# 'Soviet rockets must conquer space' – Contributions of S. P. Korolev to the Soviet space research

*M. Y. S. Prasad and K. R. Sridhara Murthy*

'Soviet rockets must conquer space'. This was the prophetic edict with which Sergie Pavlovich Korolev concluded the announcement of the launch of the first liquid propellant rocket in Soviet Union. A group called GIRD in Moscow conducted the test on 17 August 1933. The group was the result of dreams of a number of individuals committed to rocketry and space travel, and Korolev was voluntarily chosen the leader of the group. The rocket worked for 13 sec and rose to 400 m altitude before deviating from the flight path and crashing. However, it was a great success for the group as it was the first Soviet rocket to fly.

Korolev's words had come true and USSR gained the lead in space research and launches. It launched the first artificial satellite under the leadership of Korolev on 4 October 1957 – and between 1957 and 1995, the Soviet Union (and Russia) launched 2656 rockets which put 2976 satellites into orbits. At the peak, in 1980s, the Soviet Union was conducting more than 100 launches a year with an average of roughly one launch every 3 days. Such a lead was made possible by the programmes initiated by Korolev in the development of missiles, launch vehicles, earth observation satellites, communication satellites, inter-planetary missions and manned spacecraft.

## Passion for aviation

Korolev was born on 31 December 1906 (12 January 1907) in a small town in Ukraine. As a young boy, he studied in Odessa in the Building Vocational School. The Socialist government introduced training of students in different trades in schools which were till then teaching only classical Russian grammar. Korolev was benefited and was introduced to practical training at the right age.

As a young boy, Korolev was deeply interested in the hydroplanes which were taking off the coast of Odessa. This interest gradually developed into a passion for aviation. His passion traversed from flying to glider design. Very early in the efforts, he realized that he had to be sure of the design before building gliders. Since then he never experimented in the dark and never completely relied only on experience. He once challenged one of the leading designers in a technical meeting, and told his friends 'I am not afraid, I have made my calculations, and figures speak louder than words'.

Korolev passed from school in 1924, and joined Kiev Polytechnic in August 1924. He got associated with glider design and flying clubs apart from his regular courses in the Polytechnic. Life in Kiev was tough for Korolev and money was always in short. He had to take up the job of humping sugar to buy a pair of new shoes, and was always doing some odd jobs to find means of subsistence. He even acted in small roles in films to earn a few kopecks! Korolev joined Moscow Higher Technical School in 1926, which gave him more opportunities to work in the aviation field and in the exhibitions of flying.

At the age of 23, Korolev was qualified as an Aeromechanical engineer after completing studies in Aeromechanical faculty in Moscow Higher Technical School in 1930. His final project work was 'Light Plane'. His Supervisor, the famous aircraft designer, A. N. Tupolev commented about Korolev: 'He already made an excellent impression on me as regards both his personality and his talent for design. I would say that he is a man with unlimited devotion to the job and has ideas'. Tupolev had again supervised and guided Korolev later when he was arrested and sent to labour camp in 1940s. Several months before he graduated from Moscow Technical Institute, Korolev won recognition as a glider designer and tested as a pilot.

## Transition to rocketry

The transition from Aviation to Rocketry took many years. In 1931, a group of enthusiasts organized themselves into a central group for studying the reaction propulsion (GIRD). The driving forces behind this forum were Friedrich Zander, a visionary of interplanetary travel, and Korolev. They immediately started working on the liquid propellant rockets mainly with the idea of putting them on the gliders and light planes to give additional thrust. With the increasing activity, they had to find a place to work and they found an empty cellar. They themselves painted the walls and GIRD started working in the cold basement. Korolev was chosen as Head of GIRD from 1 May 1932. The first rocket test mentioned above was conducted by this group.

Another group, GDR, led by Glushko at Leningrad was also involved in rocket research at that time. In September 1932, GIRD and GDR were merged, and the Russian Propulsion Research Institute was founded. Korolev was named as Deputy Head of the Institute. Thus Korolev's team had become respectable, knowledgeable, trusted and transformed from passionate youth to men with experience. The two years from 1932 to 1934 changed Korolev from the glider designer and flyer to a major expert in the field of rocketry and the specialist with broad scientific outlook. The essential help to organize Korolev's voluntary group came from M. N. Tukhachevsky, who was the commander of the Leningrad military and who later became the Chairman of the Revolutionary Military Council in charge of Armaments. The liquid fuel rockets and several small missiles based on solid propellants were designed and tested against tight schedules by this research institute.

Korolev was arrested by secret police in July 1938 on the charges of subversion and holding back the progress of the work. Under the Stalinist purges of late thirties, it was difficult to know whether the charge was real or trumped up. Korolev was sentenced to ten years of imprisonment, and in 1939 he was sent to the most dreaded prison, gulag camp in Kolyma, Siberia. He survived Kolyma, but his health was badly affected. Tupolev, who was also arrested in 1937, got Korolev transferred to his *Sharashka*. Intellectuals, engineers and scientists were made to work in these prison workshops

called *Sharashkas*. Light bomber TU-2 and attack aircraft Ilyushin-2 were designed in Tupolev's prison-cum-design bureau. In the summer of 1944, the experimental design team was released from prison. Korolev was discharged and prior convictions were expunged. (Only in April 1957 was he finally notified of his rehabilitation.)

Development of V-2 missiles by Germany during World War II presented excellent technological and political context for the design teams in USSR to develop new, long-range missiles. A large number of specialists were sent from Russia to Germany after the second World War to study and reconstruct all technical documents on V-2 rockets. Korolev went to Germany in September 1945. After their return, most of the rocket specialists were organized into a new Institute NII-88 (Scientific Research Institute-88) in May 1946. Six principal design bureaus were established, each headed by a Chief Designer and reporting to an appropriate Ministry. Korolev was made the Chief Designer with responsibility of long range ballistic missiles. The other chief designers were Valentine Glushko, Mikhail Ryazansky, Nikolai Pilyugin, Vladimir Barmin and Viktor Kuznetsov. Korolev then distributed the elements of systems among the design bureaus, and formed a Council of Chief Designers for solving top-level system problems. Korolev was the Chairman of the Council of Chief Designers.

## R7: Not a military toy

Development of a number of missiles designated as R1, R2, R3, R5, and R7 was taken up. The most complex of these was the intercontinental ballistic missile R7. This ballistic missile later became the first launch vehicle of USSR and many versions of it continue to serve civilian launches of Russia even today. The R7 ICBM was a two-stage vehicle with capability to carry nuclear weapons weighing 1400 kg.

First stage of R7 consisted of four RD-107 engines, each with four thrust chambers arranged around the circumference of the vehicle. Four-chambered RD-108 engine was the core second stage of the vehicle. Both engines were developed by Ghushko's design bureau. Korolev's bureau developed vernier engines for thrust vector control. R7 used liquid oxygen and kerosene as the propellants, and hydrogen peroxide as an active medium for the gas generator. This is a very difficult fluid to work with, and easily decomposes in the presence of impurities. The assembly of R7 stages was done in horizontal position inside the rocket preparation building, transported on rails to pad, and then erected using a special cradle. Additional wind protection was achieved by installing the launch table 7 m below ground level.

In the course of development of R7, many technical problems were solved. They were, in addition to the development of engines, nosecone for re-entry velocities close to the circular velocity, control and stabilization of elastic structure of liquid propellant rocket, control with pivoted (auxiliary) engines, and synchronized emptying of fuel and oxidizer tanks.

The solution of these problems required serious effort on the part of scientists and engineers, yet the tight schedule of the Soviet space programme did not allow an exhaustive study of each problem. In that difficult situation, Korolev proved himself capable of planning and coordinating the work of many research and design organizations, thoroughly understanding the priorities/urgency of problems, despite the scarcity of information and lack of prior experience in space engineering. His amazing leaps of intuition provided ingenious answers to many puzzling questions.

The first R7 launch on 15 May 1957 failed at 98 sec into flight due to fire caused by a leaking fuel line. The second test on 11 June, failed when engines were accidentally switched off at lift-off. The third test on 12 July, failed due to cut-out of engines after 33 sec. The team did not panic but remained united and confident. The weight of responsibility resting on Korolev must have been enormous. (He was then not yet been formally rehabilitated.) Finally, the world's first two-stage intercontinental ballistic missile was launched successfully in the fourth attempt on 21 August 1957.

The first artificial earth satellite Sputnik-1 weighing 83.6 kg was put into orbit on 4 October 1957, six weeks after the successful test of the first Soviet ICBM, the same missile used as the launch vehicle. Korolev once said about the missile to one of the young engineers: 'The purpose of this rocket is to get there, pointing his finger to the ceiling. This is not some military toy.' He proved his words with the launch of Sputnik by R7, and heralded new space era for the humanity.

The second orbital launch was demanded by Khrushchev himself to be conducted before the anniversary of the Revolution, i.e. 7 November 1957. Korolev immediately decided that there would be no special drawings, no quality check and everybody in his team should work on his own full responsibility. The launch of Sputnik-2 took place successfully on 3 November, with dog Laika as passenger payload. The mass of the satellite was 508 kg. In less than a month from the first launch, the team under the leadership of Korolev could achieve the second successful launch with an impressive orbital capability. All engineering tasks on Sputnik-2 were achieved in less than 3 weeks time.

## Building a fleet

In 1958 and 1959, Korolev and his staff updated Sputnik carrier rocket to a three-stage launch vehicle *Vostok*. They added a third stage to the basic vehicle. The orbit capability was increased from 1400 kg to 4500 kg. This was the vehicle used for the orbital launch of Yuri Gagarin around the earth. The spacecraft, also named Vostok, was also designed and realized by Korolev's team.

The shape of the Vostok spacecraft was spherical, chosen due to its symmetrical aerodynamic and heat exchange properties. The development of the spacecraft started with a feasibility study in August 1958 and the first full-fledged orbital launch took place in May 1960. The safety aspects required for a manned launch were given the highest priority all through the development.

On the eve of the launch of Yuri Gagarin into space, Korolev told him, 'There is an element of risk in the flight tomorrow. Anything can happen. But remember whatever happens, all our brains will come to your aid'. Thus assured, the night before the launch Yuri Gagarin slept peacefully, but Korolev could not sleep at all! On 12 April 1961, Vostok spacecraft with Yuri Gagarin on board was put into orbit with a perigee of 181 km and apogee of 327 km. The total weight of the spacecraft was 4725 kg. Gagarin, as the first human to circle the earth, crowned the innovative work of

thousands of workers, technicians, engineers and scientists, led by Korolev. In all, six Vostok missions were carried out between 1961 and 1963, one cosmonaut flying in each mission.

Vostok spacecraft was modified to accommodate 3 cosmonauts and it was named Voshkod, which was planned by Korolev as a multi-mission spacecraft – a manned flight with multi-member crew, a space-walk, a long duration flight, and a docking. Voshkod-1 flew successfully with a three-membered crew in May 1964. Later an airlock was fitted to the spacecraft for its second mission so that space-walk could be attempted. During the second orbit of Voshkod-2 mission in March 1965, Alexi Leonov created history by successfully walking in the space outside his spacecraft for 12 min.

Voshkod was further improved. A new third stage was developed and the existing third stage was replaced in the rocket increasing the orbital capability from 4900 kg to 7000 kg. The modified three-stage rocket was designated *Soyuz*. This vehicle till today continues to launch Soyuz spacecrafts to orbit with high level of reliability.

In 1962 and 1963, Korolev approved the documents and initial plans on 'Assembly of vehicles in earth satellite orbit'. He proposed a three-membered spacecraft, which would link up in orbit with a stack of modules. And thus a 5800 kg *Soyuz* was born, which was successfully flown after Korolev's death in 1967.

To further the Soviet interplanetary travel programme, Korolev and his staff developed the four-stage Molniya launch vehicle based on the original R7 with the addition of new third and fourth stages. The fourth stage (a liquid oxygen engine) had to be started in the zero gravity conditions, a formidable technical challenge in those days. Many interplanetary probes, lunar launches and the launches of communication satellites were all conducted using this vehicle.

Launched aboard this vehicle on 4 October 1959, was another development by Korolev's team, Luna-3, which could orbit the moon successfully and photograph the far side of the moon. The probe was designed with capabilities of photographing, developing the film on-board and transmiting the pictures to earth through radio channel. Luna-3 started a new trend in space technology with its attitude control system, and heralded the era of controlled space flight. The control system included optical and gyroscopic instruments, a logic unit and small control thrusters. The body of Luna-3 was a cylinder with spherical end walls measuring 1.2 m in diameter, and 1.3 m in length.

Korolev also developed the Soviet Union's first communication satellite Molniya-1 which was placed in orbit by Molniya rocket. This first satellite weighing 816 kg was orbited in April 1965. The orbit of the Molniya satellite was 600 km × 40,000 km at an inclination of 65°. The orbit was so chosen as to give more than 10 h of coverage over the main land of Soviet Union. The whole concept and usage of this orbit for communication purposes goes to the credit of Korolev.

Korolev's team also developed the earth imaging spy satellite *Zenith*, the first of which was launched in April 1962. The capabilities of the spacecraft included identification of objects measuring 10–15 m, and a ground swath of 180 km. The spacecraft carried four cameras.

## Failures? Yes, of course

When admiring the success of Korolev, two aspects should not be forgotten – the teamwork responsible for the success, and the failures faced by Korolev and his team.

Every project had its share of failures. More glaring were the lunar and interplanetary launches. A number of lunar launch attempts failed due to the failure of Molniya upper stage. Seven missions to Venus failed in 1964–65, and similarly the launch attempts to Mars. The demoralizing effect of failures can be appreciated only when the effort invested in every launch attempt is realized. All these failures occurred when Korolev was the Chairman of the Council of Chief Designers and his Design Bureau designed the programmes. Korolev's leadership helped his team to come through the rough times of the failures.

The USSR planned N-1/L-3 mission to launch a crew to the moon and return. N-1 vehicle, with a lift-off weight of 2700 tons was planned as a reply for USA's Saturn vehicle for the manned lunar launches. Its first stage uses thirty NK-33 engines, second stage eight NK-43 engines, and third stage four NK-39 engines. By the end of the third stage flight, 200 km earth orbit would have been achieved. The fourth stage with only one NK-31 engine would take the lunar complex to the moon. All the engines for this vehicle were designed by Kuznetsov's Design Bureau.

The choice of liquid oxygen–liquid hydrogen propellant combination, and use of so many engines were the controversial topics among the chief designers. Glushko never believed in the combination of propellants and refused to develop the cryogenic engines, forcing Korolev to assign the task to Kuznetsov.

The first launch of N-1 took place in February 1969, under the leadership of Mishin, after the death of its architect Korolev. All the four launch attempts between 1969 and 1972 failed. Finally, the N1 programme was cancelled when Korolev's adversary Glushko took over as the Chief Designer in May 1974. Incidentally, the differences between Korolev and Glushko were considered to have greatly harmed the progress of Soviet space research, and also delayed the mastering of cryo engines by USSR.

The pressure of so many programmes started showing up on Korolev's health. At the end of 1965, Korolev used to get unusually tired, and any kind of physical activity used to fatigue him.

## The colossus departs

On 5 January 1966, Korolev was admitted to the Kremlin hospital and doctors diagnosed that an operation had to be conducted. On 14 January, Petrovsky – Minister of Health of USSR himself performed polyps operation on Korolev, who haemorrhaged on the operating table bleeding severely. The main surprise during the operation was the sight of a very big tumour, the colon cancer.

Thirty minutes after the operation was completed, Korolev's pulse stopped. This terrible misfortune came down so unexpectedly that '(USSRs) cosmonautics had been orphaned'. The publication of USSR Academy of Sciences described, 'S. P. Korolev lived giving all of his creative energy to the concern of the people and progress' – a true tribute. On 16 January 1966, a grand State funeral for Korolev was organized in the Red Square. A colossus in space research had departed.

### The man and the manager

What kind of man was Korolev, and what was his style of management to achieve so many spectacular successes? The opinions of his contemporaries help us to understand these questions.

Korolev's personal aspirations matched the needs of the age, his dreams harmonized with the compulsions of USSR to develop rocketry, and his leadership qualities filled the opportunities which were thrown up.

Korolev's motto was to move forward in accordance with the approved programme and to brush aside anything that might prevent its achievement. He would steam-roll anything and anybody that tried to prevent him from taking a decision, which he deemed necessary and proper. At the same time, one of Korolev's invaluable talents as a leader was his ability to listen to critical assessments, which he interpreted as expressions of collective wisdom and experience. Korolev often used simple but reliable technologies.

Korolev's intuition was infallible when it came to solving engineering problems. He tried to look at every report through his rocket prism, and to extract something useful for his present and future work from every communication. His attitude towards space research can be understood from what he said to one of the scientists in 1934: '... The day will never come when we shall solve all the scientific and technical problems, and say to ourselves "now let's build...". Theory and practice have to go hand in hand. It would be excellent if theory overtook practice, and lit the way for it, and prevented it from getting lost in a dead-end. But it is also possible that theory won't catch up, will lag behind, will explain, but not predict. It's happened so in the history of science'!

Korolev was strict with his colleagues. He wanted people to fear him. Many of his team members worked '15 days a week'. Rage was an art form for Korolev. Though people were a little afraid of him, everybody respected him all the same. He never did irreparable damage to anyone. The man, who raged with fury when work was not completed, wept openly when he thought that the cosmonauts of Voshkod-2 were lost.

He introduced the practice of hiring students, while they were still in university to do their 'diploma work', and identifying the best for permanent jobs. Crucially important factors in his success were the deep dedication and motivation of the workers in the manufacturing departments, who were sometimes given rewards on the spot for high-quality work. He had to work with a system in which talented people were paid no more than the lazy, untalented ones. So Korolev took special care of the good workers. In turn, they were happy to work overtime for him.

Korolev had an unique ability to inspire, command, bargain, lead, design and attend to details. He was an excellent designer, planner, administrator, prophet and politician – all in one. He was a master in delegating his authority to the people he considered particularly talented and trustworthy, promoting them to Chief Designers of their programmes and encouraging them to set up independent design bureaus.

Korolev was twice awarded the title of 'Hero of Socialist Labour', Lenin Prize, and he was the first scientist to win the Academy's Tsiolkovsky Gold Medal.

How could a man, imprisoned for ten years, work with so much dedication in the same society? Maybe Korolev's own words to Gagarin tell us how: 'Patriotism, courage, modesty, iron will, knowledge, and love for people are the qualities ... (one should have)'.

Korolev had to his credit R1, R7, Sputnik, Vostok, Voshkad, Zond, Molniya and Soyuz, and Lunar, manned and interplanetary flights. But he had only 16 roubles and 24 Kopeks to his credit in his bank account when he died. An eloquent touch on what was dear to him!

1. James Harford, *Korolev: How One Man Masterminded the Soviet Drive to Beat America to the Moon*, John Wiley and Sons Inc., New York, 1997.
2. Brian Harvey, *The New Russian Space Programme – From Competition to Collaboration*, John Wiley and Sons Inc., 1996.
3. *Roads to Space – An Oral History of the Soviet Space Program* compiled by the Russian Scientific Research Center for Space Documentation, Aviation Week Group, 1995.
4. Yaroslav Golovanov, *Sergei Korolev – The Apprenticeship of a Space Pioneer*, Mir Publishers, 1975.
5. *Yuri Gagarin To mark the 25th Anniversary of the First Manned Space Flight*, a collection of articles published by USSR Academy of Sciences, 1986.

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*M. Y. S. Prasad is at INSAT Master Control Facility, Hassan 573 201, India and K. R. Sridhara Murthy is in ISRO–HQ, Bangalore 560 094, India.*

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