---

[1] As long as Arianespace was operating only Ariane launchers, its missions were designated by V-(flight number). With the diversification of its fleet, the designation was changed. Since April 2011, Ariane launches have been designated VA, Soyuz launches are VS, and lightweight Vega launches are VV.

This marks the start of a new era for the very-long-lasting family of Semyorka vehicles, of which the Soyuz is the latest and most prominent member. With the announcement to the Duma, the Russian parliament, by Vladimir Popovkin, head of Roskosmos, that the development of the Soyuz proposed successor, the Rus-M, had been canceled because of budgetary issues, Roskosmos plans to rely on a mix of new vehicles (namely the Angara system under development by Khrunichev) and existing ones, like the Soyuz.

Part One –
Soyuz in the East

by Christian Lardier

1

The V-2's heir

The name "Soyuz" represents both a launch vehicle and a piloted spacecraft. In fact, it was the capsule which gave its name to the launcher in 1966.

Initially, this launcher was an intercontinental missile: the R-7, designed by S. P. Korolev – better known as the Semyorka (i.e. "little seventh" in Russian). It fostered a long line of various versions: Sputnik (Fellow Traveler), Vostok (East) Voskhod (Sunrise), Molniya (Lightning) and Soyuz (Union). In each of these versions, it is the composite upper (third and fourth) stages which are different. In addition, industry and the military use a specific codification: 8K71, 8K72, 8K73, 8K74, 8K78, 8A91, 8A92, 11A57, 11A58, 11A59, 11A510, 11A511 and 14A14 for the launchers, and 8D74, 8D75, 8D76, 8D77, 8D78, 8D79, 8D711, 8D714, 8D715, 8D719, 8D727 and 8D728 for the engines. Thus, since the program started, 16 different versions have flown. If we add the projects which did not fly, then the number grows significantly.

The Semyorka was descended from the Second World War V-2, which first flew successfully on October 3, 1942. The V-2 was massively used by the German army between September 1944 and March 1945 (approximately 6,000 were manufactured and 3,200 were launched against London, Antwerp, Paris and other targets). It was a revolutionary 13-ton vehicle propelled by a liquid oxygen-ethyl alcohol engine with a thrust of 25 tons, unlike other missiles such as the Wasserfall (8-ton-thrust engine) that were propelled by storable nitric acid fuels.

Fragments of a German V-2 (including the engine) were recovered in Poland near Blizna – a training site where the Germans launched hundreds of V-2s – by a Soviet team from institute N^{o}1 (NII-1) of the ministry of the aviation industry on August 5, 1944.

The expedition was led by Lieutenant-General I. A. Serov of the KGB and Major-General P. I. Fedorov, head of NII-1 from June 1944 to February 1945. The team included engineers Yuri. A. Pobedonostsev, M. K. Tikhonravov, N. G. Chernyshyov, R. E. Sorkine and A. G. Shekhman. Back in Moscow on September 24, 1944, the "Raketa" group was formed with the help of engineers who, starting in 1941, had worked on the first Soviet rocket-plane, the BI-1 (Bereznyaki-Isaiev) by designer V. F. Bolkhovitinov. In September-October, the engine designer V. P. Glushko came from Kazan, accompanied by N. L. Oumansky and G. N. List, to examine the

C. Lardier and S. Barensky, *The Soyuz Launch Vehicle: The Two Lives of an Engineering Triumph*, Springer Praxis Books, DOI 10.1007/978-1-4614-5459-5_1,

Tikhonravov and Chernyshyov in Germany in 1944.

engine. This group gave the authorities its assessment in November. A second expedition would attempt to return to Germany in February 1945, but the aircraft carrying them crashed near Kiev, leaving no survivors.

NII-1 was the new name for the jet propulsion institute, previously called RNII from 1933 to 1937, NII-3 from 1937 to 1942, and GIRT from 1942 to February 18, 1944. It had been reorganized to develop jet aviation in the Soviet Union. It was initially headed by the chief of the central institute of aviation engines (TsIAM) V. I. Polikovsky until the end of May 1944. The first deputy was G. N. Abramovich until 1948. Its leading subsidiary was the N°293 design bureau (OKB) of Bolkhovitinov at Khimki. This was taken over by M. R. Bisnovat in June 1946 and became the MKB Fakel, contractor for most of the Soviet surface-to-air and anti-missile missiles.

The propulsion work within the institute was divided into several areas: rocket engines with V. P. Glushko, A. M. Isaiev and L. S. Dushkin, turbojets with A. M. Liulka, ramjets with M. M. Bondariuk, and pulsejets with S. G. Rozental. Glushko, who worked on rockets in a specially equipped prison (a sharashka) in Kazan, was to develop an engine for N. N. Polikarpov's Maljutka rocket-plane. But Polikarpov died on July 30, 1944, and was replaced by V. N. Chelomei, who developed the Russian V-1 as the 10Kh missile. In May 1946, Glushko's group was transferred to Khimki's OKB-456 to develop the V-2 engine. As deputy to Bolkhovitinov, Isaiev built the engines for the BI-1 rocket-plane. In May 1948 his group was transferred to NII-88 (which had become TsNII Mach) as its sector N°9 (later KB KhimMach). Dushkin, who had worked with A. G. Kostikov on the 302 rocket-plane from 1942 to 1944, designed the RD-2MZV engine for Mikoyan's I-270 aircraft and the RD-2MZV-F for the Bisnovat aircraft N°5. Liulka left NII-1 to establish OKB-165 in Moscow in March 1946. Bondariuk, opened OKB-670 in October 1950. In addition, I. F. Frolov, head of the NII-1 aircraft division, built the 4302 aircraft with an Isaiev engine, and the 4303 with a Dushkin engine. However, all these rocket-planes were abandoned after 1947.

On November 30, 1946, academician M. V. Keldysh, only 35 years old at the time, took over the management of NII-1, where he stayed until June 12, 1948. He turned it into a research institute and all of the designers left, except Dushkin. It was a subsidiary of TsIAM from June 1948 to June 1952. Keldysh remained its scientific director until 1961 and became president of the Academy of Sciences of the USSR and also of its interdepartmental committee on space research (established by decree N°1388-618 on December 10, 1959).

TAKING OVER THE V-2 MISSILES

At the end of the Second World War, the Soviet Union, in its progression through the German heartland, overran Peenemünde on the Baltic coast and the underground V-2 factory at Nordhausen in the Harz mountains, which remained within the territory of East Germany (GDR) for 46 years. But the Americans had already retrieved Wernher von Braun's team (118 members recruited under contract) and a hundred V-2s and spare parts, in the context of operations called Overcast and Paperclip. From 1946 to 1952, the US Army launched 70 rockets. But the Soviets did not remain empty-handed – they gained control of factories, rocket elements, and a number of German specialists.

In February 1945 a committee to oversee the recovery of German technology was formed by the state committee for defense (GKO). Technologies of interest to the Soviets concerned many ministries: weapons industry (cannons, rifles, optics, etc.), the aeronautics industry (aircraft, engines, equipment), the naval industry (ships,

Korolev and Tiouline in Germany in 1945.

Peenemünde in September 1945 from left to right: Sudakov, Sinelchikov, Fonarev, Korolev, Zakharov, Kharlamov, driver.

submarines, gyroscopes, etc.), the munitions industry (explosives, solid fuels), the machinery and instrumentation industry (launch facilities), communications (radar and electronics), the chemical industry, etc. A permanent commission headed by representatives of the industrial ministries operated on each army's front, with assistance from members of the army's main directorate (glavka) of war trophies. Peenemünde was on the Belarus front. The army arrived on May 5, with General A. I. Sokolov, head of armaments for the Katyushas groups. Stalin issued a decree ordering the minister of the aeronautics industry, A. I. Shakhurin, and the chief of branch N°2 of NII-1 in charge of solid rocket fuel, Yuri. A. Pobedonostsev, to take charge of the recovery of the Peenemünde facilities.

THE GUNNERS LEARN TO USE ROCKETS

The armaments directorate of the Katyushas groups (GUV) relied on mortars of the guard (GMTch) of the main artillery directorate (GAU) of the ministry of defense. This entity evolved into branch N°4 of the GAU in June 1946, then the directorate of the deputy to the commander of artillery (UZKA) in April 1953, then the directorate of the chief of the armed forces rockets division (UNRV) in 1955, and finally the principal directorate of rocket munitions (GURVO) in 1960. The latter, which was part of the strategic rocket forces (RVSN), became the main client of the industry for intercontinental missiles and the military space program. Generals N. N. Kuznetsov, A. I. Sokolov, A. I. Semenov, A. G. Mrykine, G. A. Tiouline, Yuri A. Mozjorine, K. A. Kerimov, and A. G. Karas all played important roles in the development of the Semyorka.

Kuznetsov, head of GUV from 1941 to 1945, was in Germany from 1945 to 1946, and was then in charge of purchasing rockets in series until his retirement in 1963.

Sokolov, the party apparatchik, dealt with training before the war, while also taking evening classes at the institute of rail transport in Moscow. In 1941 he was sent to Chelyabinsk to oversee production of the Katyushas, and in 1943 he became deputy to Kuznetsov. In March 1945 he replaced Kuznetsov and went to Peenemünde. He soon returned to Moscow, but went back to Germany on October 14 to attend a V-2 launch organized by the allies as part of operation Backfire in Cuxhaven. At that time he was accompanied by G. A. Tiouline, Yuri A. Pobedonostsev, V. P. Glushko, and S. P. Korolev – all wearing Red Army uniforms. Then he headed the 4th directorate and UZKA. In late 1954 he was sent to the Dzerjinsky artillery academy to receive advanced training. A year later, he became head of N°4 (NII-4) Bolchevo institute, where he was in charge of strategic rockets and the first satellites. He was president of the state commission for the R-16 and UR-100 intercontinental missiles. He was given the Order of Lenin for the launch of the first Sputnik in 1957, the Lenin Prize in 1961 for implementation of the KIK tracking network, and the State Prize in 1967 for the qualification of the UR-100 missile. He submitted his doctoral dissertation in 1964, but this was not to the liking of General A. A. Vasiliev, head of GURVO, who judged he did not have the required level due to having not completed his studies at the institute of railway transport. His management responsibility was withdrawn and he was sent back to school. He was awarded his doctorate upon the second defense of his thesis. In 1969 he fell ill, and left the institute the following year. He died six years later.

Semenov completed studies at the Dzerjinsky artillery academy in 1937. He was,

Operation Backfire in Cuxhafen in October 1945, on the right: Glushko, Sokolov and Tiouline.

Operation Backfire. In the center: Tiouline, Glushko, Pobedonostsev; on the right: Korolev.

in turn, section head of the 4th directorate from 1946-1953, chief engineer of UZKA from 1953-1955, head of UNRV from 1955-1960, head of GURVO from 1960-1964, and then a member of the science and technology committee of the army chiefs of staff from 1964-1970.

Mrykine completed studies at the academy of chemical protection in 1934. He was head of the section from 1946-1953, head of development and research at UZKA from 1953-1955, deputy director of UNRV from 1955-1959, first deputy director of GURVO from 1959-1965 (during which he was president of the state commission for the R-14 rocket) and then worked at the ministry of general machines (MOM) from 1965-1972, where he presided over the state commission for a number of deep space missions (Luna, Venera, and Mars).

Tiouline, who graduated from the University of Moscow in 1941, was sent to the front before being assigned to the study of German war trophies. He was a member of the Soviet delegation at Cuxhaven. Then he headed the calculations bureau at the Nordhausen institute before becoming, in turn, section head of ballistics for the 4th directorate of GAU in 1946, sector head for the theory of flight and the laboratory of aerodynamics at NII-4 from March 1948 to March 1949, deputy chief for science at NII-4 in 1949, where he headed the creation of a network of tracking stations and a fleet of tracking ships. In 1959 he became head of NII-88. He was appointed deputy of the ministry of the defense industry (MOP) in June 1961, then first deputy in June 1963. He was first deputy of the ministry of general machines from 1965-1976. He was president of numerous state commissions for the Vostok and Voskhod manned space flights from 1962-1966, deep space probes from 1966-1972, and then Apollo-Soyuz from 1972-1975.

Mozjorine had just received his diploma from the Moscow aviation institute when war broke out. He was sent to the front in 1941, but then returned to the Jukowsky academy in 1942 to study. He stayed in Germany from June 1946 to February 1947, and then became an engineer in the theory of flight section of the 4th branch, being made section chief in 1951. He then became deputy director of NII-4 in 1955, where he participated in the creation of the KIK tracking network. He was chief of NII-88 from July 1961 to December 1990.

Kerimov (whose real name was Akhmedov) graduated from the industrial institute of Azerbaijan in 1942, and then from the Dzerjinsky artillery academy in 1944. He served as the Red Army representative in the Katyushas factory before being sent to Nordhausen to supervise telemetry devices. He worked at GAU and GURVO, where he was responsible for the purchase of rockets in series. In September 1960 he took over the 3rd directorate of GURVO, which managed the space program. In 1963, he became president of the state commission for the Zenit (optical reconnaissance) Molniya (telecommunications) and Meteor (meteorology) satellite programs. In 1966 he received the Lenin Prize for this work. In October 1964 he was appointed head of TsUKOS – the precursor of the space forces – where he headed the military space program. In March 1965, with the formation of MOM, he took charge of the 3rd glavka, devoted to space. He was president of the state commission for piloted space flights from 1966-1991 and for interplanetary flights from 1974-1991. For this work he received the State Prize in 1979 and the Hero of Socialist Labor Medal in 1987. In 1974 he left the ministry to become first deputy of TsNII Mach, where he remained until his retirement in 1991.

Karas graduated from the Odessa artillery school in 1938 and the Dzerjinsky

Special function brigade (BON) designers in 1946 seated, from left to right: Kaplun, Korolev, Riazansky, Chertok, Pilyugin, Pobedonostsev and others.

artillery academy in 1951. He became chief of staff at Kapustin Yar in 1953 and then at Baikonur in 1955. He worked as a consultant scientist at NII-4 in 1957, headed the KIK tracking network in 1960 and then TsUKOS from 1965 to 1979. He was also a member and president of several state commissions.

In addition, other generals took charge of ground infrastructures such as launch facilities, tracking networks, etc. In particular, V. I. Vozniuk was head of the rocket range at Kapustin Yar from June 1946 to April 1973, and A. I. Nesterenko was chief of NII-4 from 1946-1950, head of the rocket faculty of the Dzerjinsky artillery academy from 1950-1955, first director of the Baikonur cosmodrome in 1955-1958, and a member of the science and technology committee of the general staff from 1958-1966.

All these men were part of the artillery corps,[1] whereas in the United States the development of intercontinental missiles and military space activities was mainly in the hands of the US Air Force – in other words, pilots.

THE SOVIETS IN GERMANY

Several groups of Russian specialists went to Germany after April 18, 1945. The first group was from the ministry of the aeronautics industry. This was led by General N. I. Petrov, head of the institute of aeronautical devices (NISO). It included G. N. Abramovich (deputy director of NII-1), K. N. Sourjine (deputy director of TsAGI), V. D. Vladimirov (deputy director of TsIAM), S. R. Ambartsumyan (deputy director of VIAM), and others. Each institute had a specialized subcommission.

The NISO group, which included B. E. Chertok of NII-1, was in charge of retrieving autopilots, radars, navigation and communications systems. Among other sites, the group visited the factories of Askania, Telefunken, and Lorenz. In May, the NII-1 engine group went to BMW at Basdorf.[2]

Specialists visited Peenemünde on June 1, and then went to Nordhausen, which the Americans left on July 14. Abramovich returned to Moscow on July 31 and presented his report to minister A. I. Shakhurin in August. He requested that work on rockets be suspended in order to devote all resources to jet aircraft. He was arrested along with the air force chief A. A. Novikov in April 1946 and was not released until after Stalin's death in 1953.

The minister of munitions, B. L. Vannikov, in charge of solid-fuel rockets and explosives, was made head of the inter-ministerial commission for the development of atomic weapons. Because of this new task, he left rocket work to the ministry of armaments, headed by D. F. Ustinov. On August 20, 1945, special committee N°1, headed by the minister of the interior, L. P. Beria, was created. This would become the first main directorate (glavka) of the council of ministers (PGU) and in 1953 the ministry of medium-sized machines. In order to develop the atomic bomb, German scientists were transferred to Sukhumi in the Soviet Union. These included Manfred von Ardenne, Gustav Hertz, Heinz Pose, Nikolaus Riehl, Max Steenbeck, Peter-Adolf Theissen, Robert Döpel, and Max Volmer. They participated in particular in the development of centrifuges for the production of uranium. As for the ministry of munitions, it became the ministry of agricultural machinery (MSKhM) in 1946. As a result, until 1953, solid propellant rockets were produced by the same ministry that made combine harvesters!

Finally, on May 13, 1946, rockets were placed under the responsibility of the minister of the armaments industry, D. F. Ustinov. He had been director of the Leningrad Bolshevik factory in 1938 before becoming minister in 1941. He held this post for 16 years, during which he led the Soviet national ballistic rocket program, including the Semyorka and the space program. He became president of the military industrial commission (VPK) in 1957, first deputy of the council of ministers in 1963, secretary of the central committee of the Communist Party of the Soviet Union (CPSU) in 1965, and then minister of defense from 1976 to 1984.

In 1946 his first deputy was V. M. Riabikov, who became president of the state commission for the launch of the R-7 and the first satellites in 1957. His deputies included I. A. Mirzakhanov and N. E. Nossovsky. Mirzakhanov was director of Podlipki cannon factory N°8 near Moscow from 1931 to 1938, which later became NII-88, then TsNII Mach, where the Semyorka was built. In 1940 he became chief director, and then deputy minister in 1946. But in February 1952, after difficulties in developing an anti-aircraft gun, he was arrested along with deputy defense minister N. D. Yakovlev (who was president of the state commission for the launch of the V-2 in 1947), and I. I. Volkotroubenko, the GAU chief. They were released after Stalin's death in 1953. Nossovsky was director of Podlipki cannon factory N°8 from 1938 to 1940. He was sent to Berlin to take charge of recovering German technology. He was assisted by N. N. Kuznetsov and L. M. Gaidukov.

THE BERLIN AND NORDHAUSEN INSTITUTES

During the war, the Red Army used solid-fuel rockets called Katyushas, known as "Stalin's organ". They were developed by RNII and manufactured in series by many factories of the ministry of mortars under P. I. Parshin and also of the ministry of munitions under B. L. Vannikov. In 1941 they were entrusted to the "special" design office (SKB) of the Moscow Kompressor factory (in October 1941 part of the plant was relocated to Chelyabinsk in the Urals to put it beyond the reach of the advancing Germans). The SKB was headed by V. P. Barmine, who would later build launch facilities for Soviet rockets.[3]

On March 19, 1945, the ministry of munitions created the GTsKB-1 design office at factory N°568 in Moscow. Led by N. I. Kroupnov, its task was the development of rocket mortars of 20-30 km range. As such, it was a competitor to the ministry of the aviation industry's NII-1 subsidiary. On July 23, it was complemented by the GSKB-2 of the "Mastiajart" factory N°67 for missiles of 30-100 km range, while plant N°70 imeni Vladimir Ilyich GSKB-3 was to receive the German V-2 and other rockets. This was because minister Vannikov, whose son Rafael was at Nordhausen, saw the V-2 as the successor to the Katyushas. He planned to appoint Glushko as the main designer at GNII-70. The ministry of armaments entrusted the German missiles

Designers at Rabe de Bleicherode in February 1946, from left to right, seated: Voskressensky, ?, Bakulin, Korolev, Michin, Pobedonostsev; standing: Pilyugin, Mrykin, Brovko, Chijzhikov, Kharchev, Budnik.

The Council of Designers of 1946. From left to right: Chertok, Barmine, Riazansky, Korolev, Kuznetsov, Pilyugin, Glushko.

(V-2, Wasserfall, Schmetterling, Rheintochter, Taïfun, etc.) to Podlipki factory N°88 because this plant specialized in anti-aircraft systems, and these missiles, except for the V-2, were surface-air missiles. On November 30, P. I. Kostin was appointed main designer of the SKB. But in August 1946 he was replaced by K. I. Tritko, formerly chief engineer of the Volgograd Barricade factory.

Meanwhile in Germany, the flow of engineers investigating German technology intensified. On May 24, V. S. Budnik of NII-1 left for Berlin. On July 27 it was the turn of V. P. Glushko of OKB-16. On August 9, a group arrived in Germany with V. P. Mishin, N. A. Pilyugin, V. I. Kuznetsov, M. S. Riazansky, E. Y. Boguslavsky, L. A. Voskresensky, V. A. Rudnitsky, Florensky, Bakurine, Goriunov, and others. This group was split up for three locations: Berlin, Nordhausen and Prague. In August, Korolev, then in Kazan, returned to Moscow to the Tushino air show. Then he went to Germany on September 8. A group of ballistics specialists from the Dzerjinsky artillery academy led by Professor Y. M. Shapiro also traveled to Germany twice.

On July 8, 1945, GKO decree N°9475 created the commission for the study of German rockets. It was entrusted to General L. M. Gaidukov.[4] He was also an apparatchik who headed the managers' sector for general machines of the central committee in charge of the Katyushas production plants. Later, he was appointed head of the Nordhausen institute from February 1946 to January 1947. He then headed sector N°10 of "special" committee N°2 of the council of ministers in charge of rockets, and then held different jobs at the rocket armaments directorate (UZKA, UNRV, GURVO) until 1962. He worked until the end of his career at NII-4, where he headed the 7th "space" directorate before his retirement.

Gaidukov's deputy was Yuri A. Pobedonostsev, who had the task of bringing the top Soviet rocket specialists to Germany; though some of them were imprisoned in sharashkas (design-office-prisons), such as Glushko and Korolev. They were civilian engineers, but had to don military uniforms. Pobedonostsev was a former colleague and friend of Korolev's. He graduated from the Bauman technical school (MVTU) in 1930, worked at TsAGI, and became leader of the 3rd GIRD brigade in 1931 (wind tunnels and ramjets), and then joined RNII in 1933, where he defined the Kappa combustion stability test criteria for rocket mortars, for which he received the Stalin Prize in 1941. In February 1944 he headed section N°5 of NII-1, and then was head of NII-1 subsidiary N°2 from December 1944 to May 1946, and a member of the technical commission on German rockets from 1945-1946. From 1946-1947 he was chief engineer of NII-88. In 1946 he also worked as a professor at the academy of artillery sciences (AAN) and as a consultant to NII-4. He taught courses on rocket technology at MVTU in 1947, then taught at the "special" academy (pro-rector in 1950). In 1956 he returned to industry and worked on solid-fuel missiles at NII-125 until 1973. He died in the corridors of the international astronautical congress being held in Baku.

The Soviets created two institutes in Berlin and Nordhausen. One, headed by D. G. Diatlov, was located in the Berlin-Köpenick Gema plant. The chief engineer was V. P. Barmine. There were three design offices and six construction sectors made up of Russian and German engineers:

- KB-2, headed by E. V. Sinelchikov of V. G. Grabin's OKB, dealt with the Wasserfall surface-air missile.
- KB-3, headed by S. E. Rachkov of A. E. Nudelman's OKB, rebuilt the Schmetterling and Rheintochter missiles.
- KB-4, headed by N. A. Soudakov, was in charge of a 283-mm ramjet-powered shell.
- Sector N°5, headed by N. I. Kroupnov, head of GTsKB-1, dealt with the Taïfun R, the Kh-7 Rotkäppchen (also known as the Fritz X), and boosters for the Schmetterling and Rheintochter missiles.
- Sector N°6, headed by N. L. Oumansky of OKB-16 in Kazan, dealt with liquid-fuel engines (Wasserfall, Schmetterling, Rheintochter).

- Sector N°7, headed by V. A. Goviadinov, was in charge of equipment for radio guidance and radio detonators.
- Sector N°8, headed by P. K. Kliaritsky, dealt with calculation and stabilization (control surfaces, composites, etc.).
- Sector N°9, headed by V. A. Timofeiev of GSKB Kompressor, specialized in launch facilities.
- Sector N°10, headed by A. K. Polevik of GAU, was a chemical laboratory involved in the synthesis of liquid fuels (Tonka 250, Tonka 841, etc.).

In addition, the Berlin institute included a science and technology sector, a test sector, an experimentation plant and subsidiaries (including the Peenemünde center).

The underground plant for the production of the V-2, known as Mittelwerk, was located at Nordhausen and had used deportees from the Dora concentration camp

The state commission for the R-1 in October 1947 from left to right: ?, ?, ?, Ustinov, Yakovlev, Vetochkin, Korolev.

Participants in the R-1 launch campaign in October 1947 at Kapustin Yar. From left to right, third row: Lavrov, ?, Riazansky, Korolev, Voskressensky, Pilyugin, Chertok, Borissenko.

The Germans at Kapustin Yar in October 1947. From left to right: Karl Stahl, Johannes Hoch, Helmut Gröttrup, Fritz Viebach, Hans Vilter.

for labor. The institute established there in February 1946 by the Soviets was headed by L. M. Gaidukov and the chief engineer was S. P. Korolev.

It included:

- The Rabe institute (Raketenberg) of Bleicherode, headed by B. E. Chertok (deputy to Korolev).
- Factory N°1 (KB Olympia) at Sömmerda, 80 km east of Leipzig, headed by V. S. Budnik.
- Factory N°2 "Montania" of Nordhausen in charge of the V-2 engine, headed by V. P. Glushko.
- Factory N°3 at Kleinbodungen, headed by E. M. Kourilo.
- Factory N°4 of Zondershausen (steering system devices).
- Factory N°5, which was in fact the Peenemünde center (V. K. Shitov) and Lehesten testbed 150 km south of Nordhausen, headed by V. L. Chabransky.
- The calculation bureau (also known as the ballistics group) headed by G. A. Tiouline, which included S. S. Lavrov, R. F. Appazov, N. F. Guerrasiouta, and others.
- The Vystrel group, headed by L. A. Voskresensky, was responsible for test flights of the V-2 and had to be rebuilt at Nordhausen.

On July 15, 1946, in the village of Berk, 6 km from Zondershausen, the first brigade of rockets BON RVGK was placed under the direction of Major-General A. F. Tveretsky. Unfortunately, it was not able to launch the V-2 from German territory. After being transferred in August 1947 to Kapustin Yar it carried out eleven launches in October-November. The members of the brigade included B. A. Komissarov, N. N. Smirnitsky, A. I. Nosov and Y. I. Tregub. Komissarov became a representative of the ministry of defense at YoujMach, then chief of the 7th main directorate (glavka), deputy minister of the defense industry, and ultimately vice president of the VPK. Smirnitsky was head of GURVO from 1969-1976. Nosov