History of Rocketry and Astronautics

Proceedings of the Ninth, Tenth and Eleventh History Symposia of
The International Academy of Astronautics

Lisbon, Portugal, 1975

Anaheim, California, U.S.A., 1976

Prague, Czechoslovakia, 1977

Frederick I. Ordway, III, Volume Editor

R. Cargill Hall, Series Editor

AAS History Series, Volume 9

A Supplement to Advances in the Astronautical Sciences

IAA History Symposia, Volume 4

AAS Publications Office
P.O. Box 28130
San Diego, California 92128

Affiliated with the American Association for the Advancement of Science
Member of the International Astronautical Federation

First Printing 1989

ISSN 0730-3564

ISBN 0-87703-309-9 (Hard Cover)
ISBN 0-87703-310-2 (Soft Cover)

Published for the American Astronautical Society
by Univelt, Inc., P.O. Box 28130, San Diego, California 92128

Printed and Bound in the U.S.A.

Chapter 21

S.P. KOROLEV AND SOVIET ROCKET TECHNOLOGY*

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In the history of science and technology, an enormous role has always been played by those who have blazed new trails and whose names are associated with great discoveries and achievements, especially in fields that have attained vitally important significance for all of humanity.

In our age of numerous fundamental discoveries and rapid scientific and technological progress, a special place among the new applications of human energy is occupied by cosmonautics which has absorbed into itself the achievements of a large number of sciences. It is possible that, in the future, humanity will call the 20th century the Age of the Opening Up of Space.

At the beginning of our century, there appeared in science at first little noted works of K.E. Tsiolkovsky, who theoretically substantiated the feasibility of cosmonautics. The middle of the same century has been marked by the activities of many scientists and engineers who set for themselves the task not only of the further development of the ideas of cosmonautics, but also of the practical implementation of this ages-old dream of humanity. Among these scientists, a quite exceptional place belongs to S.P. Korolev.

If you were to follow all the activities of Korolev from the beginning of the 1930's, when he was closely involved in the problems of rocket technology, up to the last days of his life, you would be astonished not only by the energy with which he worked, but also by his strict sense of purpose. The impression is created that, from the very first days of his own work in this engendered field of technology, he had already seen Gagarin's future flight.

Understanding the conditionality of clearly defined periodizations, we will try all the same to divide Korolev's activities into three stages:

1. The period of emergence of rocket technology (1930-1946).
2. The period of development of powerful rockets (1946-1957).
3. The period of development of spacecraft (1957-1966).

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* Presented at The Eleventh IAA History of Astronautics Symposium, Prague, Czechoslovakia, September 1977.

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EMERGENCE OF ROCKET TECHNOLOGY (1930-1946)

The first period is characterized by the fact that rocket technology was just springing up. In order for it to get firmly established, to develop and to gather strength, it was faced with feasible "terrestrial" tasks: the installation of rocket ships and the use of rocket engines for short-term improvement of aircraft flight characteristics and as a secondary aim -- the development of classical design rockets as craft for scientific purposes with a planned vertical lift altitude on the order of several kilometers.

This stage was necessary, inasmuch as, in opening up the possibility of involving industry in the work on rocket technology, it made possible the development of liquid rocket engines [LPRE] and their systems not on an amateur basis, but rather using all the capacities and traditions of power machine building. The task of developing automatic flight control systems became a reality and it became possible to involve in the work powerful scientific organizations. All this was associated with the fact that the results of the majority of the named operations were supposed to be put to practical use immediately upon their completion. It is precisely this possibility of the immediate use of developed designs that made "profitable" not only the final result -- the entry of man into space -- but also the intermediate stages.

By 1931, Korolev had decided to dedicate all his activities to rocket technology and later on to space technology. This decision was influenced by Tsiolkovsky's ideas, with which Korolev had become acquainted in previous years; and as a result of a meeting with F.A. Tsander, a zealous space flight enthusiast. Tsander, at that time, had attained fame as the author of works associated with the exploitation of space and as an engineer who had already begun tests with the OR-1 rocket engine [Experimental Rocket engine No. 1]. Korolev immediately understood that here was an opportunity to begin practical work on the achievement of space flight. With his own energy, he undertook to organize this matter and Tsander's works, which for many years had drawn no response, immediately attained a practical direction. At the end of 1931, an agreement was signed according to which financing became available for the work on installing a rocket engine in a rocket aircraft.

Overall supervision of work was entrusted to Korolev and the development of the rocket engine, which received the designation OR-2, was entrusted to Tsander. Korolev not only took upon himself the overall supervision of the work and not only supervised the completion of the light-engine, tailless aircraft, the BICh-9, into which it was proposed that the OR-2 be installed, but also, as a test pilot himself, conducted flight tests of this unusual craft. Although this work was not yet completed, it made it possible to gather a group of rocket technology enthusiasts around Korolev and Tsander. Soon the originally social organization GIRD (Jet Propulsion Study Group [JPSG]) had actually become a scientific research and experimental design organization, had obtained solid financing for its work, and sharply expanded its own areas of study.

Korolev was appointed the head of this organization and no one had any doubts about this appointment, inasmuch as Korolev's exceptional creative and organizational capabilities had been clearly manifested from the very start of JPSG's work.

Typical of Korolev's activities as head of JPSG and, after the formation of the Jet Propulsion Scientific Research Institute as a result of the merger of the JPSG and the Gas Dynamics Laboratory (1933), as the leader of one of the foremost schools of study of this institute, were initiative, boldness in the formulation of tasks and, simultaneously, a maximum sobermindedness -- all this work had a clearly defined purpose and could undoubtedly be realized.

In 1933, they launched the modestly sized GIRD-09 and GIRD-10 rockets developed under his supervision; the latter, developed according to Tsander's design studies, had all the typical features of ballistic missiles with LPRE's. Korolev's basic efforts were directed at that time at developing winged flying craft. This trend in his activities is completely understandable -- the relatively modest capabilities of the rocket engines of that time made it possible to lift the necessary loads only by using the lifting force of wings. Under Korolev's supervision, winged rockets were developed with the "201" and "212" LRE's, the first of which would be comparable today to air-to-air missiles, and the second to surface-to-surface missiles. These rockets were already equipped with automatic flight control systems and the "201" also had a remote guidance-to-target radio system. Both rockets were developed in the period from 1934 to 1938; and, in 1939, flight tests of the "212" rockets were conducted and the completion of the "201" rocket had begun.

In 1937 and 1938, ground tests were conducted on the Korolev-designed RP-318-1 rocket plane, in which pilot V.P. Fedorov completed the USSR's first flight [of a craft] with a working rocket engine in 1940. In those same years, Korolev developed a plan for a record climb into the stratosphere in a rocket plane with a sealed cabin.

This broadly developed work was suspended prior to the war in order to concentrate all the Jet Propulsion Institutes' forces on the development of rocket artillery, in particular, the Katyushas that later became famous. At this time, and until the end of World War II, Korolev continued to work on the application of LRE's in aviation, participating in the installation of rocket engines in combat airplanes.

DEVELOPMENT OF POWERFUL ROCKETS (1946-1957)

The second period of Korolev's activities began in 1946 when, after the end of the war, there was an opportunity to return to long-range developments and he was appointed chief designer for the development of sets of automatically controlled long-range ballistic missiles. By this time the development of rocket engine construction in the USSR had reached such a level that lifting large masses without using aerodynamic forces, in accordance with the principle of ballistic missiles, had become a complete reality. At the same time, along with Korolev, chief designers were appointed for engines, for control systems, for radio systems, for ground equipment and so on. The group of chief designers, headed by Korolev, was faced with a most important defense task, associated with the development of a new and terrible weapon.

During this period, having turned out to be in charge of grandiose projects, Korolev developed a highly flexible and clearly defined organization for a complex set of operations and established the Chief Designers' Council. In this small council, he managed to create an amicable working atmosphere, in which the most important principle of leadership became common sense and the interests of the matter at hand. All this made it possible to develop one missile system after another with unimaginable speed. The development of large-scale ballistic missiles required not only the development of new and varied engines, control systems, ground equipment sets and so on, but also of a qualitatively new approach to the designing of the rockets themselves.

All rockets built up to this time (not only in the USSR but also in other countries) had been designed and produced based on aviation technology developed contemporaneously with them. They thus still lacked many specific rocket features, which alone would make it possible to bring the relative fuel reserve up to the necessary level. Therefore, Korolev and his associates, conducting an extensive cycle of tests and experiments, developed in the end rocket designs that completely met the requirements that had confronted them. The various types of long-range rockets developed in the period from 1946 to 1957 were, for their time, prominent examples of rocket technology. The triumphal completion of this work was the successful flight test in August of 1957 of the world's first intercontinental ballistic missile.

The potential feasibility of developing a launch vehicle based on intercontinental missiles capable of placing spacecraft onto space trajectories was clear from the very beginning. Therefore, it would be a mistake to think that the work on the exploitation of space began after the launching of a missile over intercontinental distances. The sense of purpose of Korolev's work, who never lost sight of the prospects for exploiting space, was evidenced in particular by the fact that the theoretical and experimental work in preparation for the development of space flight was begun long before 1957.

By 1949, under Korolev's supervision, the first geophysical rocket had been developed, which had been intended for vertical probing of the atmosphere up to altitudes on the order of 100 km. Launches of similar rockets, of ever more improved design, were conducted and continued even after the launch of the first satellite. In the end, the altitude attainments of such sounding rockets exceeded 500 km. The task of such rockets was the study of the upper atmosphere and space. In addition to what has been mentioned, animals were carried on rockets of this type and a study of the effect of space flight conditions on a living organism was conducted. Thus, it is possible to state that the various experiments on penetrating space and accumulating space flight experience were begun several years before the signals of the Earth's first artificial satellite were heard on the ground.

In addition to the regular launches of research rockets, from the beginning of 1950's, intensive theoretical work was conducted on questions concerning the exploration of space. A study of the problem of attaining space velocities with rockets was begun in 1950 in our country under Korolev's leadership. This was work in which the paths to the achievement of space flight were studied not as a possibility in principle (which Tsiolkovsky had already indicated) but rather as something realizable on the basis of the existing level of technology, taking into account its short-term prospects. Beginning in 1954, the possibility of developing artificial Earth satellites was studied attentively. Korolev was also the leader of this work cycle.

Thus, by 1957, when, along with the intercontinental ballistic missile, its space version was also prepared, the answers to a whole series of principal questions associated with the development of spacecraft had already been obtained in the process of launching research rockets and as a result of the theoretical work of an applied nature. Therefore, the 4 October 1957 launching of the Earth's first artificial satellite, which opened humanity's space era and turned out to be completely unexpected for many people, was the result of years-long and purposeful work.

If you return to the first satellite, then you are struck by its utmost simplicity of design, the practically complete absence of scientific equipment, the elementary nature of the radio transmitter installed in it and Korolev's evident desire to get by with an absolute minimum of necessary and adequately evident measures, capable of giving the radio transmitter the opportunity of operating over the course of a specific and comparatively insignificant amount of time. Paradoxically, this simplest of articles quite naturally became the symbol of the new era, associated with the enormous scientific and technological achievements of humanity in one of the most complex fields of human endeavor. The first satellite is of value not in and of itself (all the same, it made it possible to refine our ideas about the density of the upper atmosphere and radiowave propagation), but as a junction point in the development of technology. On the one hand, it symbolized the completion of a difficult path in the development of rockets, which have become space rockets; and, on the other hand, it was an embryo from which space technology grew. Even after the launching of the first satellite, the process of improving space rockets continued as well and Korolev's main efforts after 1957 were directed towards the development of spacecraft.

DEVELOPMENT OF SPACECRAFT (1957-1966)

The third period of Korolev's activities, which began after the launching of the first satellite, was characterized by the rapid, explosive development of space technology and the appearance of spacecraft intended for the most diverse purposes. A listing of all these craft, developed under Korolev's leadership, which are distinguished from one another by diagrams of design decisions, designations, sizes and so on, would be inappropriate here. We will limit ourselves, therefore, to only a general description of the basic trends in space technology that arose under his direct leadership.

The trend, which was a natural continuation of the work associated with the development of the first satellite, was the further development of various types of automatically operating spacecraft for the study of near-Earth space. The second satellite, launched a month after the first one, contained equipment for the study of the Sun and cosmic rays and the experimental animal -- the small female dog Layka. On the third satellite there were already 12 different scientific instruments. In the future, the degree of complexity of the scientific programs and the quantity of launched satellites increased more and more and in the process of their development, a new field of technology was born and developed -- space technology.

The originality of space technology was the result of the solution of a series of tasks, which had not been encountered in engineering until this time. While making no claim to completeness, we will name here just some of the problems confronting Korolev and his associates. It was necessary to develop methods for the selection of trajectories for the movement of spacecraft and for the prediction of their evolution. This required the development of new chapters in celestial mechanics, which began to change from a pure science to an applied one. Space confronted engineers with the problem of the operation of movable joints in a vacuum, which turned out to be sharply different from terrestrial conditions, and weightlessness, for all practical purposes, caused the complete disappearance of the thermal convection of gases, which filled sealed areas. The contribution of thermal radiation to the task of a spacecraft's heat exchange increased sharply, and this required new methods for calculation and the development of new technological equipment for controlling the temperature within a spacecraft. The task of power supply involved the development of solar batteries. This list could go on and on.

The solution of such tasks required the closest of cooperation in the work of the design, production and research organizations. This process of mutual enrichment of science and technology proceeded in close cooperation with the USSR Academy of Sciences, of which Korolev was a member, with the very active participation of Academician M.V. Keldysh.

The development of space technology initiated by the development of the first artificial Earth satellites proceeded further not only along the path of development of automatic satellites for scientific purposes, but also of interplanetary-type spacecraft, the development of satellites for economic purposes, and the advent of manned spaceships.

Even before the launching of the first artificial Earth satellite, Korolev's associates, under his supervision, were developing the corresponding projects. It is not surprising, therefore, that by January 1959, the first rocket had been launched towards the Moon and in that same year a pennant with the emblem of the Soviet Union had been placed on the lunar surface and photographs had been obtained of its far side. In 1966, less than a month after Korolev's death, a spacecraft made a soft landing on the lunar surface -- Korolev's last work in the lunar studies program. At the same time, work was also conducted on the study of Venus and Mars. Korolev's highest achievement in this field was the first flight of a man-made object to another planet and the placing of a pennant with the emblem of the Soviet Union on the surface of Venus (March 1966).

During the development of similar-type spacecraft, it was necessary to solve a large group of new tasks. First and foremost among them was that of controlling motion. Already, on board the Luna 3 automatic interplanetary station, the world's first attitude control system had been installed without which it would have been impossible to direct the immobile camera installed on it towards the Moon. The task of getting to Venus required not only attitude control, but also the capability of carrying out accurate flight trajectory correction maneuvers. Luna 9, which made a soft landing on the Moon, in addition required the development of a system for landing on a world without an atmosphere. In addition to the tasks of controlling the motion of a spacecraft, there arose in parallel the enormous task of ultra-long-range radio communications, trajectory measurements and flight trajectory prediction with extremely high accuracy. It is natural that all these tasks were again solved in cooperation with scientific and production organizations. Korolev coordinated all this work and had the deciding word during the selection of the basic technical trends of this set of operations.

If the interplanetary flight of the spacecraft developed under Korolev's leadership opened up new paths to science, then the Molniya-1 communications satellite developed under his leadership was a shining example of the solution of a complex but very necessary economic task. Many years after his death satellites of this type in combination with the Orbita system ground stations continued to implement radiotelegraph, radiotelephone and television communications over long distances. In particular, it is precisely these satellites which have been ensuring up to the present time the transmission of Moscow television programs to the Far East.

Manned flights into space are justly considered to be the high point of Korolev's creativity. He always considered manned flights to be especially important and he was influenced not only by considerations of scientific and technical necessity, but of no less importance those of a moral nature. Here in addition, in all probability, was evidence of long-held and steadfast feelings -- it must not be forgotten that in his youth he was a glider and an aircraft pilot and in conversations with friends he frequently lamented the fact that age and health had deprived him of the opportunity to fly in space.

It is perfectly natural that the new direction required the solution of new problems -- life-support systems, the development of manual ship control systems, the ensurance of a safe descent to the Earth's surface, and, consequently, the solution of the task of thermal protection of the descent craft, and so on. All this work was begun early and carried out efficiently, at an impressive pace. At the same time, the requirements for the gradual completion of the systems and of guaranteeing complete reliability were taken completely into consideration. The completion of the Vostok manned spacecraft was begun in the spring of 1960 when a series of ship-satellites were placed into orbit and the latter of these were exact copies of the future Vostok and carried animals as passengers. In less than a year, five ship-satellites were launched, which made it possible to conduct a reliable completion and testing of all the on-board systems.

It goes without saying that parallel with the completion of the technology, the training of the cosmonauts was begun under the general supervision of S.P. Korolev.

On 12 April 1961, with the launch of the Vostok with Yuriy Alekseyevich Gagarin on board, humanity completed the second epoch-making step in the exploitation of space -- it was not an automatic craft, developed by the genius of man, that penetrated space, but man himself.

Following Gagarin's flight came other manned flights and after the Vostoks the Voskhods were launched, and later the Soyuzs also, the planning for which had been started under Korolev's supervision. It must be noted that Korolev personally supervised the flight control of all the spaceships launched during his lifetime.

KOROLEV IN PERSPECTIVE

This brief outline of S.P. Korolev's activities indicates his exceptional role in the development of the USSR's space rocket technology. He was constantly at the center of all the new space rocket programs, beginning with the design study, the postulation of the scientific problems, the preparation of industry and right up to the supervision of flight control.

In summing up his activities, it is possible to note the following three features of his working style:

1. A systematic approach. A clear understanding of the fact that modern space rocket technology is a "big system," where all of its component elements are identically important -- from the ground launch complex to the spacecraft. Personal participation in the solution of key tasks, which arose during the development of this large system, is vital.

2. A clearly defined work sequence. Each step should not only lead to the remote goal, but also have independent significance.

3. An incessant craving for what is new. After having developed any kind of example to space rocket technology and having brought it up to the necessary level of perfection, Korolev frequently "made a present" of the developed theme with all its long-range studies to some related enterprise for the further development of the space rocket technology trend opened up by his work. He himself again proceeded to the unknown.